Robotics and Inquiry: Addressing the Impact on Student Understanding of Physics Concepts (Force and Motion) from Select Rural Louisiana Elementary Students through Robotics Instruction Immersed within the 5E Learning Cycle Model

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ROBOTICS AND INQUIRY: ADDRESSING THE IMPACT ON STUDENT UNDERSTANDING OF PHYSICS CONCEPTS (FORCE AND MOTION) FROM SELECT RURAL LOUISIANA ELEMENTARY STUDENTS THROUGH ROBOTICS INSTRUCTION IMMERSED WITHIN THE 5E LEARNING CYCLE MODEL

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The School of Education

by
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B.S., Louisiana State University, 2005
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December 2014
This study is dedicated to my family, for always supporting me and understanding that in life forging ahead and staying on course is the best way for one to achieve personal success.

To my mom, sister and brother, for always lending a listening ear throughout this whole process. Yes, I finally finished.

To my wonderful, realistic and patient husband, Michael, for always grounding me. I am so thankful for you and know that I am truly blessed to have you by my side day after day.
ACKNOWLEDGEMENTS

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I would also like to thank my family, friends and co-workers for their continued support and words of encouragement. It is because of you all that I have continued on this journey and finally finished! Jen Tynes, I couldn’t have made it through this without you. You have become such a dear friend and I sincerely am grateful for all of the feedback and support you have given me throughout this process. Thank you all so very much.
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ABSTRACT

This embedded mixed methods study investigates the development of rural elementary students’ conceptual understanding of force and motion as a result of the implementation of robotics instruction immersed within a 5E Learning Cycle Model lessons. Three treatment groups and one controlled comparison group (n=96) participated in pretests and posttests (Science Series Assessment 1, Russell and McGuigan, 2001) the day the activities were completed as well as one week after the completion of the treatment, 5E Learning Cycle Model lessons and draw and tell interviews. Prior to the intervention, the Iowa Test of Basic Skills stanine scores were grouped into three levels: high, medium and low, and provided a sample size of 36, three from each ability level from each experimental and control groups. These participants were pulled three at a time and participated individually in the draw and tell activity before the intervention, during and one week following the close of the intervention. Observations, field notes, coded interviews and quantitative data were used for meta-inference.

The data suggests that with respect to long term retention of accurate understanding of concepts related to force and motion, participants who utilize robotics instruction immersed within 5E Learning Cycle Model lessons are more likely to successfully retain correct concepts of force and motion (p>.05). According to the findings from this study, participants who did not utilize robotics instruction were less likely to have accurate long term retention of concepts related to force and motion and were more likely to return to their original misunderstandings of said topic. With regards to ability level, low ability participants who utilized the robotics component were more likely to retain knowledge on topics related to force and motion; whereas only one participant in the control group identified as low ability could do the same. This study addresses a gap in the literature by providing the quantitative and qualitative data that supports
the importance of immersing robotics into 5E Learning Cycle Model lessons as a means to assist students of various ability levels in addressing their understandings of physics concepts.
CHAPTER 1
INTRODUCTION

Statement of Problem

The National Research Council (NRC) released the Next Generation Science Standards (NGSS, 2013) which are the current basis for K-12 science education. These standards have been created by the National Research Council, National Science Teachers Association (NSTA), Achieve, an independent, nonprofit educational reform organization, and the American Association for the Advancement of Science (AAAS) (Next Generation Science Standards, 2013). The Achieve organization also worked alongside the Partnership for Assessment of Readiness for College and Careers (PARCC) in order to develop and implement the Common Core State Standards (CCSS) for Math and English Language Arts (NGSS, 2013). Although in 2009, 48 states, 2 territories and the District of Columbia signed a memorandum of agreement with the National Governors Association (NGA) and Council of Chief State School Officers (CCSSO), committing to a state-led process - the Common Core State Standards Initiative (CCSSI) (Achieve, 2014); this transition process has had political and economically driven undertones and many states have reconsidered their initial commitment. While the CCSS writers state these new Math and English Language Arts standards support “college and career readiness”, the NGSS writers approached their standards from an discovery based viewpoint; emphasizing science inquiry as the driving force behind students’ development of problem solving and communication.

The implementation process of these newly released standards has varied between each state. The NRC states, “The decision to adopt the standards lies in the hands of the states themselves” (NGSS, 2013, p. 336). As of February 2014, there are ten states (Nevada,
California, Delaware, the District of Columbia, Kansas, Kentucky, Maryland, Rhode Island, Vermont, and Washington) which have fully adopted the standards (NGSS, 2013). According to the NRC, the NGSS “does not provide a curriculum for which teachers to follow; therefore, states and districts will have the responsibility for providing more detail to classroom teachers” (NGSS, 2013, p. 336). While the NGSS represent a new vision for science education; state curriculum development aligned with the NGSS, along with teacher training are two areas of concern according to many state leaders (NGSS, 2013). During the NGSS development, the NRC was partnered with 26 lead states as a means to assist in possible issues in the adoption and implementation process and over 40 state education departments expressed interest during the initial development process (table 1.1) (NGSS, 2013). With each state having the option to adopt these standards, educators must now closely examine the NGSS for ways in which to align or possibly shift their classroom teaching practices.

The NGSS contain science and engineering strands in each grade focusing on the interconnectedness of science, math and engineering (Appendix A). Science, math and engineering require both knowledge and practice. “Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. When students actively engage in science practices, they deepen their understanding of core science ideas” (NRC, 2012, pg. xi). In addition to educators examining these changes within the science standards, many government initiatives and policies are in place to bring STEM (science, technology, engineering, and math education) awareness and education to the earlier grades (Barron et al.’ 2011; ISTE 2007; National Association for the Education of Young Children & Fred Rogers Center 2012; U.S. DOE 2010a, b).
Table 1.1 Next Generation Science Standards state breakdown. (NGSS, 2014)

<table>
<thead>
<tr>
<th>Lead States</th>
<th>Interest Expressed</th>
<th>Adopted Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Arizona*</td>
<td>1. Nevada</td>
<td>1. Nevada</td>
</tr>
<tr>
<td>5. Georgia*</td>
<td>5. Missouri</td>
<td>5. Kansas</td>
</tr>
<tr>
<td>11. Maryland*</td>
<td>11. North Dakota</td>
<td></td>
</tr>
<tr>
<td>12. Massachusetts*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. New Jersey*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. New York*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. North Carolina*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Ohio*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Oregon*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Rhode Island*</td>
<td></td>
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</tr>
<tr>
<td>22. South Dakota*</td>
<td></td>
<td></td>
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<tr>
<td>23. Tennessee*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Vermont*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Washington*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. West Virginia*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Denotes lead states who also expressed initial interest in the NGSS.

In the past decade educators have been in competition with digital devices, striving to capture student’s attention. Some researchers predict that due to our rapidly changing technological society 65 % of the children entering our schools today may have jobs as adults that do not yet exist (Barseghian, 2011; Davidson, 2011; Ito, 2011). As 21\textsuperscript{st} century educators it is necessary to incorporate tools in the classroom that will give students the opportunity to reflect, analyze and apply ideas in various science contexts. 21\textsuperscript{st} century learners need to be actively engaged in order to attain deeper understanding for future science topics and yearn for
the opportunity to BE scientists and have meaningful learning experiences through interactions with science content. Utilizing robotics instruction in the classroom may provide students with a tool that can help make abstract ideas more concrete, as children can directly view the impact of their programming commands on the robots’ actions (Bers, 2008).

Robotics enables students to interact with technology at a different level through interactive social collaborations and cognitive development. Educational curriculum materials have been created to coincide with many robotics kits to ensure educators are incorporating both science and math concepts in the classroom. Mimicking the actions of real life engineers; robotics assists students in the synthesis of the process of science and mathematical tasks. Through the use of robotics, each student is empowered with a platform of which analysis, reflection and application can all be contained in one arena. Historically, research has shown that although inquiry-based learning environments, robotics and STEM activities provide students the vehicle to go beyond memorizing basic science content, many issues can arise surrounding students’ created conceptions of a topic (Madill, Campbell, Cullen, Armour, Einsiedel, & Ciccocioppo, 2007; Metz 2007; Steele, 1997).

Wandersee, Mintzes and Novak (1994) generated eight “emerging” research-based claims relating to alternative conceptions in science (Table 1.2). In addition to this extensive study highlighting the evolution of research on alternative conceptions, Wandersee, Mintzes and Novak (1994) discussed many theories that have been developed to address alternative conceptions, most focusing on metacognitive change. Research has reported positive results in combating alternative conceptions when students use metacognitive strategies (Novak & Gowin, 1992; Wandersee, Mintzes & Novak 1994; Wittrock, 1992). These strategies assist students in
reflecting on “what and how they know in order to monitor their own learning” (Wandersee, Mintzes & Novak 1994, p.202). Metacognitive theorists (Baker & Brown, 1984; Flavell, 1979; Sternberg, 1981, 1986) support strategies which assist students in effectively harnessing knowledge with precision. Self-reflection, self-analysis and self-regulation are all essential pieces to the metacognitive puzzle. These aforementioned pieces are all keys to learning and make up a large portion of many metacognitive strategies. Metacognitive strategies are one of the underlying components of conceptual change theory. As studied by Posner, Strike, Hewson, and Gertzog (1982), conceptual change theory employs a framework in which alternative conceptions may be overcome by “replacing existing faulty knowledge with the scientifically sound ones”(Baser, 2006, p.67).

Posner et al. (1982) emphasized using disequilibrium strategies through a four step process to showcase how the students’ understanding of the scientific phenomenon can be viewed differently than their own understanding of the concept (e.g. Dykstra, 1992; Hewson & Hewson, 1983). One main component to this process is the willingness for a student to change his or her idea, which many times is attributed to disequilibrium. Disequilibrium can be caused through the observation of a discrepant event, or an event that is observed which conflicts with the idea that a student currently holds about the presented science topic (Posner et al. 1982). Observation alone cannot cause disequilibrium; the student must try to apply their own personal conception of the science concept in the presented situation in order to understand how and why their original understanding of the scientific concept is flawed. As highlighted in the conceptual change model (Posner et al. 1982) which embodies a four step cycle that students must participate in for conceptual change to occur: (1) dissatisfaction with present understanding of
existing conception; (2) new presentation of concept must be understandable; (3) current problem must be solved by using new concept presented; (4) utilization of new concept for future situations is possible. The use of this conceptual change model has been documented as one way to “close the gap between children’s science and scientists’ science” (Baser, 2006 p. 69). However, some studies suggest that employing more of an inquiry-based learning cycle model may be more effective in altering students’ misinterpretation of various science concepts (Carey, 1999; Vosniadou & Ioannides, 1998).

The 5E Learning Cycle Model (Bybee, 1997) supports inquiry teaching as a means to capitalize on student engagement, elicit prior knowledge, and to emphasize formative and summative assessment. The 5E Learning Cycle Model (Bybee, 1997) offers teachers and students a structured way to conduct inquiry-based scientific investigations by moving them through five sequential phases: (1) “students engage in a learning task to prompt disequilibrium in any preconceptions and expose any misconceptions (engagement)” (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook, Landers, 2006 p.8); (2) opportunities are given to explore student ideas through hands on, concrete activities in order to restructure their understanding about the concept (exploration); (3) expansion upon student understanding and explanations of thoughts while the teacher connects the student understandings to scientific or technological explanations of the concepts (explanation); (4) the newly attained knowledge is transferred and applied to closely related, but new situations (elaboration); (5) formal teacher and student assessment (evaluation) (Bybee et al., 2006).

Harnessed in educational theory as well as research based findings, particularly findings from multiple National Research Council reports including How People Learn: Brain, Mind
Table 1.2: Research-based claims relating to authentic alternative conceptions. (Wandersee, Mintzes, & Novak, 1994)

<table>
<thead>
<tr>
<th>Claim</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claim 1: Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events.</td>
<td>Alternative conceptions span the fields from physics and earth &amp; space science to biology, chemistry, and environmental science. Each associated subfield within the disciplines seems to have its alternative conceptions.</td>
</tr>
<tr>
<td>Claim 2: The alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries.</td>
<td>No matter how gifted a group of students concerned, each group will have students with alternative conceptions regardless of background.</td>
</tr>
<tr>
<td>Claim 3: Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies.</td>
<td>Students’ alternative conceptions are very difficult to change; only very specific teaching approaches have shown promise of getting students to accept new explanations.</td>
</tr>
<tr>
<td>Claim 4: Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.</td>
<td>Students often hold to the same views as those held by very early scientists that are frequently referred to as “Aristotelian” in nature</td>
</tr>
<tr>
<td>Claim 5: Alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture, and language, as well as in teachers’ explanations and instructional materials.</td>
<td>The many sources of alternative conceptions are at best speculative, but research and inference suggest that a student’s worldview is strongly influenced by his or her social environment.</td>
</tr>
<tr>
<td>Claim 6: Teachers often subscribe to the same alternative conceptions as their students.</td>
<td>It is not at all uncommon for science teacher educators to see alternative conceptions in their teacher candidates; likewise, even experienced science teachers and scientists with advanced degrees will sometimes cling to alternative conceptions that are held by their students.</td>
</tr>
<tr>
<td>Claim 7: Learners’ prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse variety of unintended learning outcomes.</td>
<td>Not only can alternative conceptions be a hindrance to new learning; they can also interact with new learning resulting in “mixed” outcomes. It is not unusual to see different students draw different conclusions from the same experiences and observations.</td>
</tr>
<tr>
<td>Claim 8: Instructional approaches that facilitate conceptual change can be effective classroom tools.</td>
<td>Several conceptual change approaches have been developed to identify, confront, and resolve problems associated with alternative conceptions.</td>
</tr>
</tbody>
</table>
Experience and School (Bradsford, Brown and Cocking, 1999) and America’s Lab Report: Investigations in High School Science (NRC, 2006); the 5E Learning Cycle Model creates a firm bridge between practice and research. The 5E Learning Cycle Model encompasses multiple teaching strategies and provides pathways for teachers and students as a means to bridge the gap in student misunderstandings of science topics (Bybee et al. 2006; Maidon & Wheatley, 2001; Meichtry, 1993; Musheno & Lawson, 1999; National Research Council, 2005). According to the latest version of Pfundt and Duit’s 2006 Bibliography, there are 7000 sources focused on analyzing students’ understanding of scientific phenomena and while this showcases that published research on student misunderstandings of various science topics is plentiful; little published research has examined the misunderstandings of physics concepts in rural elementary students, specifically these students’ misunderstandings surrounding force and motion.

Even fewer studies have examined utilizing robotics instructions through the 5E Learning Cycle method in order to teach force and motion concepts with elementary students. The research as outlined in this document focuses on the teaching of force and motion concepts through the utilization of the Lego MindStorms Robotic NXT kit to specifically examine the incorporation of robotics instruction and the 5E Learning Cycle Model as a means to address students’ understandings.

Robotics instruction has made a marked impact on the extracurricular activities of students, particularly middle and high school students (Fagin, Merkle, & Eggers, 2001; Klassner, 2002; Mataric, Koenig, & Feil-Seifer, 2007). Over the past ten years, robotics competitions such as FIRST LEGO League (FLL) have supplied a platform for students, which facilitate exploration and interaction with advanced tools and devices used by engineers and technologists.
(Lau, McNamara, Rogers, & Portsmore, 2007). President Obama showcased his support for implementing STEM activities in the classroom when he stated, “I believe that robotics can inspire young people to pursue science and engineering” (U.S. DOE 2010a, b). Although there have been several research studies documented showcasing middle and high school teachers integrating the use of robotics instruction into the classroom (Bers, 2008; McWhorter & O’Connor, 2009; Liu, 2010), many reports show that a consistent use of robotics as a means to teach math and science instruction is limited and most research is focused on utilizing robotics strictly as a motivational tool (Bers, 2008; McWhorter & O’Connor, 2009; Pintrinch & DeGroot, 1990).

In the fall 2010, a survey was conducted in New York City (NYC) on FLL coaches that revealed approximately 50% of respondents do not use robotics for classroom use and focus more on educational outreach through enrichment activities (Brophy, Klein, Portsmore & Rogers, 2008; Iskander & Kapila, 2012). While the majority of robotic kit research is focused in the middle and high school areas, few studies have been located focusing on using robotics strictly as an instructional tool in the elementary classroom. In fact, most research examines how the use of robotics can motivate elementary students interests in STEM like fields, instead of measuring their understanding as a result of using the robots to complete tasks (Eubanks, Strader, & Dunn, 2011; Williamson, El Sawalf, Abdel-Salam & Mohammed, 2008). This research has utilized robotics in the classroom as a vehicle to guide inquiry based learning about force and motion concepts.
Purpose

As an elementary school science educator, the researcher has seen many students express misunderstandings during curriculum units focused on physics concepts, particularly on the topics of force and motion; therefore, it is of interest to the researcher to investigate how to address this confusion. The purpose of this embedded mixed methods study is to investigate the development of rural elementary students’ conceptual understanding of force and motion as a result of the implementation of robotics instruction immersed within a 5E Learning Cycle Model. The rationale for this study is utilizing a combination of robotics instruction and the 5E Learning Cycle Model to facilitate understanding of force and motion concepts that could provide students with a different technique with which to replace their misunderstandings.

A review of the literature provides limited studies examining rural or suburban/urban elementary students addressing their alternative conceptions of force and motion (Diakidoy, Kendeou, & Ioannides, 2003; King, 2005). A number of studies investigated middle, high school and undergraduate students’ alternative conceptions of force and motion of objects (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Kikas, 2003; McCloskey, 1983, Montanero, Perez, & Suero, 1995). The benefit of using the conceptual change model to effect students’ conceptions has also been examined in the literature (e.g. Duit & Treagust, 1998; and Tytler, 2002). Numerous studies utilizing the 5E Learning Cycle Model to promote students’ understanding of science have been published as well (e.g. Abell & Volkman, 2006; Boddy, Watson & Aubusson, 2003; Bybee et al. 2006).

Robotics instruction facilitates a development of abstract thinking and collaborative problem solving abilities; it also supports learning in specific scientific, literary and artistic disciplines (Bredenfeld, Hofmann & Steinbauer, 2010; Catlin & Balmires, 2010). Although there
have been a numerous studies dedicated to the benefits of utilizing robotics instruction in the classroom (Bredenfeld, Hofmann & Steinbauer, 2010; Catlin & Balmires, 2010), many teachers have yet to implement this use during their allotted instructional time, (Brophy, Klein, Portsmore & Rogers, 2008; Iskander & Kapila, 2012 or embed this use within a 5E Learning Cycle Model (Bybee, 1997). This study addresses the combination of these components, robotics and the 5E Learning Cycle Model, in teaching rural elementary students about the topics of force and motion.

Specifically, the research questions addressed by this embedded mixed model design study are:

How does the utilization of robotics instruction embedded within the 5E Learning Cycle Model assist students in gaining a deeper understanding of force and motion?

In what ways have the robotics instruction utilized in this study empowered students of different ability levels to retain these newly developed conceptions over a period of time?

**Research Method**

An embedded mixed method research design has been utilized where quantitative and qualitative methods have been used concurrently throughout the study (Creswell & Clark, 2011; Tashakkori & Teddlie, 2003, 2009). Creswell (2002, 2003) states that this multi-strand design is where both qualitative and quantitative data are collected and analyzed to answer a single type of research question. The final inferences are based on both data analysis results. The two types of data are collected independently at the same time or with a time delay (Tashakkori & Teddlie, 2003, 2009).
The quantitative portion encompasses a quasi-experimental design through the nonequivalent comparison group design with more than one experimental group (Johnson & Christensen, 2010). The quantitative data has been analyzed by comparing the experimental and control groups’ posttest scores after they have been adjusted for any differences that may exist on their pretest scores using analysis of covariance (ANCOVA). The independent variable, robotics instruction, has been manipulated in a presence or absence technique. In order to control for an equal ability level, the ANCOVA method has been used to statistically equate groups that could differ. The conceptual variable being examined here is force and motion concepts recognition and this was measured through the operational variable of the posttest and post-drawing scores. To assess students’ conceptual understanding of force and motion, Science Series Assessment 1, consisting of 12 items, based on Russell and McGuigan’s 2001 study was given.

Paper and pencil based tests are not the only way to assess mastery of a topic; therefore, many researchers have turned to drawings for students to express their understanding (Kose, 2008). The qualitative portion of this study has employed the draw and tell technique. Through this technique, students were able to journal, sketch and explain their interpretation of the force and motion concepts being presented. Children give more information with draw and tell than words alone (Kenney, 2008). These writings also assisted in coding their alternative conceptions of force and motion topics. To assess this qualitative portion of the study, student understanding of force and motion was examined through student drawings and individual interviews. Coding framework based on Reiss and Tunnicliffe’s (2001) study was utilized as well as coding
methods derived from Kenney’s books (2008) establishing priori codes. The results from the aforementioned phases are integrated into the discussion section of the dissertation.

**Summary**

This study has been designed to analyze the effectiveness of the use of robotics to facilitate physics topics to elementary students. As a current elementary educator, the researcher’s primary goal is to examine the effect of robotics instruction immersed within the 5E Learning Cycle Model on students’ understandings of force and motion. Through this study the researcher aims to appeal to both practitioner and researcher in the elementary science education field. This study is designed to entice those who are interested in gaining a different perspective on incorporating robotics instruction and the 5E Learning Cycle Model as a way to better address student’s understandings of force and motion. Addressing both the researcher interests and educator concerns simultaneously, it is critical to remember the very essence of science is embodied by trials and often missteps of groups of learners working cooperatively, that turned into amazing discoveries. The process of science is not always about the outcome, students can learn more through struggles and creating their own appreciation for the deeper meaning of the concept at hand. Therefore, it’s important for an educator “not to impose adult expectations on a child’s thought processes, but rather to look at the child’s behavior as a manifestation of movement to an ensuring way of reasoning” (Brooks, 1993, p.83).

The mixed methods design was chosen specifically because the researcher believes when working with children it is necessary to examine the child as a whole in order to gain an accurate picture of mastery of a concept. Also, the voices of participants are not directly heard in
quantitative research. Mixed methods research provides a multifaceted view for studying a research problem than either quantitative or qualitative research alone (Johnson, Onwuegbuzie, & Turner, 2007). Combining quantitative analysis with rich qualitative descriptions create a more complete picture of the proposed study.

**Definitions of Terms**

**5E Learning Cycle Model**- A model to support inquiry teaching as a means to capitalize on student engagement, elicit prior knowledge, and to emphasize formative and summative assessment, as studied by Bybee (1997).

**Alternative Conception**- Experience based explanation constructed by a learner to make a range of natural phenomena and objects intelligible, confers intellectual responsibility on the learner who holds the ideas because it implies alternative conceptions are valid in context and rational, can also lead to even more scientific ideas, as studied by Abimbola (1988); Gilbert and Swift (1985) and Wandersee, Mintzes and Novak (1994).

**Conceptual Change Theory**- Theory which outlines a framework for which alternative conceptions can be overcome, as studied by Posner, Strike, Hewson, and Gertzog (1982).

**Constructionism**- Theory which shares constructivism’s view of learning as building knowledge structures through progressive internalization of actions then adds the idea that this happens in a context where the learner is consciously engaged in constructing a public entity, as studied by Seymour Papert (1970).

**Constructivism**- Theory of learning and understanding in which there is an external and knowable work and individuals actively construct knowledge of the world, as studied by Jean Piaget (1946a; 1946b).
Naïve Beliefs- Understanding of a topic based upon impulse ideas, can also be due to no previous interaction with topic presented, as studied by Caramazza, McCloskey and Green (1981).

Preconceptions- Informal ideas developed by children prior to teaching, as studied by Hasweh (1988).

Prescientific Conception- Specific to science emphasizes that the learners’ ideas may eventually lead him or her to the current scientific conception about a concept, as studied by Good (1991).

Misconception- Concepts that a learner holds which are inconsistent with, or even contradictory to, scientific views as studied by Lawson and Thompson (1988).

Rural School District- A territory that is more than five miles but less than or equal to 25 miles from an urbanized area, as well as rural territory that is more than 2.5 miles but less than or equal to 10 miles from an urban cluster, specific to the “distant” category, as defined by the United States Department of Education, Institute of Educational Sciences, National Center for Educational Statistics (2013).
CHAPTER 2
REVIEW OF LITERATURE

The purpose of this study is to examine the effect of robotics instruction embedded within a 5E Learning Cycle Model to address student’s understandings of force and motion concepts. An overview of constructivist and constructionist teaching practices in the science classroom is necessary in order to truly understand the foundation of this study. While there have been other educational theorists whose research has focused on constructivism such as Montessori, Dewey or Kolb, the researcher has chosen to focus on the work of Piaget. Glasersfeld (1995) stated, “Constructivism was set apart from the other theories of cognition 60 years ago by Jean Piaget and was the idea that what we call knowledge does not and cannot have a purpose of producing representations of an independent reality, but instead has an adaptive function” (p.3). In this chapter, the researcher highlights the theoretical framework that impacted the foundation for this study.

Constructivism serves as the basis for many of the reforms in education. In order to understand where the future of science education is going in the United States one must thoroughly examine its’ past; therefore this chapter presents the development of the United States science standards. Robotics instruction is also discussed in this chapter, as many United States youth are now more than ever becoming exposed to technological devices in and outside of a school setting.

The focus of this study is to make use of constructivist teaching practices (5E Learning Cycle Model) accompanied with robotics instruction as a means to assist students in addressing their understandings of force and motion topics. Through an embedded mixed methods study these selected practices have been applied within the classroom setting for rural elementary
students in order to determine how this teaching style (5E Learning Cycle Model) affected their understanding.

**Historical Roots of Science Education Standards**

Surprisingly the science standards that United States educators are basing the current standards throughout K-12 education stem from a report written by the Committee of Ten in 1895. These scholars described what students should know and learn as well as suggested methods for teaching (Mitchell, 1999). At the turn of the 20th century, a progressive or naturalist style of science began to emerge in the classroom. With educational philosophers like John Dewey and Joseph Schwab at the forefront of science education reform, educators began to move away from rote memorization of basic scientific facts (National Research Council, 2000). In addition to the progressive education movement of the early 1900’s, the National Society for the Study of Education (NSSE) published three yearbooks that outlined major science guidelines for assessment and science teaching (Powers, 1932; Whipple & Freeman, 1938; Henry &Brownell, 1946).

The NSSE yearbooks differed from the recommendations provided by the Committee of Ten because they included research-based examples of how science education should be facilitated and assessed, whereas the Committee of Ten mainly focused on “tracking or course differentiation based upon postsecondary pursuit” (National Education Association of the United States, 1894). In the 1950’s education began to shift rapidly after World War II, with technology becoming the driving force behind educational changes. Finally, with the launch of the Soviet’s Sputnik in October 1957, United States education began to rapidly evolve causing the “Golden Age of Science Education” (Bybee, 1997) to emerge and for the Federal government to focus
more on K-12 education. Between the years of 1954 and 1975 more than $117 million was spent on 53 separate curriculum course improvement projects. Multiple National Science Foundation (NSF) projects were funded, featuring research on content-focused disciplines, as opposed to the needs of the child (Bruner, 1977). Some critics opposed this type of curriculum, claiming content should be child centered, and voiced strong opinions against this shift. Paul DeHart Hurd (1963) stated, “What is expressed is more a point of view for the teaching of science” (p.84).

In the early 1980’s an examination of science education began to develop. With the publication of A Nation at Risk: The Imperative For Educational Reform (National Commission on Excellence in Education, 1983), Americans began examining their educational system more critically. Showcasing the educational system as an “incoherent, outdated patchwork quilt” (National Commission on Excellence in Education, 1983, p. 8)” of learning which ultimately led students to progress through schooling with little effort, A Nation at Risk heightened Americans awareness of the immediate changes that needed to occur to the educational system. This Reagan administration report was continuously surrounded with political and economic undertones and in some circles this document was said to tout the privatization of United States schools through public reform (Scott, 2006; Spring, 2010). Around the same time the National Science Resource Center, American Chemical Society and Biological Sciences Curriculum Study released various science curricula projects causing United States education system policymakers and stakeholders to note the changes needed for the current U.S. science standards (National Science Education Standards, 1996).

The American Association for the Advancement of Science’s James Rutherford and William Carey founded Project 2061 (a long term research and development initiative focused
on improving science education, AAAS, 1985) in 1985. Soon after, *Science for All Americans* (Project 2061, 1989) was published. This long term strategic plan for scientific literacy for all students in grades Kindergarten through 12 became the catalyst for the development of a set of national science education standards (Rutherford, 2009). The strategic plan, as outlined by *Science for All Americans*, helped to create a set of national science education standards and was spearheaded by the National Academy of Sciences and the National Research Council.

Presidents and co-chairs from various U.S. educational entities enlisted the support of the National Science Foundation and the U.S. Department of Education to fund a project that would begin examining the development of national science standards in the areas of content, assessment and teaching (National Science Education Standards, 1996).

In the early 1990’s education began to center more on standards-based reforms. Many researchers began to express concerns for standards-based curriculum models in science education due to inquiry-based science not being classified as a core component of many standardized programs. Researchers also expressed uncertainties surrounding the lack of evidence showcasing that a standards-based curriculum definitely improves student learning (NRC, 2000). In the 1998 report, *Preparing Our Children: Math and Science Education in the National Interest* (National Science Foundation) revealed that although science education had made large strides in regards to the evolution of teaching practices, the curriculum projects of the early 1990’s were in fact quite similar to those of the 1960’s; suggesting not much change had been made in science curriculum efforts.

In their study, Linn, diSessa, Pea, & Songer (1994) stated that “emerging science standards describe curriculum that individuals who are now successful research scientists would
have preferred when they were precollege students. Such a curriculum may be laudable for those who wish to become scientists, however for those who do not aspire to be scientists the curriculum is flawed, fleeting and fundamentally irrelevant” (p.5). Linn et al. (1994) proposed that science standards focus more on the science literacy needs of all citizens instead of only future scientists. This proposal paved the way for later developments in the science standards and resulted in social aspects of learning as well as alternative models of science education being included in the 1996 standards.

The National Committee on Science Education Standards and Assessments was formed in 1992 and consisted of representatives from the National Science Teachers Association, the Council of Science State Supervisors, the Earth Science Education Coalition and many other science organizations (National Science Education Standards, 1996). These groups collaborated to compose the National Science Education Standards for K-12 science education. Multiple drafts were released for public comment between 1993 and 1994 as a means of engagement to gain feedback for the final report release. In 1996, the National Science Education Standards (NSES) were released causing the findings from the previously mentioned 1994 study to be of less interest to public science educators. The 1996 NSES were used as the framework for most individual state science standards. For instance, science educators in Louisiana utilized these resources among other National Science resources when the Louisiana Department of Education (LDE) leaders created the Grade Level Expectations (GLE) in 2003.

The Louisiana Grade Level Expectations were developed to meet the requirements of the No Child Left Behind Act of 2001 which was a piece of federal legislation that mandated each state define the expectations for all students at all grade levels (LDE, 2004). In 2002, the
Louisiana Department of Education and the Data Recognition Corporation began enlisting the help of national consultants; recruiting teacher committees’ and developed initial drafts for each of the four content areas (English Language Arts, Math, Science and Social Studies) (LDE, 2004). The final drafts of the GLE’s completed an external review from a board composed of Council of Chief State School Officers (CCSSO), 12 content specialists (three per content area) from outside states or from universities or educational organizations across the nation. In 2003 the LDE staff presented the GLEs to the Louisiana State Board of Elementary and Secondary Education (BESE) for review and latter approved. In January 2004 all Louisiana educators were informed of the new Louisiana grade level expectations (LDE, 2004).

The GLE Handbook, released February 2004, states that the organization of the science grade level expectations are aligned with the *Louisiana Science Framework* (1997) and additional resources are said to come from the National Science Assessment Standards, Project 2061’s publications and the American Association for the Advancement of Science. The handbook also states that the Louisiana Science Standards are broken into five categories: Science as Inquiry, Physical Science, Life Science, Earth and Space Science and Science and the Environment, and although they are broken into categories, this is for organizational purpose only, educators are encouraged not to teach these separately, but to integrate these categories throughout science instruction (LDE, 2004). Based upon the National Science Standards released in 1997, Louisiana’s created GLEs have been divided into each grade level so that educators can grasp a better understanding of the core content that should be mastered at the end of each grade level and maintained in future grade levels, according to the LDE.
In 2011, the National Research Council released *The Framework for K-12 Science Education*. With STEM-related careers emerging; the U.S. Department of Education was forced to reexamine the standards of and framework for science education that had been developed 15 years prior, resulting in the development of *The Next Generation Science Standards* (NGSS) in 2012. The NGSS writers focused on coupling inquiry-based and STEM-related concepts in order to produce deeper understanding of crosscutting engineering, science and math related concepts. To be better prepared for the NGSS implementation, educators must acknowledge the theoretical foundations supporting hands-on learning as well as be made aware of the cognitive pitfalls that may occur.

The NGSS (2012) contain science and engineering strands throughout each grade that focus on the interconnectedness of science, math and engineering. The framework on which the NGSS was developed and is rooted in three dimensions, “the specific science and engineering practices, disciplinary core ideas (DCIs) and crosscutting concepts that were combined to produce the performance expectations (PEs)” (NGSS, 2012, p. R13). Throughout the NGSS there is a strong emphasis on engineering practices. According to the NRC (2012), a clarification of the term “engineering” is necessary in order to address common misconceptions associated with science and engineering practices. “We use the term “engineering” in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems” (NRC, 2012, p.11).

NGSS writers stress, “Engineering design is not just applied science and the engineering design process has a different purpose and product than scientific inquiry; therefore, engineering must be defined more broadly to emphasize engineering design practices that all citizens should
learn” (NGSS, 2013, p.1). Understanding that engineering practices have differences to science inquiry as well as similarities to science practices is a key piece to the NGSS puzzle. Collaboration, devising multiple solutions to problems and testing various explanations to find final answers, are all components that resonate in the engineering and scientific communities.

According to NSF (2010), “From a global perspective engineering offers opportunities for “innovation” and “creativity” at the K-12 level. Engineering is a field that is critical to undertaking the world’s challenges, and exposure to engineering activities (e.g., robotics and invention competitions) can spark interest in the study of STEM or future careers” (National Science Foundation, 2010, p.2). And, while educators and researchers agree that engineering has been shown to engage nontraditional science students (e.g. females, bilingual students) (Duderstadt, 2008; Jackson, 2002; National Science Board, 2006, 2007, 2008), the NRC suggests it is important to remember that engineering is integrated into the NGSS and each dimension contributes equally to provide each learner with an authentic science learning experience (NRC, 2012).

One dimension in particular, titled “Crosscutting Concepts,” reflects the same unifying concepts outlined in Benchmarks for Science Literacy (Project 2061, 1989). This dimension also mirrors the five unifying concepts and processes as outlined in the National Science Education Standards developed in the early 1990’s (NRC, 2011). The NSES’ five unifying concepts have been called, “The Big Ideas of Science” due to their ability to unify and provide a foundation for science teaching across grade levels.

The NGSS is based upon seven unifying concepts as outlined in Framework for K-12 Science Education (2012). These new unifying concepts are: patterns, similarity, and diversity;
cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; stability and change (NGSS, 2012). Although the NGSS are infused with 21st century practices necessary for today’s youth to succeed, the scientific concepts accepted by educators today are based upon the research of early 17th century scientists.

**Force, Motion and the Next Generation Elementary Student**

According to Isaac Newton, “forces are causes of changes in motion rather than motion itself and forces are the way we describe the effect of external influences on an object” (Tytler, Darby & Peterson, 2011, p.117). First published in 1687, Isaac Newton’s Three Laws of Motion have been the foundation of the theory of motion for over three centuries (Table 2.1a). Although Newton provided educators with the scientific foundation of force and motion, the academic expectations for elementary students are more developmentally appropriate than the principles Newton discovered centuries ago.

**Table 2.1a. Isaac Newton’s Three Laws of Motion (Crowell, 2000)**

<table>
<thead>
<tr>
<th><strong>Newton’s First Law:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>An object that is at rest will stay at rest unless an external force acts upon it.</td>
<td></td>
</tr>
<tr>
<td>An object that is in motion will not change its velocity unless an external force acts upon it.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Newton’s Second Law:</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>When a force is applied to an object, it accelerates.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th><strong>Newton’s Third Law:</strong></th>
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<tbody>
<tr>
<td>Forces are always produced in pairs, with opposite directions and equal magnitudes.</td>
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</table>

The National Science Education Standards (NRC, 1996) placed the concepts of force and motion under the physical science strand, which states that all students in grades K-4 will “develop an understanding of position and motion of objects” (NRC, 1996, p. 26). These standards also state that there are fundamental concepts and principles that underlie the standard (shown in Table 2.1b).
Table 2.1b. Position and Motion of Objects fundamental concepts and principles (National Science Education Standards, 1996)

<table>
<thead>
<tr>
<th>Principle 1: The position of an object can be described by locating it relative to another object or the background.</th>
<th>Principle 2: An object’s motion can be described by tracing and measuring its position over time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle 3: The position and motion of objects can be changed by pushing or pulling.</td>
<td>Principle 4: The size of the change is related to the strength of the push or pull.</td>
</tr>
</tbody>
</table>

The NGSS state that “the new standards support integration of multiple core concepts throughout each grade band and focus on a deeper understanding and application of content rather than fact driven standards currently utilized by many states across the U.S.” (NGSS, 2013 p. 326). Fueled by the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC, 2012), the NGSS replace the NSES that were adopted in 1996. In order to understand the concepts of force and motion outlined in the NGSS, one must first examine the framework from which these concepts originated.

According to the Framework for K-12 Science Education (NRC, 2012) there are four core ideas in the physical science standard: “Matter and Its Interactions”, “Motion and Stability: Forces and Interactions”, “Energy and Waves” and “Applications in Technology”. Each of the four core ideas are further broken down into underlying sub-components. For instance, an outline of the core idea of “Motion and Stability: Forces and Interactions” and its three underlying sub-components that students should try to master by the end of second grade are located in Table 2.1c. Similar to the NSES, the Framework for K-12 Science Education (NRC, 2012) also proposes three underlying principles of force and motion: push and pull and the interaction between objects.

<table>
<thead>
<tr>
<th><strong>PS2.A: Forces and Motion:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects pull or push each other when they collide or are connected. Pushes and pulls can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object’s motion.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PS2.B: The Types of Interactions:</strong></th>
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<tbody>
<tr>
<td>When objects touch or collide, they push on one another and can change motion or shape.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PS2.C: Stability and Instability in Physical Systems:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Whether an object stays still or moves often depends on the effects of multiple pushes and pulls on it (e.g., multiple players trying to pull an object in different directions). It is useful to investigate what pushes and pulls keep something in place (e.g., a ball on a slope, a ladder leaning on a wall) as well as what makes something change or move.</td>
</tr>
</tbody>
</table>

The original NSES of 1996 stated that the content standard was to be mastered upon completion of activities in grade bands (K-4, 5-8 and 9-12). The *Framework for K-12 Science Education* (NRC, 2012) has done the same; however, the framework provides a set of end points for grades 2, 5, 8 and 12 that are based upon learning progressions research to determine grade appropriateness (NRC, 2012). Although the framework lists the above mentioned three sub-component principles for completion at the end of grade 2, the NGSS writers have placed those ideas in a different grade band.

According to the NGSS, PS2.A, PS2.B and PS2.C should be implemented and mastered in kindergarten. With a focus on push and pull, kindergarten students will be able to analyze data collected from their own designed experiments that test elements of force and motion, direction and speed. The NGSS then revisits the concepts from PS2.A and PS2.B again in grade 3, with no mention of “Core Idea PS2: Motion and Stability: Forces and Interactions” at all in grades 1 or 2. Like kindergarten students, grade 3 students will also be expected to design their own experiments; however these investigations should be focused on balanced and unbalanced forces.
surrounding the motion of an object. Appendix A illustrates the NGSS implementation of the “Core Idea PS2: Motion and Stability: Forces and Interactions” at kindergarten and grade 3 levels. As seen in Appendix A, the Framework of K-12 Science Education guides the NGSS through each grade band. The NGSS (2012) embraces a STEM-like stance by coupling technology and engineering alongside elements of force and motion. The NGSS have placed each cross-cutting concept at each at an age-appropriate grade band. Even though these new standards have been created with a 21st Century learner in mind, the conceptual foundations developed by Isaac Newton still remain.

**The Evolution of Research on Misconceptions**

A “conception” is defined as “The way in which something is perceived or regarded, or one’s understanding” (Miriam-Webster, 2013) and to “misconceive” is to “fail to understand” (Miriam-Webster, 2013). When children hold views that differ from scientific explanations these views are often called “naive beliefs” (Caramazza, McCloskey, & Green, 1981), “preconceptions” (Hashweh, 1988), “prescientific conceptions” (Good, 1991), “misconceptions” (Lawson & Thompson, 1988) or “alternative conceptions” (Gilbert and Swift, 1985; Abimbola, 1988) (Wandersee, Mintzes & Novak, 1994, p. 178). Because the terms are so closely related, a clarification is helpful (Table 2.2). While the origin of children’s beliefs are sometimes uncertain, it is important to remember that children are not passive recipients of knowledge and each child will bring their own personal ideas and thoughts with them to a science lesson, which may or may not affect their end understanding of the topic presented. Wandersee, Mintzes and Novak (1994), states that while there are multiple terms that surround the phenomenon of how
children understand science, previous research suggests that there has been a shift from using “misconception language to alternative conception language” (Millar, 1989 p.177).

Table 2.2. Terms and their definitions surrounding children’s’ understanding of science education topics (Wandersee, Mintzes & Novak, 1994).

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve beliefs</td>
<td>Understanding of a topic based upon impulse ideas, can also be due to no previous interaction with topic presented</td>
</tr>
<tr>
<td>Preconceptions</td>
<td>Informal ideas developed by children prior to teaching</td>
</tr>
<tr>
<td>Prescientific Conception</td>
<td>Specific to science, emphasizes that the learners’ ideas may eventually lead him or her to the current scientific conception about a concept</td>
</tr>
<tr>
<td>Misconception</td>
<td>Concepts that learner’s hold which are inconsistent with, or even contradictory to, scientific views</td>
</tr>
<tr>
<td>Alternative Conception</td>
<td>Experience based explanations constructed by learners to make a range of natural phenomena intelligible, implies their alternative conception is context valid and rational</td>
</tr>
</tbody>
</table>

Alternative Conceptions and Conceptual Change Theory

In 1929 Piaget documented a study of children’s ideas concerning various topics through the use of the clinical interview technique (Akerson, 1998). Years later many researchers have conducted versions of the clinical interview technique as a means to obtain information on students’ understandings of multiple science topics (Osborne & Freyburg, 1985; Posner & Gertzog, 1982). Over time, researchers began noting that although educators emphasized direct instruction of science topics, many students continued through most of their schooling to rely on alternative conceptions of topics (Anderson & Smith, 1986; Bar, 1989; Bishop &Anderson, 1990). As a result of these findings, research began to emerge identifying, combating, or eliminating students’ alternative conceptions of science topics.

In 1982, Posner et al. proposed the conceptual change theory as an approach by which to explore ways in which students can change their incorrect understandings of topics pertaining to
physics and biology. The basis of this approach drew primarily upon two theoretical frameworks: one from the history and sociology of science (Kuhn, 1970) and one from developmental psychology (Piaget, 1977). Conceptual change theory will be defined here as a learning process in which a current understanding or belief about how the world works that is held by a student can be shifted away from an alternative conception and toward the dominant conception held by experts in a field (Chi & Roscoe, 2002, Fulmer, 2013).

The Conceptual Change Model (CCM) was later formed through the 1982 Posner et al. study which merged the ideas of Piaget and Kuhn and provided a new research paradigm in science education (diSessa, 1988; Feldman, 2000). There have been criticisms for this model, which include the lack of attention paid to knowledge growth in social situations (O’Loughlin, 1992), as well as too much attention to the teacher’s role in facilitating conceptual change (Wandersee et al., 1994). Many of the criticisms for the original CCM are in support for a more student-centered instructional approach and suggest utilizing concept maps or framing the activities with a learning cycle (Chi, Feltovich, & Glaser, 1981; Novak & Gowin, 1984; White & Gunstone, 1989).

The set of requirements for the CCM as outlined by Posner et al. (1982) and as discussed in Chapter 1 (pg. 8) are the overarching lens from which many conceptual change strategies have been developed in order to address students alternative conceptions. These include: conceptual change text with a designed program (Guzzetti, Snyder, Glass, & Gamas, 1993), analogy (Linnenbrek & Pintricher, 2004), cognitive conflict (Hynd, 2003), modeling (Calik, Ayas, Coll, Unal, & Costu, 2007), refutation text through small group discussions (Broughton, Sinatra, & Nussbaum, 2013) and an inquiry approach coupled with concept substitution (Harrison,
Traegust, & Venville, 1998). Utilizing the above mentioned strategies to teach for conceptual change has been documented as difficult due to the issue of students confronting their own existing ideas, or their alternative conceptions, with the new information being presented (Diakody, Mouskounti, & Iaonnides, 2011; Linnenebrink & Pintrich, 2004; Mason & Gava, 2007; Pekrun, Elliot, & Maier, 2009).

Wandersee, Mintzes and Novak (1994) states that “alternative conceptions are tenacious and resistant to extinction and are present at all levels of formal instruction, including college, and cut across ability level, gender, and cultural boundaries, as well as age” (p. 178). Where these alternative conceptions originate is difficult and often impossible to determine (Wandersee, Mintzes & Novak, 1994). Taylor and Dana’s 2003 study outlines several examples of situations where a student’s alternative conception of various science concepts has caused incorrect conclusions to be made during experiments. Taylor and Dana (2003) discuss students who are presented with correct information through Posner et al.’s (1982) CCM and asked to apply the new information to a different setting. In this study, many students’ most often return back to their own well-reasoned or overgeneralized explanation of the featured science topic even with the correct scientific explanation within access to solve the presented problem. Although this study is just one example which reaffirms the fact that alternative conceptions are extremely difficult to alter; educators must remember that the research surrounding alternative conceptions and conceptual change methods goes back many years.

**Force and Motion Confusion: The Early Years**

**Piaget, Inhelder and the Conservation of Motion.** In 1928 Einstein and Piaget discussed the age range for which children understand the concepts of time and velocity. This
prompted 30 years of research that revealed much more than the answers to Einstein’s questions (Piaget, 1946a, 1946b). Einstein admired Piaget’s method of intense observation of his subjects as a means to understand the concepts being examined and, in turn, Piaget continued to explore concepts dealing closely with Einstein’s inquiry of the concepts surrounding motion (Howe, 2002). Piaget and Inhelder (1958) studied the concept of the conservation of motion with children of different ages and documented their responses predicting when balls of various sizes were shot out of a spring-powered plunger. This task prompted children to predict, “where the balls would stop, to explain why the balls stop and why some balls may stop earlier than others” (Piaget & Inhelder, 1958, p. 48). A summary of these results in Table 2.2a shows children in grades pre-kindergarten to second grade’s viewpoint on this specific concept of motion, meaning that they are unable to express a deep understanding of the concept.

Table 2.2a. Piaget and Inhelder’s study on motion with children ages 2-15. (Piaget & Inhelder, 1958)

<table>
<thead>
<tr>
<th>Stage/Age/Characteristics</th>
<th>Possible Conceptions of Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperational Stage: Ages 2-7  One dimension and take one perspective</td>
<td>The big ball will go further because it is stronger.</td>
</tr>
<tr>
<td>Concrete Operational Stage: Ages 7-11 Multiple dimensions and take multiple perspectives</td>
<td>Examination of the surface of which the ball rolls on, as well as the material the ball is made out of could cause it to go further but not necessarily.</td>
</tr>
<tr>
<td>Formal Operational Stage: Ages 11+ Sophisticated scientific concepts and conceptualize with idealized terms</td>
<td>Asks questions like, “What if there was no air resistance or friction? Would this cause the ball to go further?”</td>
</tr>
</tbody>
</table>

In Piaget and Inhelder’s study (1958) children who were in late second grade to fourth grade displayed a multidimensional view on the concept of the conservation of motion; they were able to see how different variations of the plunger task could manipulate the outcome of the situation because they possibly had been exposed to other situations that aided their understanding of the concept of motion. Children in grades fourth and up displayed a full
understanding of the concepts involving motion. These older children were able to examine more possibilities that came along with the movement of an object because they had been exposed to much more and developmentally these students were able to understand the concepts at a deeper level. The findings in Piaget and Inhelder’s 1958 study continue to resonate in current research on force and motion. Although Piaget’s work has been documented as being misinterpreted at times (Metz, 1995), his discovery of children’s conceptions of motion continues to be one of the major cornerstones for research today.

**Piaget, Movement and Speed.** In 1970 Piaget published his examination of children’s (ages 5-14) views on movement and speed and found that these concepts are extremely difficult for younger children to understand (Piaget, 1970). The main findings from Piaget’s study focus on young children’s conceptions of objects that they felt moved at a faster pace, which were objects that had most often finished ahead of or overtook the other object at the finish line. This study did not support Einstein’s hope for young children to have an understanding of the separation of time and speed. However, Piaget’s research began to spark ideas for other researchers about children’s conceptions surrounding concepts of physics (Howe, 2002).

Seigler and Richards in 1979 elaborated on Piaget’s 1958 findings with a study focusing on a child’s conception of faster moving objects with children in kindergarten, second and fourth grades. Results from their study aligned with Piaget’s findings, especially the explanations from the children in kindergarten. These five- to six-year-olds demonstrated a poor understanding of the relationship between speed and time; in contrast, the children in fourth grade displayed a more consistently correct explanation of the faster object. Seigler and Richards’ study falls in line with many other research studies that emerged in the late 1970’s that examined a child’s
perception of science and math topics at various ages. Research studies like these were able to highlight the importance of a child’s prior understanding of topics even before formal instruction has been given on said topics. This caused researchers to take a closer look into how and why alternative conceptions pertaining to force and motion have evolved over time.

**Force and Motion Confusion: Generation X**

In the early 1980’s the United States began to examine science education as a whole, resulting in the publication of many studies across different age ranges of students, elementary to college level, and their science understandings. Palmer and Flannagan (1997) state, “One alternative conception that has been extensively studied is the Aristotelian idea that a continuous action of a force is necessary to keep an object in motion; although it represents a way of thinking that has long been rejected by the scientific community, it has now been established that this idea often predominates among students” (p. 318). In addition to the Aristotelian idea that constant force is necessary for motion, impetus is another conception that often confuses students (Caramazza, McCloskey, & Green, 1981). Impetus was thought to be an inanimate motive power or intrinsic force that keeps things moving; it can be gained, lost, or reconstructed in a variety of ways varying from student to student (Halloun & Hestenes, 1985; McCloskey & Kohl, 1983). In 1985, Gilbert and Watts documented four common conceptions children have when explaining their ideas of force and motion (Table 2.2b).

Since Gilbert and Watts’ findings, other studies have confirmed these naïve student conceptions pertaining to force and motion (Chi, 2005; Sokoloff & Thornton, 1998). Many times researchers found that although naïve, these conceptions are often backed by confidence (Waldrip, Prain & Sellings, 2013). As documented by Wandersee et al. (1994), alternative
Table 2.2b. Research-based claims relating to children’s conceptions of force and motion. (Gilbert & Watts, 1985)

<table>
<thead>
<tr>
<th>Conception 1:</th>
<th>Conception 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forces are to do with living things (gravity and friction are not forces, but people can apply force).</strong></td>
<td><strong>Constant motion requires a constant force (rather than constant motion resulting from no force and a net force causing speeding up or slowing down).</strong></td>
</tr>
<tr>
<td><strong>Conception 3:</strong></td>
<td><strong>Conception 4:</strong></td>
</tr>
<tr>
<td><strong>The amount of motion is proportional to the amount of force (faster moving objects are thought to have greater force).</strong></td>
<td><strong>If an object is not moving there is no force acting on it and if a body is moving there is a force acting on it in the direction of motion.</strong></td>
</tr>
</tbody>
</table>

Conceptions are extremely difficult for students to abandon and continue to plague students’ understandings of force and motion even into college. Studies have documented that secondary and undergraduate college level students continue to hold onto alternative conceptions about force and motion (Brown, 1989; Clement, 1982; Nussbaum & Novick, 1982; Peters, 1982). Several studies have shown that even physics and chemistry teachers continue to harbor their own alternative conceptions dealing with force and motion (McCloskey, 1983, Montanero, Perez, & Suero, 1995; Pozo & Carretero, 1994).

The 1980’s and early 1990’s research on alternative conceptions surrounding force and motion were plentiful. With educational shifts on the horizon researchers began to look to organizations and policymakers such as the American Association for the Advancement of Science (AAAS) and the National Research Council for guidance. After years of preparation and multiple revisions from consultants and teams all over the United States, the National Science Education Standards (NSES) were released in 1996 (NRC, 1996). The No Child Left Behind Act followed soon after in 2001, which mandated each state define the expectations for all students at all grade levels and create assessments to measure the attainment of the created standards. In an effort to meet this new mandate, many science educators and researchers began
to search for the literature surrounding the creation of the NSES, as well as developmental and cognitive psychology research coupled with a historical timeline of the development of science education and topics. In 2007 the National Research Council’s *Taking Science to School* was released making many researchers and educators able to access all of these resources and more in one publication.

**Force and Motion Confusion: The New Millennium Takes Science to School**

When *Taking Science to School* (NRC, 2007) was released, it was a highly praised critique on the current K-8 science education practices. At that time there had not been a major publication released that compared the science student of the new millennium to the science students of twenty to thirty years ago. *Taking Science to School* (NRC, 2007) highlighted the potential that young children possess when interacting with science concepts and supported these claims with current research in science education fields. This was contrary to the belief for many years that certain topics were inappropriate for younger children due to developmental inabilities as Piaget’s work had suggested (Metz, 1995).

*Taking Science to School* (NRC, 2007) dissects the processes that young children go through in order to learn concepts as well as examines the foundations upon which these processes occur. There is also an analysis of the ways in which young children perceive their physical world, particularly highlighting children’s ability to correctly interpret the underlying physics concepts. The report cites studies that suggest young children, in fact, do understand the concept of force or motion. However, in the context that it is being presented in, the student cannot communicate it effectively (diSessa, 2004).
The NRC report suggests that some of the confusion for children about topics concerning time and speed may be attributed to the culture in which U.S. children are exposed to math and science education topics (NRC, 2007). With the release of the Common Core Math standards, U.S. students will be exposed to many mathematical topics at an earlier age, which may increase younger students’ abilities to understand certain scientific concepts which in previous years may have been difficult to understand (NGSS, 2012). While *Taking Science to School* (NRC, 2007) reports that children of the new millennium better understand physical mechanisms (e.g. gears), the alternative conceptions on force and trajectories remain through elementary school and even into adulthood. A comparison of these updated understandings as well as historical understandings of physical science concepts can be found in Figure 2.2.

Some researchers are concerned that these alternative conceptions of critical physical science concepts, students will be left without an authentic basis for understanding the topic at hand; however, the NRC states that many times these alternative conceptions exist alongside the correct understanding of the concept (Chinn & Malhotra 2002; NRC, 2007). And while those correct understandings may exist, researchers and educators have continued to explore methods of which to combat student’s alternative conceptions of science topics. While many studies showcase the use of refutable text (Eryilmaz, 2002; Palmer & Flannagan, 1997), representational focus (Hubber, Tytler, & Haslam, 2010), cognitive conflict (Limon, 2001) and analogies (Clement, 1993) as a means to combat students alternative conceptions few studies exist that utilize robotics instruction as a means to examine force and motion alternative conceptions (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Liu, 2001).
Figure 2.2. Graphic Organizer Comparing and contrasting historical ideas surrounding children’s understanding of physics concepts to Ideas based upon the National Research Council’s Taking Science to School (2007).

According to Clement, Brown and Zietsman (1989), “not all preconceptions are misconceptions” and not every student expression is an alternative conception; therefore, educators must be aware of the effort and strategies that are involved for students to actively comprehend how their original ideas fit within the framework of scientific understanding and how to address whether or not these ideas need to be adjusted, modified or replaced.

5E Learning Cycle Model

Karplus and Thier (1967) introduced a framework consisting of three stages (exploration, invention and discovery), to support inquiry instruction that was derived from Piaget’s model of mental functioning. Since that time there have been several versions of the learning cycle that have developed (Table 2.3). The 5E learning cycle, as mentioned in Chapter 1, has also received criticism, although minimal studies have reported students’ lack of attainment for instructional
targets (Butts, Koballa, & Elliot, 1997; Lindgren & Bleicher, 2005). Regardless of those criticisms, the most successful modified version is the 5E model developed by Rodger Bybee in 1997, which focuses on the capitalization of student engagement, eliciting prior knowledge, and emphasizes formative and summative assessments (Maerck, 2008). Specifically the five phases are: Engage, Explore, Explain, Expand and Evaluate (Table 2.3). Several research studies focusing on the 5E Constructivist Model have been conducted: Abell and Volkmann (2006); Boddy, Watson and Aubusson (2003); Bybee and Taylor (2006). While the type of learning cycle model may be titled differently, after an examination of the cycles utilized in research, this proposed research study uses the 5E model established by Bybee (1997).

**Piaget and Constructivism**

“Constructivist teaching practices help learners to internalize and reshape or transform new information” (Brooks 1993, p. 15), thus this type of teaching is most often linked with studies involving conceptual change and alternative conceptions. Why the addition of the term constructivist? The 5E model has strong roots in constructivism and Piagetian concepts. Consistently, research of Jean Piaget’s constructivism theory has supported more of an evolutionary (continuously adjusting) approach to understanding concepts in the science related field.

Piaget examined the ways in which children analyzed and understood situations at several levels of cognitive development. His findings continue to ground theoretical frameworks surrounding children’s cognitive structures developed today. Piaget’s findings surrounding children’s cognitive development resulted in the formation of constructivism.
Table 2.3. Historical and Contemporary Models of the 5E Learning Cycle. (Modeled after Gallagher, 2006)

<table>
<thead>
<tr>
<th>Historical Models</th>
<th>Contemporary Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hebert (Early 1900’s)</strong></td>
<td><strong>Atkin and Karplus (1980’s)</strong></td>
</tr>
<tr>
<td>- Preparation</td>
<td>- Exploration</td>
</tr>
<tr>
<td>- Presentation</td>
<td>- Intervention</td>
</tr>
<tr>
<td>- Generalization</td>
<td>- Discovery</td>
</tr>
<tr>
<td>- Application</td>
<td></td>
</tr>
<tr>
<td><strong>Dewey (Circa 1930’s)</strong></td>
<td><strong>Bybee (1990’s)</strong></td>
</tr>
<tr>
<td>- Sensing Perplexing Situations</td>
<td>- Engagement</td>
</tr>
<tr>
<td>- Clarifying a Problem</td>
<td>- Exploration</td>
</tr>
<tr>
<td>- Formulating a Tentative Hypothesis</td>
<td>- Explanation</td>
</tr>
<tr>
<td>- Testing the Hypothesis</td>
<td>- Elaboration</td>
</tr>
<tr>
<td>- Revising Rigorous Tests</td>
<td>- Evaluation</td>
</tr>
<tr>
<td>- Acting on the Solution</td>
<td></td>
</tr>
<tr>
<td><strong>Heiss, Obourn and Hoffman (Circa 1950’s)</strong></td>
<td><strong>Eisenkraft (2000’s)</strong></td>
</tr>
<tr>
<td>- Exploring the Unit</td>
<td>- Elicit</td>
</tr>
<tr>
<td>- Experience Getting</td>
<td>- Engage</td>
</tr>
<tr>
<td>- Organization of Learning</td>
<td>- Explore</td>
</tr>
<tr>
<td>- Application of Learning</td>
<td>- Explain</td>
</tr>
<tr>
<td></td>
<td>- Elaborate</td>
</tr>
<tr>
<td></td>
<td>- Evaluate</td>
</tr>
<tr>
<td></td>
<td>- Extend</td>
</tr>
</tbody>
</table>

From constructivist theories of psychology “we take a view of learning as a reconstruction rather than as a transmission of knowledge” (Papert, 1991, p. 193); as a means to better understand the ways in which children form constructs. In a constructivist classroom, children aren’t simply given information via a textbook and expected to spout out definitions of science concepts. Children are allowed the freedom to explore the concepts presented and construct their own understanding of the topic through their own personal discoveries.

The transformation of knowledge occurs through the creation of new understandings (Jackson, 1986; Gardner, 1991) that result from the emergence of new cognitive structures. For example, when an infant interacts with a kitchen spoon for the first time, he or she can see their
face smiling back at them; this transforms their understanding of the spoon. In later years this infant, now a child may interact with kitchen spoons again after learning about the concept of reflection. This presence of new information may prompt an emergence or enhancement of cognitive structures that enable the child to rethink his or her prior ideas of which mediums can show a reflection, thus a deeper understanding of the concept of reflection has been created.

It is evident that in order for the constructivist classroom to be effective educators must focus on the needs of the learner and center around an interactive inquiry-based environment where the instructor is continuously exposing students to new information that serves as a catalyst that prompts students to form questions about the concepts presented in the lesson. Constructivist-based classroom practices are context-based and students are encouraged to collaborate with others in order to solve problems. These problems could be related to their own experiences; thus facilitating the creation of deeper understanding surrounding the topic at hand. While Piaget’s research indicates capturing children’s thinking at various developmental stages is essential to understanding cognitive processes among youth, some studies indicate that Piaget’s theory “tends to overlook the role of context, uses or applications, and media, as well as the importance of individual preferences or styles, in human learning and development” (Ackerman, 2008, p. 5). With the digital age upon us, educators must understand how to effectively couple constructivist practices with the fast paced technological world.

**Papert and Constructionism**

In 1970 Seymour Papert introduced the learning theory constructionism. As described by Papert, “Constructionism—the N word as opposed to the V word – shares constructivism’s view of learning as “building knowledge structures” through progressive internalization of actions… It
then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it’s a sand castle on the beach or a theory of the universe” (Papert, 1991, p.1). Based on Piaget’s ideas of children’s cognitive development (Table 2.4), Papert’s constructionism was developed for the world of computer technology. Focusing on the importance of physical constructions in the digital world and representing them through mental thoughts, Papert’s theory embraces the examination of how children formulate thoughts and express those ideas through media (Papert, 1980). This idea of investigating students’ digital media artifacts as a means to gain a deeper understanding of the whole student is necessary when dealing with the 21st century learners of today.

Table 2.4. Constructivism and Constructionism. (Modeled after Ackermann, 1996)

<table>
<thead>
<tr>
<th>Constructivism</th>
<th>Constructionism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jean Piaget (Switzerland, 1896-1980)</strong></td>
<td><strong>Seymour Papert (South Africa, 1928)</strong></td>
</tr>
<tr>
<td>- Focuses on Individual isolated knowledge</td>
<td>- Importance on people not technology</td>
</tr>
<tr>
<td>- Builds knowledge</td>
<td>- Learning environments for collaboration</td>
</tr>
<tr>
<td>- Learning happens in context where learner is engaged</td>
<td>- Distributed view drawn from surrounding culture</td>
</tr>
<tr>
<td>- Structure in Linear Form</td>
<td>- Focuses on the process that helps learners make connections in making sense of the world they interact with</td>
</tr>
<tr>
<td>- Focuses on Accommodation, or making sense of the world learners interact with</td>
<td></td>
</tr>
</tbody>
</table>

Constructionism underlies an examination of the processes in which learners make connections in making sense of the world they interact with. In order for our digitally immersed students to feel connected to the classroom, educators must bridge the gap between necessary traditional math and science topics and real life representations of such concepts. Constructionist programming environments are tools for “engaging children in thinking about their own thinking; a place where abstract ideas can become more concrete and thereby subject to
reflection” (Papert, 1980, p. 379). Making abstract ideas concrete is task that many educators struggle with, however the utilization of technology in the classroom has made a marked difference in providing a platform for which students can express themselves. Many schools are now embracing more of a technology and engineering framework as a base for curriculums as a way to make real life connections with students.

**Papert’s Mindstorms and Education**

Using constructionism as a platform, in 1960 Papert developed an environment using the Logo programming language that combined technology and mathematics for young children to manipulate. Connecting mental models of concepts to technological modes of presentation allowed the children in Papert’s study to understand programming language as well assist their understanding in other disciplines (Papert, 1993). In the 1970’s and 1980’s, Papert participated in a number of educational projects focused on children exploring their own ideas through computer interactions at the Massachusetts Institute of Technology (MIT) that resulted in the publication of *Mindstorms: Children, Computers, and Powerful Ideas* (Papert, 1980). Soon thereafter, a group of researchers from MIT, supported by Papert’s idea of constructionism merged with the LEGO Group, a company which produced motors, gears and beams for children to assemble into structures. This LEGO company emphasized the importance of connecting the Logo computer program language and concrete structures to technology. With Papert’s vision of children learning by “building ideas in one’s mind as part of building artifacts in the world” (Martin, Mikhail, Resnick, Silverman, & Berg, 2000, p.10), this newly formed group quickly began marketing the first true robotic construction kit for children to schools across the United States.
Lego Robotics in the Classroom

In the 1980’s the first Lego/Logo kit was released to schools. Being the only researched-based robotics kit released to the United States public at the time (Bers, 2010), Lego/Logo researchers soon began researching the effects of utilizing the kits in the classroom. Researchers examined the interactions between middle and high school students with the kits and documented the possibilities and limitations of this new partnership (Martin, 1988). Only one other robotic platform emerged at this time, Parallax, and its Boe-Bot robot was not fully developed until the late 1990’s. Lego/Logo stood alone in the world of classroom robotic kits for the majority of the 1990’s and into the early 2000’s.

Due to technology innovations in the early 1990’s, an expansion of the Lego/Logo’s original design kit for classrooms was released. This kit featured more technological components which were easily manipulated by teachers and students, thus allowing researchers to conduct more field observations in a variety of areas including international schools. With technology evolving rapidly in the mid 1990’s, the 1980 Lego/Logo design soon evolved again into a more collaborative, adaptable design for students and teachers. Each time the robotics kit was modified; researchers gathered data and continued to produce positive results (Martin, 1988; Resnick, 1996).

Historically, educators have used manipulatives in the classroom as a way to make concepts more concrete to students. Cuisenaire rods, base ten blocks, counting chips, these are all materials educators can provide to students as a means to better understand mathematical concepts. Following the Lego/Logo technology trend, digital manipulatives, such as programmable building bricks and communicating beads, emerged during the mid-1990’s all of
which helped to expand the range of concepts that children could explore (Resnick, 1996). While these digital manipulatives did expose students’ to technology, they were not nearly as effective as the Lego/Logo robotics kits had been (Martin 1988; Resnick, 1996). Lego/Logo researchers released the Lego Mindstorms development and programming kit in 1998 to schools. Figure 2.3 features the Lego Mindstorms NXT Robot that was used by participants in this research study.

Figure 2.3: Lego Mindstorms NXT Robot used in this study.

**Lego Mindstorms to NXT: The Next Generation**

From the late 1990’s to the early 2000’s, computer programming combined with robotics tools continued to be an emergent field from an educational research perspective. Research presenting benefits to students’ interactions with computer programming and robots with age-appropriate materials yielded positive results, such as allowing students to learn and apply mathematical thinking concepts to various situations (Liao & Bright, 1991; Clements & Battista, 1990; Resnick, 2003).

Few robotics kits have had the sustained success that Lego has enjoyed for over three decades. Various robotic platforms have emerged that showcase multiple coding methods such as Arduino (created in 2005) and Tetrix (created by Pitsco in 2011) (Rogers, Wendell, & Foster,
These platforms, in addition to Vex (created in 2006), are most often utilized in secondary, undergraduate and graduate computer engineering courses (Repenning, Webb, & Ioannidou, 2010). Few research have examined the use of the above mentioned robotic platform kits with rural elementary students (Eubanks, Strader, & Dunn, 2011; Williamson, El Sawalf, Abdel-Salam & Mohammed, 2008) and these studies focus mainly on using the robots as simply a motivational tool.

Based on the background knowledge regarding alternative conceptions, the 5E Learning Cycle Model, constructivism, constructionism and robotics instruction in the classroom; there appears to be a gap in the literature that would benefit not only rural elementary students but educators as well. This study is designed to analyze the approach by which educators present physics topics to elementary students. As a current elementary educator, the researcher’s primary goal is to examine the effect of robotics instruction through the 5E Learning Cycle Model on students’ understandings of force and motion. Through this examination the researcher in turn hopes to appeal to both practitioner and researcher in the elementary science education field. Those who are interested in gaining a different perspective on incorporating robotics instruction and the 5E Learning Cycle Model as a way to better address student’s alternative conceptions on force and motion should find this study of interest.
CHAPTER 3
METHODOLOGY AND PROCEDURE

Purpose

The purpose of this study was to investigate the development of rural elementary students’ conceptual understanding of force and motion as a result of the implementation of robotics instruction immersed within a 5E Learning Cycle Model. The study attempted to answer the following questions:

How does the utilization of robotics instruction embedded within the 5E Learning Cycle Model assist students in gaining a deeper understanding of force and motion?

In what ways have the robotics instruction utilized in this study empowered students of different ability levels to retain these newly developed conceptions over a period of time?

Second grade students, located at a rural elementary school in Louisiana, participated in lessons involving robotics instruction immersed within a 5E Learning Cycle Model to better understand concepts of force and motion. These lessons include programming the robot to manipulate items in order to address common conceptions children have when explaining their ideas of force and motion in addition to the students’ own stated conceptions or misunderstandings of force and motion all through the 5E Learning Cycle Model format.

A pilot study was conducted at a rural elementary school in February 2014 across four groups of second grade students consisting of 23-24 students in each group: one control group, received four 60 minute lessons featuring force and motion 5E Learning Cycle Model type activities without robotics instruction and three experimental groups, Groups E1, E2 and E3, received the same four 60 minute lessons with the added robotics component. The groups were
intact and not randomly assigned due to the protocol of student assignment; therefore the sampling strategy for the quantitative portion was convenience and quota. The protocol of student assignment is conducted by the administration at the research site; the researcher was not given the exact procedure of the classification system as it was identified as confidential administration information only. The researcher was not provided any information as to how each student was placed into his or her homeroom classes. According to the research site administrative faculty, parental request of certain teachers is not considered. A full description of the demographic data collected during this study is featured in the results section of the dissertation. Due to this study being mixed methods, sampling for the qualitative data was obtained through criterion sample selection.

Data collected from the quantitative portion of the pilot showed mixed results; yielding a split between groups. This data compared to the qualitative questions conducted throughout the study gave more insight to the data produced from the post-test scores. A closer examination of the 5E activities for each group occurred and as a result small changes were made in the experimental groups, Group E1, E2 and E3. In order for the students to understand the physics concepts presented alongside the use of the robots, certain materials had to be altered before the Full Research Study could be conducted.

The full research study was conducted at the same rural, Louisiana elementary school in May 2014 among four new groups. The collection of data was through pre-test, post-test (full research study: quantitative phase) and draw and tell (full research study: qualitative phase) as showcased in Figure 3.1. The intervention lessons applied during the pilot study were repeated, along with the altered components found in the pilot study, to a new set of control students (no
robotics component), and to a new set of three groups containing 25 students, Group E1, E2 and E3, the experimental groups. As previously mentioned, the groups were intact and not randomly assigned due to the protocol of student assignment; therefore the sampling strategy for the quantitative portion is convenience and quota while the qualitative sampling is criterion. An overview of this study as well as the implementation phases is located in Figure 3.1.

The null hypothesis (Ho) stated that robotics instruction immersed within the 5E Learning Cycle Model in order to address rural elementary students’ understandings of force and motion will not have an effect and will not enable students of different ability levels to retain newly developed concepts over a period of time. The alternative hypothesis (Ha) stated that robotics instruction immersed within the 5E Learning Cycle Model in order to address rural elementary students’ understandings of force and motion will have a positive effect and will enable students of different ability levels to retain newly developed concepts over a period of time. One week prior to the intervention, a pretest was administered; the same test was employed immediately after the intervention is complete (quantitative component). Qualitative data was gathered through the draw and tell technique throughout all aspects of the study due to the embedded design utilized. (See Figure 3.1)

Figure 3.1: The Framework for Overview of Study. Pilot study was conducted in February 2014, with all components of embedded mixed methods design implemented (pretest, posttest, draw and tell).
Objectives

The objectives of this study included the following:

- Complete a pilot study: (a) Test pilot instruments; (b) Test lessons/activities; (c) Compare pretest and posttest assessments.
- Describe the sample population of the full research study: (a) Gender; (b) Race; (c) Ability level.
- Compare pretest and posttest scores among four groups (including a control):
  Whether or not robotics exposure influenced information obtained at varying intervals: 1. Upon completion of activity; 2. One week after activity.
- Discover students’ viewpoint of Robotics use on conceptions or misunderstandings: Overall student perception of robotics use to assist in understanding force and motion: 1. Before; 2. During and 3. One week after the activity.

Research Design

Mixed methods research is the type of research which combines elements of qualitative and quantitative approaches for the purpose of breadth and depth of understanding and corroboration (Johnson & Christensen, 2011). Qualitative methods have constructivism roots with logic being inductively obtained and the data is typically represented textually or pictorially. Traditionally, quantitative methodology has philosophical underpinnings of positivism or post positivism viewpoints, where logic is deductively obtained and data is represented numerically (Creswell & Clark, 2011). In statistical data analysis, an adequately large sample size increases the statistical power which in turn detects reasonable departures from the null hypothesis.
(Hinkle, Wiersma, & Jurs, 2002). This can also contribute to generalizing the data; however, the quantitative data set would only provide one viewpoint to this study’s research problem. Although quantitative data can be generalizable, the qualitative component enhances the experimental data overall by assisting in determining whether or not the intervention had a significant effect. Therefore, utilizing a mixed methods approach combines a more in depth understanding of the research questions at hand, rather than either approach on its own (Creswell & Plano Clark, 2007).

An embedded mixed methods design was utilized to address students’ understandings of force and motion concepts when robotics instruction is embedded into 5E Learning Cycle Model lessons. This specific design type is described as one in which one data set (qualitative data) provides a different insight to the experimental data set (quantitative) (Creswell, Fetters, Plano Clark & Morales, 2009). The embedded mixed methods design, also called the nested design, is often used in educational research as well as social and behavioral research. This study employs a variant of the embedded mixed methods design, which is defined by having qualitative data embedded within a quasi-experimental design and takes a two phase approach where the qualitative data comes before, during and after the intervention has occurred (Creswell, Plano Clark, Gutman & Hanson, 2003). This type of design was specifically chosen due to the nature of the study itself. Having elementary aged children serving as the participants for this study, utilizing multiple data collection methods was necessary. At times, when analyzing children’s quantitative responses to an intervention, additional explanations are needed (e.g., Victor, Ross, & Axford, 2004); hence the incorporation of the qualitative component of the study.
To fulfill objective 1, the pilot study was conducted in February 2014. The full research study which took place in May 2014 fulfilled objectives 2, 3 and 4. The pilot study included one Control Group, which received four 60 minute lessons featuring force and motion 5E Learning Cycle Model type activities without robotics instruction and three experimental groups, Groups E1, E2 and E3 which received the same four 60 minute lessons with the added robotics component as seen in Table 3.1. The groups were intact and not randomly assigned due to the protocol of student assignment, which as previously mentioned, the researcher was not allowed access as to the exact procedure of the student assignment. The researcher was not provided any information as to how each student was placed into his or her homeroom classes. According to the research site administrative faculty, parental request of certain teachers is not considered.

The full research study, focused on a new set of three groups containing 25 students, (Groups E1, E2 and E3) and the control lessons without the robotics component with one group of 25 students, Control Group (Table 3.1). As previously mentioned, the groups were intact and not randomly assigned due to the protocol of student assignment. The intervention of four 60 minute lessons on force and motion took place on Tuesday and Thursday of the first week and Monday and Wednesday of the following week to collect data which showcased the effects of the intervention overtime.

The quantitative phase consisted of a pre-test to assess students’ conceptual understanding of force and motion (Science Series Assessment 1, based on Russell and McGuigan’s 2001 study) given to second grade elementary students one week prior to the intervention. The post-test was administered immediately following the conclusion of the
intervention and then again one week following the intervention. The second phase of the study, the qualitative phase, employed the draw and tell technique as described by Kenney (2008).

Table 3.1 Groups and Treatments

<table>
<thead>
<tr>
<th>Study</th>
<th>Group Name</th>
<th>Type of Group</th>
<th>Type of Treatment</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>Control</td>
<td>Control</td>
<td>5E Learning Cycle</td>
<td>Comparison Baseline</td>
</tr>
<tr>
<td>Pilot</td>
<td>E1</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>E2</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>E3</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
<tr>
<td>Full Research</td>
<td>Control</td>
<td>Control</td>
<td>5E Learning Cycle</td>
<td>Comparison Baseline</td>
</tr>
<tr>
<td>Study</td>
<td>E1</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
<tr>
<td>Full Research</td>
<td>E2</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>E3</td>
<td>Experimental</td>
<td>5E Learning Cycle +Robotics</td>
<td></td>
</tr>
</tbody>
</table>

This technique was used to further explain different ability-leveled students understandings of force and motion from start to finish as well as examine the knowledge gained throughout the experiment. This includes the chosen student’s individual perception of the concept before, during and after the intervention. Figure 3.2 provides an overview of this study’s use of the embedded mixed methods research design as well as the phases of study, the procedures for data collection and products from data collection. Figure 3.3 showcases a timeline for completion of dissertation.

**Population and Sampling Procedures**

Participants in this study were comprised of 191 grade 2 students (ages 7-8 years) from four classes enrolled at a rural elementary school in Louisiana. There were approximately an
equal number of males and females and ethnicity groups in each of these classes that had been predetermined by the protocol of student assignment per the school administration. Demographic information was gathered through the abovementioned protocol.

Second grade students attending the site of this study, a rural elementary school in Louisiana, are frequently exposed to technology and have had previous interaction with robotics instruction through monthly lessons facilitated by the computer lab teacher. In addition to the robotics exposure, these second grade students have been exposed to extensive use of science notebooks and journaling prior to the intervention.

Figure 3.2. Overview of the research design. Figure shows Phases of Study, Procedures for Data Collection and Products from Data Collection

Due to this study embodying an embedded mixed method design, mixed method sampling techniques used involved simultaneous use of both quantitative (probabilistic/non-
probabilistic) and qualitative (purposive) sampling (Johnson & Onwuegbuzie, 2004; Creswell & Clark, 2011).

The sampling strategy for the Full Research Study’s Quantitative component was the nonrandom sampling technique of convenience; this sample was then be randomly assigned to the experiment or control groups, which generated similar groups, as well as quota sampling, which are both used in the strongest of the mixed methods experimental research designs (Teddlie & Tashakkori, 2009). The resulting three experimental groups (n=75) and a control group (n=25) were used to conduct the study.

Traditionally, qualitative research utilizes purposive sampling, which leads to greater depth of information from a smaller number of carefully selected cases (Patton, 2002). The exact

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<table>
<thead>
<tr>
<th>Pilot</th>
<th>Pilot</th>
<th>Full Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2014</td>
<td>February-March 2014</td>
<td>March-April 2014</td>
</tr>
<tr>
<td>QUAN/QUAL Pre/Post Test Draw and Tell</td>
<td>QUAN/QUAL Analyze Quan data</td>
<td>QUAN/QUAL Enhance/Adjust Pre/Post Test Draw and Tell</td>
</tr>
<tr>
<td>Full Study June-July 2014</td>
<td>Full Study May 2014</td>
<td>Full Study May 2014</td>
</tr>
<tr>
<td>Integrate all data</td>
<td>QUAN/QUAL Analyze Quan data Code &amp; Transcribe Qual data</td>
<td>QUAN/QUAL Pre/Post Test Draw and Tell</td>
</tr>
<tr>
<td>July-August 2014</td>
<td>September 2014</td>
<td>November 2014</td>
</tr>
<tr>
<td>Write Chapters 4-5</td>
<td>Submit Dissertation to chair and committee/ Defend Dissertation</td>
<td>Defense/Edits Complete Dissertation submitted to grad school</td>
</tr>
</tbody>
</table>

Figure 3.3. Time line for completion of this dissertation
sample size for qualitative research varies; too many samples could produce saturation, and too few samples may not enable researchers to compare particular groups or to consider frequency distribution (Teddlie & Yu, 2007). Baker and Edwards (2012) state, “there is a need within qualitative research to build convincing analytical narrative based on ‘richness, complexity and detail’ rather than on statistical logic” (p.13) and suggest a sample size ranging from 12 to sixty depending on the individual study. Keeping these numbers in mind, the qualitative component of this research study is identified as a case study due to the smaller size of the sample.

According to Stake (1995) and Yin (2003) the interaction between researcher and participant throughout most case studies has its roots in constructivism. With these interactions, the participants are able to describe their views of reality, which enables the researcher to gain a deeper understanding of the participants’ actions (Lather, 1992; Robottom & Hart, 1993). A sample size ranging between six and twenty-four participants is suggested by Teddlie & Tashakkori (2009). When conducting qualitative research, researchers are less often interested in finding a general theme for a larger group, and more often interested in finding why a particular, smaller group or subset of people from the larger group, feel a certain way, and why and how they came to feel that way. This normally consists of a purposive sample that is non-representative of the larger population (Onwuegbuzie & Leech, 2005). The type of purposive sampling that was utilized in this study was criterion. This sampling technique is used when the researcher is searching for cases that contain extreme, typical, or multiple perspectives in relation to the phenomenon one is studying (Creswell & Clark, 2011).

The sampling strategy for the qualitative component of this research study was criterion sampling based upon the three ability levels identified from the students’ first grade ITBS
science test scores. Prior to the intervention, the stanine scores were grouped into three levels: high, medium and low, and provided a sample size of 36, three from each ability level from each class (including the experimental and control groups). These 36 students were pulled three at a time from ancillary classes and participated individually in the draw and tell activity before, during and one week following the close of the intervention. Although there were three students pulled at one time, two of the students were placed with headphones on a computer, while one student worked with the researcher to complete the draw and tell task. A coding framework based on Kenney’s books (2008) as well as Reiss and Tunnicliffe’s study (2001) was created in order to establish and use a priori codes.

**Limitations**

As with any research study, there were limitations that needed to be addressed within this study. The first limitation is geographical because this study is limited to one rural elementary school in Louisiana. In addition, all of the students involved in this study were instructed by the researcher, therefore a cross sectional comparison between instructors cannot be obtained. Also, having all the students under the instruction of the researcher, not their homeroom teacher, could create a performance issue. This may be viewed as problematic if one seeks to replicate this content elsewhere. However, there is also consistency in having the same individual instruct both the control and treatment groups as a means to control the delivery of the lesson which could affect the results of the study. Secondly, the sampling of the participants was not be randomly assigned due to the assignment of students based on the principal’s discretion; therefore, there is limited generalizability of findings as generalizing must occur among similar groups. Furthermore, the chosen control group was skewed to the lower academic end; the
researcher had previously chosen this group prior to examining any academic information on the students that were placed in the control group. Additionally, the previous instruction provided to the students pertaining to measurement varied due to classroom assignment; therefore, the preparation of this topic was not consistent across classes. Furthermore, the ability level classification method, conducted by school administration, was not revealed to the researcher; therefore the researcher was not allowed access to this data in order to independently check for validity and reliability of the assigned ability level. In addition to these limitations, a factor analysis was conducted in order to find common factors inside of the instrument in order to counteract validity issues. Lastly, the qualitative portion of the study involved an analysis of visual images created by students’ conceptions of force and motion concepts throughout the study. Due to the data being qualitative, there may be variances in interpretation of the data from one reader to the next.

**Ethical Considerations and Study Approval**

The study was approved by the Institutional Review Board at Louisiana State University, number E8463, on October 10, 2013. An overview of the research protocol is outlined in Figure 3.1 and Figure 3.2 of this chapter. The approval for the study is found in Appendix B. All participants volunteered and signed forms of consent found in Appendix C.

**Instrumentation**

This portion of Chapter 3 outlines each instrument utilized in this study: pretest and posttest as well as the draw and tell technique. Each section describes the instrument; including its appropriateness as well as the sampling strategy used for collection of data. In addition to this methods regarding validity, reliability and trustworthiness are discussed.
The lessons described in this study have been conducted through a two-part science unit on force and motion concepts that all second grade students enrolled at elementary school partake in. The exact time during the school year in which these units are implemented can be at the individual teachers’ discretion; therefore the researcher conducted the lessons and the research study during the timeframes outlined in Figure 3.3.

**Pretest and Posttests**

During the pilot portion of the study, a pretest and posttest (Appendix D) was administered to participating students to assess students’ conceptual understanding of force and motion. The pretest and posttest were the Science Series Assessment 1 (Russell & McGuigan, 2001) which consisted of 12 items. Permission to use this assessment had been granted. This instrument has been reviewed in the *Mental Measurements Yearbook* (2010). Information pertaining to standardization and reliability of this instrument is discussed in the validity and credibility section.

The pretest was administered to participants two weeks prior to the intervention, the participants then performed the intervention, and this same test was employed immediately after the intervention was complete in order to assess for knowledge retention of force and motion understanding (Posttest 1). The same posttest containing 12 force and motion type questions was administered one week after the intervention to test for the effect of the instructional activities over time (Posttest 2). In the spring of 2014, the pilot data was analyzed and an adjustment to how the test was administered was made. During the pilot, students who received tests read aloud accommodations did not receive this accommodation during the pretest or posttest. Not receiving accommodations might drastically alter these students performance on the pre and
posttests. This was noted and adjusted for the full research study implementation in May 2014. The quantitative data gathered from these tests was analyzed by comparing the experimental and control groups’ post-test scores after they had been adjusted for any differences that may exist on their pre-test scores using analysis of covariance (ANCOVA).

The full research study contained one pretest and two posttests in order to measure retention of knowledge. Similar to the pilot study, the pretest was administered two weeks prior to the treatment; this same test was employed immediately after the intervention was complete to assess for knowledge retention of force and motion understanding (Posttest 1). The same posttest containing 12 force and motion type questions was administered one week after the intervention to test for the effect of the instructional activities over time in May 2014 (Posttest 2).

The quantitative data was analyzed by comparing the experimental and control groups’ post-test scores after they have been adjusted for any differences that exist on their pre-test scores using analysis of covariance (ANCOVA). The independent variable (robotics instruction) was manipulated in a presence or absence technique. In order to control for an equal academic ability level, the ANCOVA method was used. The ANCOVA method statistically equated the groups that could differ; the covariate was the students’ first grade Iowa Test of Basic Skills (ITBS) test scores. The conceptual variable being examined here is force and motion concept recognition and this was measured through the operational variable of the post-test scores.

**Draw and Tell Technique**

The qualitative portion of this study utilized the draw and tell technique, which allowed participants to express their understanding of force and motion concepts through the creative process offered through drawing. The technique of drawing and telling provides infinite
possibilities, rather than “a pre-determined set of options” (Harris, 1996, p. xi). Through the drawings and personal interviews of the students, the researcher gained deeper insight into the participants’ overall view of force and motion concepts throughout the study. This technique was conducted in February 2014, through the pilot with 36 participants, and then again in the full research study, in May 2014. As discussed in section 3.3, the participants were chosen based upon their pre-established ability level (high, medium, low) identified by first grade ITBS stanine scores.

The researcher met with the participants and provided each student with clean sheets of paper and drawing utensils. The researcher then read simple, neutral instructions pertaining to force and motion concepts to the students, avoiding leading questions to avoid undue bias (Appendix F) (Kenney, 2008). The children were allowed as much time as needed to illustrate the concepts presented in order to complete the draw and tell process with all of the participants.

All field notes and transcriptions of draw and tell interviews were explored through a coding technique of circling and highlighting sections of the texts that contain words or phrases thought to be meaningful (Saldaña, 2012). This coding method was followed up with another analysis of transcriptions using a non-hierarchal axial coding approach (Saldaña, 2012) in order to sort themes and codes into an order or group. A priori codes were used and developed before the researcher examined the data. Chapters 4 and 5 contain more information on this process as well as the participant descriptions. All descriptive coded field notes and draw and tell interview information assisted the researcher in gaining a deeper understanding of each student’s understanding of the overall experience. The transcripts and field notes were coded multiple times by the researcher and a peer reviewer to ensure reliability. The information gathered from
these transcripts was cross validated with the researchers’ interpretations of the participants’
drawings (Gonzalez-Rivera & Bauremeister, 2007; Kenney, 2008). Each participant’s draw and
tell data was merged with his/her pretest and posttest data. With this information, the researcher
created a description of each draw and tell contributor. The draw and tell instrument provided
insight to the statistical data collected from the quantitative portion of the study.

Validity, Reliability, and Biases

Trustworthiness

“There are times we wish to know not how many or how well, but simply how” (Shulman, 1988, p. 7). Qualitative research provides insight to more than just numbers provided in a data collection. Researchers can identify common themes that may emerge through qualitative data collection that could provide a deeper explanation as to why or how the participants came to certain conclusions and that couldn’t have been identified using solely quantitative data. The emerging themes assist researchers in developing new hypotheses and grounded theory from data collected during field work (Johnson, Onwuegbuzie, & Turner, 2007).” Researchers use the draw and tell technique when they want to learn if drawing can improve the communication between children and adults” (Kenney, 2008, p.52). Opening the lines of communication for children to effectively express ideas through visual mediums can assist researchers in pinpointing emerging themes which aid in the explanation of the phenomenon being studied.

Children struggling to explain their understanding of scientific concepts have shown relief when participating in a draw and tell type process (Kose, 2008; McNair & Stein, 2001; Reiss & Tuncliffe, 2001). Many studies utilize a composite measure, or scale, to analyze the
drawings collected and to create an ordinal-level measurement (Kose, 2008; Osborne & Cosgrove, 1983). This study used a coding framework based upon the Likert scale from Kose’s 2008 and Reiss and Tuncliffe’s 2001 studies. Through the utilization of this scale, trustworthy measurements were made from the units of analysis (symbols) obtained from the draw and tell portion of the study. The use of a scale is important when conducting a qualitative study, particularly one which employs the draw and tell technique because the information collected can be “contained in a single numerical score and still retain the specific details of the individual indicators” (Kenney, 2008, p.60). A frequency distribution table showcased the frequency of which each unit of analysis appeared in each of the student’s drawings as a means to categorize the data collected.

In addition to the abovementioned demonstrations of categorizing the qualitative data, member checks throughout the study were conducted to increase trustworthiness. According to Guba and Lincoln (1980), “reliability and validity are substituted with “trustworthiness” and can be demonstrated through specific methodological strategies such as the audit trail, member checks when coding and categorizing and confirming results with participants” (p. 278). An audit trail was maintained to better ensure the accuracy of all documents collected through this study. The audit trail along with any findings gathered from this study were peer reviewed as a means to further support the transferability of this study (Holloway & Wheeler, 2002; Morse & Field, 1995). While qualitative researchers focus on transferability and trustworthiness to support the quality of their conclusions (Guba & Lincoln, 1980; Yin, 1994), the quality of quantitative research depends heavily on whether or not its findings can be generalizable (Maxwell, 1992).
Validity and Reliability

The utilization of the quasi-experimental design through the nonequivalent comparison group design (with more than one experimental group and the ANCOVA), the internal validity was established for the quantitative portion of the study. Shaffer (2001) indicates that the Science Series Assessment 1 instrument does have evidence of content validity. Shaffer also states that the alpha coefficients for each subtest range from .72 to .85, and the unconditional standard errors range from 1.69 to 2.15; which provides evidence of reliability. The Science Series Assessment 1 manual suggests using 2 as the standard error due to this instrument being labeled as a low-stakes test; therefore these standard errors appear to be reasonable. Portions of the pilot study were replicated and occurred with this research in May 2014 as well as methodological triangulation (interviews/observations) (Denzin, 1978) occurring with both the pilot and the full research studies; thus augmenting the reliability and validity of the methods chosen for the study. Potential threats to validity have been minimalized through the utilization of methods as stated by Creswell and Clark (2011).

Employing a mixed methods study allowed the researcher to collect and analyze both sets of qualitative and quantitative data rigorously and capture each strand of data within the overall research design that guides the study as a whole (Creswell & Plano Clark, 2011). The actual research questions are what guide the overall methodology for a study. Quantitative questions are driven by description, explanation and prediction; while qualitative questions are framed with exploration and discovery in mind. In this study, both the quantitative and qualitative questions are answered through different methodologies; however one doesn’t overshadow the other, instead they work symbiotically to strengthen each other.
**Biases**

Qualitative data interpretation could have different meanings from one reader to the next; therefore showcasing dependable or trustworthy data is critical (Lincoln, 1995). Seale (1999) states that while establishing quality studies through reliability and validity in qualitative research; the “trustworthiness of a research report lies at the heart of issues” (p. 266). In order to make the data from this study dependable, the researcher must own her own biases. She has previously utilized statistical data in order to analyze and create generalizable statements based upon her own science teaching as a means to better her instructional delivery for her students’. In addition to this, the researcher has employed qualitative methodology as a means to unearth her children’s authentic understanding of scientific topics. Combining these two types of data has provided her with a plethora of information on how to present science concepts to elementary students more effectively and efficiently for almost a decade.

Being a Nationally Board Certified Teacher, a Presidential Awards for Excellence in Math and Science Teaching finalist and receiving an International Early Science Educator National Science Teachers Association award, has allowed the researcher to showcase not only her own journey but the stories of her students as well. Although she has been rewarded with many practitioner accolades, she is simply a second grade educator who deeply believes providing rural elementary students the opportunity to spark their understanding of science topics lies in continuous exploration and examination of presented material.

To assist in decreasing the researcher’s personal biases, an audit trail was maintained throughout the study to ensure the completeness and accuracy of documentation (Holloway & Wheeler, 2002). The audit trail provides others insight to the researcher’s detailed method
(Figure 3.2 and 3.3) as a means for others to follow the methodology used for this study. Each portion of this study has been documented by the researcher, including: the proposal stage, data collection and analysis as well as the combination of data sets. Appendix G showcases lessons utilized for the pilot and full research studies.
CHAPTER 4
RESULTS

Overview

This study encompasses a mixed methods design; therefore, both quantitative and qualitative data was collected. Pretests and posttests provided the quantitative data while the drawings and interviews from the draw and tell portion of the study provided the qualitative data. Similar to the methods section, in chapter 4 the results for the primary questions and objectives of this study are reported. Background information of the participants, including demographic information for the sample population through the use of descriptive statistics and data analyses is also provided in this chapter. In addition to this, both sets of findings, qualitative and quantitative are discussed in this chapter.

The quantitative results are discussed first and include findings from the following groups: Control Group (5E Learning Cycle lessons/activities) and Experimental Groups E1, E2, E3 (5E Learning Cycle lessons/activities+ robotics). The qualitative results include: field notes of observations during the data collection, drawings produced by children during the data collection and narrative data collected from the student interviews. Qualitative data was coded and transcribed by the researcher and an inter-rater team and produced emerging themes, which are discussed in Chapter 6.

Research Questions

How does the utilization of robotics instruction embedded within the 5E Learning Cycle Model assist students in gaining a deeper understanding of force and motion? In what ways have the robotics instruction utilized in this study empowered students of different ability levels to retain these newly developed conceptions over a period of time? This study investigated robotics
use accompanied with the 5E Learning Cycle Model to answer the abovementioned questions. In
order to answer each research question, specific objectives were created. Presentation of results
from this study are further explained under each objective. The objectives of this study were:

- Complete a pilot study: (a) Test pilot instruments; (b) Test lessons/activities; (c)
  Compare pretest and posttest assessments.
- Describe the sample population of the full research study: (a) gender; (b) race; (c)
  ability level.
- Compare pretest and posttest scores among four groups (including a control):
  Whether or not robotics exposure influenced knowledge of force and motion
  concepts obtained at two time intervals: 1. upon completion of the activity; 2. one
  week after activity.
- Discover overall student perception of robotics use to assist in understanding
  force and motion: (a) before; (b) during; (c) one week after the activity.

**Objective One**

A pilot study was conducted in February 2014, to fulfill this first objective. The pilot
study also allowed the researcher to test the instruments and activities/lessons. The pilot study
encompassed the use of pretests and posttests (Science Series Assessment 1, Russell and
McGuigan, 2001), 5E Learning Cycle lessons, draw and tell questions and the five point Likert
scale (Table 4.2) created to score the drawings. The Control Group received the 5E Learning
Cycle lessons without the robotics component and the three experimental groups (Groups E1, E2
and E3) received the 5E Learning Cycle Model lessons with the robotics component. This
preliminary study, modeled the same in design as the full research study, differed in the delivery of the assessments. 

As mentioned previously, when administering the pilot assessments, students who typically receive the accommodation of tests read aloud and extended time were not given those accommodations due to the researcher error. This was noted by the researcher and corrected when the full research study was conducted. In addition to this, the students’ in the full research study were given the option to hand record their answers for the assessment. Due to the Science Series Assessment 1 being an online assessment, many students expressed concern that the computer didn’t record the answer they had entered. The researcher examined these claims from the pilot study and allowed the students in the full research study to use both a paper pencil version of the assessment as well as the computer version. This allowed the students who may have been struggling answering the questions using only the computer, to have an additional recorded version of their answer. 

After examining the students’ responses to the pretest and posttest pilot data no modifications to the assessment itself were required. Science Series Assessment 1 instrument utilized in both the pilot and full research studies has been reviewed by the Mental Measurements Yearbook and has been reported to have evidence of content validity (Shaffer 2001). Lessons and activities created for each activity (Appendix G) were not all altered; however, the materials for the experimental group lessons were changed. The original experimental lessons included containers filled with sand of varying amounts for the robots to push to showcase the physics concepts being tested. After the pilot study was conducted, the researcher noted that there wasn’t a significant difference in the distance traveled by each
container of sand. The researcher added a C size battery to each sand container to adjust this issue for the full research study.

The ANCOVA test was used to compare data collected from pretest and posttest. The covariate used was the students’ first grade science Iowa Test of Basic Skills (ITBS) test scores. The covariate data was collected alongside the demographic data through the protocol of student assignment, which was explained in Chapter 3. The conceptual variable being examined here is force and motion concept recognition and this was measured through the operational variable of the post-test scores. A pairwise comparison was also conducted through SPSS version 21 between pretest and posttest score differences compared across all four groups. Following the ANCOVA and pairwise comparison in order to determine significance between groups, a post hoc analysis was conducted. The Bonferonni post hoc test located in Table 4.1, indicates the significance found between control and experimental groups (p<.05). After examining this data, the researcher concluded that the use of robotics embedded within 5E Learning Cycle lessons did assist students in understanding concepts of force and motion in the preliminary study.

Table 4.1 Post Hoc Bonferroni of Difference from Pretest and Posttests

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental 1</th>
<th>Experimental 2</th>
<th>Experimental 3</th>
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<td>---</td>
<td>1.000</td>
<td>0.008*</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>0.001*</td>
<td>1.000</td>
<td>---</td>
<td>0.00*</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>0.008*</td>
<td>0.00*</td>
<td>1.000</td>
<td>---</td>
</tr>
</tbody>
</table>

Note: significant values are identified by asterisk *

Instruments utilized for the draw and tell portion of the pilot study were adjusted for the full research study. Based on the student responses to the draw and tell questions, alterations to the draw and tell questions were required. After analyzing the responses, it was deemed that
questions four and five of question set 2 (Appendix F) caused confusion because of the sequence of questions. It was noted that several students, after drawing and discussing their experiment (Questions 2 and 3), had multiple answers for questions 4 and 5. This caused the remainder of the questions to be off task, many students became more focused on questions 4 and 5 instead of clearly answering the remainder of the questions, which were written to explicate questions 4 and 5. By adjusting the location of questions 4 and 5 to the end of the question sequence (Appendix F), the researcher noted that the flow of the draw and tell interview was smoother. This adjustment proved necessary when in the full research study.

An analysis of student created drawings was conducted. A five point ranking system was utilized based upon studies conducted by Reiss and Tunicliffe (2001) and Kose (2008). This five point system was designed to reflect varying levels of elementary physics understanding and used the operational definitions shown in Table 4.2. The conceptual understandings of elementary physics concepts (force and motion) for this study were identified through five levels: no drawing; non-representational drawings; drawings with alternative conceptions; partial drawings; and comprehensive representational drawings. Details for the levels are located in Table 4.2.

A Chi square test was used to compare the observed values obtained from the pilot study to the expected values based upon the sample of 36 draw and tell participants with an equal proportion hypothesis producing an expected observed value of 5.4 in each category. To determine whether or not the differences between the observed values and the expected frequencies to a random fluctuation, while evaluating the drawings, the researcher assigned “1”
to the given data input if the students showed evidence of force and motion (arrows) and “0” if they did not.

Table 4.2 Five point scale used to score evidence of conceptual understanding of elementary physics concepts (Reiss & Tunicliffe, 2001; Kose, 2008).

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>No Drawing: Response, “I don’t know,” or no response given to question.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Non-representational Drawings: One or more arrows (evidence of force/motion) placed at random.</td>
</tr>
<tr>
<td>Level 3</td>
<td>Drawings with alternative conceptions: One or more arrows (evidence of force/motion) in the appropriate position, but no extensive relationship shown. These drawings showed some degree of understanding of the concepts of force and motion, but also demonstrated some evidence of alternative conceptions pertaining to force and motion.</td>
</tr>
<tr>
<td>Level 4</td>
<td>Partial Drawings: One or more arrows (evidence of force and motion) in the appropriate position, with extensive relationship shown. The drawings in this category show partial understandings of the concepts.</td>
</tr>
<tr>
<td>Level 5</td>
<td>Comprehensive representation Drawings: All arrows (evidence of force and motion) in the appropriate position. Drawings in this category show the most competent understanding of force and motion.</td>
</tr>
</tbody>
</table>

This analysis in SPSS version 21 and the use of the Chi square test for Goodness of Fit demonstrated the researchers support of rejecting the null hypothesis (Ho: Ability level and drawings of force and motion are independent of one another).

Test Instruments

The pretest and posttest (Appendix D) asked 12 questions to determine force and motion knowledge. Nine questions focused on the students drawing the arrows to show the forces on the image and three questions asked what happened to the objects when force was applied to the objects shown. As previously mentioned, the Science Series Assessment 1 instrument has been previously established in other studies and according to the Mental Measurements Yearbook reviewer, Shaffer (2001), this instrument does have evidence of content validity. The alpha coefficients for each subtest range from .72 to .85, and the unconditional standard errors range
from 1.69 to 2.15; provides evidence of reliability (Shaffer, 2001). The pretest and posttest assessment were not altered in content following the pilot study.

Each pretest and posttest was conducted in the second grade computer laboratory. There was no expression of frustration in navigation through the online assessments; however, during the pilot study many students expressed concern over their answers being recorded incorrectly. In order to eliminate this issue, for the full research study, the researcher allowed the students a paper and pencil version of the test in addition to the computer version. This allowed students to record and transfer their answers into the computer and fewer students expressed concern during the full research study in the spring of 2014.

To measure internal consistency of the Likert-type draw and tell survey questions (Appendix F) and the five point drawing scale (Table 4.2), Chronbach’s Alpha was calculated. Three sets of questions were posed to the 27 students in the experimental groups and nine students in the control group. One set of six questions were conducted prior to the intervention, Question Set A, a second set of 17 questions total, Question Set B, were asked during the intervention, and Question Set C, containing 18 modified questions from Question Set B, were asked upon completion of the intervention. All questions are located in Appendix F. Question Set B contained eight questions focused strictly on drawing the arrows to indicate understanding of force and motion and nine questions focused on the students explaining said drawings. Questions pertaining to robotics were not asked to students in the control group. Pilot results suggested moving questions four and five of question set B to the end of the question list, resulting in fewer students expressing confusion in the full research study. Questions that resulted in a Cronbach’s
Alpha near or greater than 0.7; which included all questions asked, remained for the final study. The overall reliability coefficient of .725 indicates a high level of internal consistency.

**Comparison of Pretest and Posttest Assessments**

The ANCOVA test and post hoc Bonferonni were used to compare data collected from pretest and posttests. The covariate used was the students’ first grade science Iowa Test of Basic Skills (ITBS) test scores. As previously indicated in Table 4.1, the Bonferonni post hoc indicates the significance difference found between control and experimental groups (p<.05); therefore, the use of robotics embedded within the 5E Learning Cycle lessons did assist students in understanding concepts of force and motion.

**Pilot Student Demographics**

Demographic data (gender, race and ability level) for each group was gathered through the protocol of student assignment (Chapter 3). Ninety-three students participated in the pilot. All individuals’ information was provided by participating teachers; therefore the researcher was able to correlate each student’s demographic information to the pretest and posttests as well as which treatment group they belonged to. As previously discussed in Chapter 3, the researcher was not allowed access to the exact procedures which outline the protocol of student assignment; therefore the ability level of the participants being determined by an outside party is a limitation to this study and are addressed in Chapter 6.

The protocol of student assignment identified the majority of students as having a medium ability level compared to the total group of students (Figure 4.1). The Control Group contained 21 students; two were classified as having a high ability level, which accounted for 10% of the sample, ten were classified as having a medium ability level, which encompassed
48% of the group, and nine were classified as having a low ability level, which accounted for the remaining 43% of the sample. Twenty-four students were in Group E1 three or 13% were classified as having a high ability level, 11 or 46% were classified as having a medium ability level and ten students or 42% of the group were classified as having a low ability level. Group E3 had the lowest percentage of students classified as having a low ability level and the highest percentage of students classified as having a high ability level. Containing 24 students, 13 or 54% were classified as having a high ability level and 11, or 46%, were classified as having a medium ability level. Group E3 contained 24 students and had the highest percentage of students classified as having a medium ability level. Seven, or 29%, were classified as having a high ability level, 15, or 63%, were classified as having a medium ability level and two, or 8%, and were classified as having a low ability level.

Figure 4.1. Students' Classified Ability Levels for Pilot Study Across Treatments. The majority of students within each treatment are of the medium ability level.
All of the students were classified as second grade students. The male to female ratio for the Control Group was ten to 11, or 48% of the Control Group consisted of males. Group E1 contained a male to female ratio of 13 to 11, or 54% of experimental group 1 consisted of males. The remaining groups (Group E2 and E3) contained equal male to female ratios of 12 to 12.

**Objective Two**

Objective two describes the demographic information of the participants for the full research study. The characteristics being described here are a) gender, b) race, and c) ability level. Similar to the pilot participants, the full research study participants’ data was collected through the protocol of student assignment.

**Demographic Data**

Ninety-five students participated in the full research study. Throughout this chapter these groups have been identified as: 24 students in the Control Group (Control), 23 students in experimental group 1 (E1) and 24 students in experimental groups 2 and 3 (E2 and E3). All participants were classified as second grade students and had been identified as having a high, medium or low ability level based upon each individual’s first grade ITBS scores and other factors. Figures 4.3 and 4.4 showcase the majority of the participants were African American and the males outnumbered the females.

**Gender.** Males comprised 53% of the participants, and females were in the minority with 47% (Figure 4.3). The ratio of males to females in the Control Group was 13 to 11. The Control Group and Group E3 contained the second highest percentage of males (54%). These two groups also contained the most equal distribution of male to female ratio with 54% males and 46%
females. Group E1 was comprised of ten males and 13 females, this group contained the highest percentage of females (57%) out of the overall sample.

Figure 4.3. Gender of Participants within Treatments

Fourteen males and ten females participated in Group E2; this group contained the highest percentage of males (58%) and the lowest percentage of females (42%). As previously mentioned, similar to the Control Group, the ratio of males to females in Group E3 was 13 to 11. These students were assigned through protocol enforced by administration at the research site. The researcher or participants did not have any involvement in the placing of gender assignments for each group.
**Ethnicity.** Each participant’s ethnicity was gathered through the protocol of student assignment. Upon entering the school district, each parent submits demographic information for each student to the school site; here the parents indicate which ethnicity best describes his or her child. Parents sign consent forms stating demographic information can be released to teachers if needed. This information is released to all teachers that interact with the child and is a part of the protocol of student assignment enforced by the administration at the research site. The majority of the participants identified as African American or Black, totaling to 48% of the total population of the full research study. A total of 44% of the participants identified as White, 1% identified as Asian or Pacific Islander, 3% Hispanic American and 3% identified as “Other”. Figure 4.4 showcases the demographic data obtained for ethnicity.

The Control Group contained 46% African American or Black participants, making this the majority ethnic classification for this treatment group. A total of 38% of the students in the Control Group identified as White. The Control Group also contained the highest percentages of students identified as “Other” (4%) and Asian or Pacific Islander (8%). Two students in this group identified as “White and African American”. Hispanic Americans comprised 4% of the Control Group as well as Groups E1 and E3. Group E1 contained the most equal distribution of African American or Black students to White students, both having a percentage of 48%. This treatment group did not contain any students identified as “Other” or Asian or Pacific Islander. Group E2 contained the highest percentage of students classified as White (54%). There were no students identified as Asian or Pacific Islander or Hispanic Americans in Group E2 and one student (4%) identified as “Other” with Native American ethnicity. A total of 42% of students within this group identified as African American or Black.
The final treatment Group, E3 contained no students identified as “Other” or Asian or Pacific Islander. This group contained the highest percentage of students identified as Black or African American (58%). It also contained 4% of students identified as Hispanic Americans and 38% of students identified as White. Figure 4.4 contains information pertaining to ethnicity percentages among the groups.

**Ability Level.** Participant’s ability levels were gathered through the protocol of student assignment. Each student is classified by having a High, Medium or Low ability level based upon his or her ITBS scores from the previous grade as well as other factors determined by administration at the research site. This classification is conducted by the administration at the research site; the researcher was not given the exact protocol of the classification system as it was identified as confidential administration information only.
Similar to the demographic information, test scores and ability level labels are released to all teachers that interact with the child and are a part of the protocol of student assignment enforced by the administration at the research site. The majority of the participants were classified as having a medium ability level (41%). Thirty (32%) of the participants were identified as having a high ability level, while 27% of the students were identified as having a low ability level. Table 4.3 and Figure 4.5 contain the information regarding ability level classification for the participants.

The Control Group contained the highest percentage of students classified as low (12%) as well as the lowest percentage of students classified as having a medium ability level (5%). This group contained only 8% of students classified as having a high ability level. The majority of students in Group E1 were identified as having a medium ability level (14%). This group contained the highest percentage of medium ability level students in the sample; it also contained the lowest percentage of students classified as having a high ability level (4%). Only six students in Group E1 were identified as having a low ability level.

Seven students in Group E2 were identified as having a low ability level. This was the highest number of students classified as having a low ability level within the group as a whole. 12% of students were classified as having a medium ability level, while 6% were identified as having a high ability level. The majority of the students in Group E3 were identified as having a high ability level (13%). This group also contained the most equal distribution between high ability level (13%) and medium ability level (11%). The minority of the students in this treatment group were identified as having a low ability level (2%). Group E3 also contained the lowest percentage of students classified as having a low ability level (2%) of the population.
### Table 4.3. Ability Level Percentages among Groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Ability Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Control</td>
<td>8%</td>
</tr>
<tr>
<td>Experimental 1</td>
<td>4%</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>6%</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>13%</td>
</tr>
<tr>
<td>Total</td>
<td>32%</td>
</tr>
</tbody>
</table>

Figure 4.7. Percentage of students within each treatment based on ability level

**Objective Three**

The third research objective focuses on comparing the pretest and posttest scores among the four groups; particularly focusing on whether or not robotics exposure influenced information obtained at varying intervals: a) upon completion of the activity (Posttest 1) and b)
one week after activity (Posttest 2). One week prior to the intervention, a pretest was administered; this same test was employed immediately after the intervention was complete to assess for knowledge retention of force and motion understanding (Posttest 1). The same posttest containing 12 force and motion type questions was administered one week after the intervention to test for the effect of the instructional activities over time (Posttest 2). This final assessment was given one week before the release of students for summer vacation; therefore students did not have time to review any information pertaining to force and motion topics (Appendix E).

An analysis of the pretest and posttest scores occurred soon after each participant’s test was scored and recorded in Microsoft Excel. A gain score was calculated through the difference between each student’s pretest and posttest score. This data alongside each participant’s first grade ITBS score was imported into SPSS version 21. Due to mixed ability levels within and between each treatment group, the researcher decided to use the first grade ITBS score to adjust for differences across all ability levels. ANCOVA tests were then run using the gain score and the ITBS score as the covariate. Due to ITBS scores being reported as percentages, an arcsine-square root transformation occurred of the percentage data to account for any data not being normally distributed.

**Quantitative Exploration of Pre/Posttests**

Statistical significance between treatments was determined through the use of an ANCOVA test. A one way analysis of covariance (ANCOVA) was conducted. The independent variable was robotics instruction and the dependent variable was the students’ posttest scores on the Science Series Assessment 1. The students’ first grade ITBS scores were used as the covariate. A preliminary analysis evaluating homogeneity-of-regression of slopes assumption
identified the relationship between the covariate and independent variable did not differ significantly as a function of the independent variable, F (2,37)= 2.416, p= .108. ANCOVA results showed significance, F (2, 41) = 105.51, p= <.001 (See Table 4.4). P-values were examined from a pairwise comparison using the post hoc Bonferonni adjustment (Table 4.5). All statistical tests had an alpha level set at .05, with the Bonferonni correction accounting for alpha inflation. An examination of Posttest 1 data indicates that the Control Group is significantly different than Groups E1 and E3. Posttest 1 data also yielded that there was a significant difference between Groups E1 and E3. This data also yielded there was a significant difference between Group E2 and Groups E1 and E3. Posttest 2 data resulted in significant differences between the Control Group and all experimental Groups (Groups E1, E2 and E3) (Table 4.4).

Table 4.4. Analysis of Covariance for Science Series Assessment 1 Achievement by Robotics Instruction Use

<table>
<thead>
<tr>
<th>Tests of Between Subjects Effects</th>
<th>Dependent Variable: Posttest 1 Science Series Assessment 1 Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Type III Sum of Squares</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Corrected Model</td>
<td>17.687^a</td>
</tr>
<tr>
<td>Intercept</td>
<td>.001</td>
</tr>
<tr>
<td>ITBS</td>
<td>13.412</td>
</tr>
<tr>
<td>Robotics Instruction Error</td>
<td>2.626</td>
</tr>
<tr>
<td>Total</td>
<td>1494.874</td>
</tr>
<tr>
<td>Corrected Total</td>
<td>18.196</td>
</tr>
</tbody>
</table>

a.R Squared=.972 (Adjusted R Squared=.970)
Table 4.5. Pairwise Comparison from ANCOVA using post hoc Bonferroni for treatments using posttest means

<table>
<thead>
<tr>
<th>Source</th>
<th>Control</th>
<th>Group E1</th>
<th>Group E2</th>
<th>Group E3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Posttest 1</td>
<td>--</td>
<td>0.00*</td>
<td>1.00</td>
<td>&lt; 0.00*</td>
</tr>
<tr>
<td>Group E1 Posttest 1</td>
<td>0.00*</td>
<td>--</td>
<td>0.003*</td>
<td>0.392</td>
</tr>
<tr>
<td>Group E2 Posttest 1</td>
<td>1.00</td>
<td>0.003*</td>
<td>--</td>
<td>0.000020*</td>
</tr>
<tr>
<td>Group E3 Posttest 1</td>
<td>&lt; 0.00*</td>
<td>0.392</td>
<td>0.000020*</td>
<td>--</td>
</tr>
</tbody>
</table>

Control Posttest 2 -- .015* 0.00* .002*
Group E1 Posttest 2 .015* -- 0.245 0.265
Group E2 Posttest 2 0.00* 0.245 -- 1.00
Group E3 Posttest 2 .002* 0.265 1.00 --

Note: Alpha level set at 0.05 and significant p-values identified with an asterisk *

Knowledge Retention upon Completion of Activity. Improvement was shown in all treatment groups from pretest to Posttest 1, which was given upon completion of the activity. Experimental Group E3 had the highest average pretest score and the Control Group had the lowest average pretest score (Table 4.6). Each participant’s first grade ITBS score was used as the covariate within the ANCOVA analysis in order to control for variations among the levels. Prior to the ANCOVA analysis, an arcsine-square root transformation was conducted to transform the percentage data of the ITBS scores. The experimental groups (Groups E1, E2 and E3) posttest average scores yielded similar results and the Control Group resulted in the lowest first posttest average (Table 4.6).

Table 4.6. Means for Pretest and Posttests

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest 1 (after activity)</th>
<th>Posttest 2 (after 1 week)</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.8</td>
<td>8.0</td>
<td>6.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Experimental Group 1</td>
<td>1.9</td>
<td>11.0</td>
<td>10.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Experimental Group 2</td>
<td>1.6</td>
<td>9.0</td>
<td>7.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Experimental Group 3</td>
<td>1.8</td>
<td>10.6</td>
<td>9.9</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Knowledge Retention One Week after Activity. The final posttest was administered one week before the release of students for summer vacation; therefore the students were unaware any testing covering force and motion topics would occur at this time. The last two weeks of school do not contain any testing so that teachers can prepare final report card grades. When students arrived at their normally scheduled computer lab time, all of the participants were surprised and confused as to why they were taking the posttest again. Multiple students questioned the researcher about the reasoning as to why the test was administered again. Posttest 2 indicated that Groups E1 and E3 had the least amount of decrease in knowledge, while the Control Group and Group E2 had the largest decrease in knowledge retention (Table 4.6).

Objective Four

The final objective examines the student’s viewpoint of using robotics to address alternative conceptions. This includes the overall student perception of robotics use in order to further understand topics of force and motion before, during and one week after the experiment. The draw and tell data collection was employed before, during and one week following the close of the activity. This technique contained Likert-type scale questions and short answer questions. Prior to the intervention, the ITBS stanine scores were grouped into three levels: high, medium and low, and provided a sample size of 36, three from each ability level from each experimental and control groups. This criterion sample of 36 students were pulled three at a time from ancillary classes and participated individually in the draw and tell activity before the intervention, during and one week following the close of the intervention. Recording, transcription and coding was conducted for all the participant interviews, which resulted in themes. Each participant was given a physical, written description and field notes collected were
coded. Lastly, all data from previously mentioned sources was merged to give full insight and understanding of each student’s viewpoint.

**Survey Reliability**

To measure internal consistency of the Likert-type draw and tell survey questions (Appendix F) and the five point drawing scale (Table 4.2), Chronbach’s Alpha were calculated. Three sets of questions were posed to the 36 students from the four groups. One set of six questions took place prior to the intervention, Question Set A, 17 questions, Question Set B, were asked during the intervention and Question Set C containing modified questions from Question Set B (18 questions), were asked upon completion of the intervention. All questions are located in Appendix F. Question Set B contained eight questions (out of the 18 total questions) that focused strictly on drawing the arrows to indicate student understanding of force and motion, and ten questions focused on the student’s explanation of their drawings. Questions posed to students in the Control Group did not contain robotics references.

As previously mentioned, the order of questions in Question set B was altered to enhance the quality of the draw and tell portion of the full research study. When examining the Chronbach’s Alpha for the pilot study’s Question Set B, interview questions four and five (factors affecting final experiment) yielded a low data result of .376, which can be seen in Table 4.7. Typically, data with a Chronbach’s Alpha level less than 0.7 would not remain in the question set; however, the researcher examined the transcription interviews and found that the two questions provided essential information and insight to the overall experiment. A reordering of Question Set B was done for the full research study and the Chronbach’s Alpha level for those two specific questions increased to .760, resulting in the questions staying within the set (Table
All questions resulting in a Chronbach’s Alpha near or greater than 0.7 remained in the question set as seen in Tables 4.8 and 4.9.

Table 4.7. Cronbach’s Alpha Results for Pilot set of Question set B, Questions 4 and 5 of Survey Regarding Factors Affecting Final Experiment

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.376</td>
<td>.402</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4.8. Reliability of Question Set A (Prior Understanding of Force and Motion) of Survey

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.725</td>
<td>.705</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 4.9. Specific Cronbach’s Alpha if Portions of Question Set A Were Deleted

<table>
<thead>
<tr>
<th>Question</th>
<th>Scale Mean if Item Deleted</th>
<th>Scale Variance if Item Deleted</th>
<th>Corrected Item-Total Correlation</th>
<th>Squared Multiple Correlation</th>
<th>Cronbach’s Alpha if Item Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1A</td>
<td>24.6667</td>
<td>16.923</td>
<td>.569</td>
<td>.777</td>
<td>.762</td>
</tr>
<tr>
<td>Q2B</td>
<td>24.8519</td>
<td>17.670</td>
<td>.716</td>
<td>.840</td>
<td>.682</td>
</tr>
<tr>
<td>Q3C</td>
<td>24.5926</td>
<td>18.328</td>
<td>.508</td>
<td>.812</td>
<td>.678</td>
</tr>
<tr>
<td>Q4D</td>
<td>24.1111</td>
<td>17.487</td>
<td>.586</td>
<td>.856</td>
<td>.780</td>
</tr>
<tr>
<td>Q5E</td>
<td>22.7778</td>
<td>16.410</td>
<td>.609</td>
<td>.899</td>
<td>.751</td>
</tr>
<tr>
<td>Q6F</td>
<td>23.1481</td>
<td>22.285</td>
<td>.044</td>
<td>.891</td>
<td>.774</td>
</tr>
</tbody>
</table>

Question Set A was asked to 27 experimental group participants and nine control group participants one week prior to completing the treatment. Participants were asked six Likert scale questions to probe their understanding of concepts of force and motion as well as robotics (Appendix F). In order to determine the reliability of these questions a Chronbach’s Alpha was used. The overall statistic for Question Set A was .725 (Tables 4.7 and 4.8). Groups E1, E2 and E3 yielded a Chronbach’s Alpha greater than 0.7 (Table 4.7). All groups (Control, E1, E2, and E3) were asked questions from Question Set B during the treatment process. The reordered
Question Set B yielded a Chronbach’s Alpha of .760, with all groups scores greater than 0.7 (Tables 4.10 and 4.11).

Table 4.10. Reliability Statistics for Question Set B - Full Research Study Questions

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.760</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 4.11. Cronbach’s Alpha for “Reordered” Question Set B among Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Original Cronbach’s Alpha</th>
<th>Chronbach’s Alpha following question adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.543</td>
<td>0.763</td>
</tr>
<tr>
<td>Experimental 1</td>
<td>0.743</td>
<td>0.802</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>0.490</td>
<td>0.871</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>0.462</td>
<td>0.761</td>
</tr>
</tbody>
</table>

Question Set C (Appendix F) was asked during week following the completion of the experiment. These 18 questions were based on Question set B (Appendix F) with additional questions probing their memory about the actual intervention activity. The overall reliability statistic for Question Set C was .779, as seen in Table 4.12.

Table 4.12. Reliability Statistics for Question Set C Questions

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.779</td>
<td>18</td>
</tr>
</tbody>
</table>

Survey Results

All statistical tests conducted were set at an Alpha level of .05. Each question set had the Means Procedure performed prior to the researcher conducting the nonparametric Kruskal-Wallis test. The Kruskal- Wallis test was conducted determine if there was a statistically significant difference in change scores between each group. After a visual examination of the boxplot, the
researcher found that the distribution of question set scores were similar; however, the median question set scores were significantly different between groups. Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. This post hoc analysis revealed statistically significant differences in median question set scores between all groups with regard to Question Set A ($x^2(3) = 13.134, df=3, p=0.003$) and Question Set B ($x^2(3) = 15.463, df=3, p=0.001$). There was also a statistical significant difference between groups for Question Set C ($x^2(3) = 14.468, df=3, p=0.002$) as seen in table 4.13.

**Question Set A.** Questions concerning force and motion topics prior to the treatment had varying levels among the groups. Groups E1 and E3 had the highest rankings for Question Set A; while the Control Group and Group E2 had the lowest rankings for Question Set A (Table 4.13).

**Question Set B.** Questions concerning force and motion during the treatment also had statistical significances among the groups. Similar to questions asked prior to the intervention, Groups E1 and E3, ranking at 29.88 and 24.17 showed varying levels from Group E2 ranking at 20.46 and the control Group (ranking at 13.88).

**Question Set C.** A Kruskal-Wallis test determined that there was also a statistical significance among groups for Question Set C ($x^2(3) = 14.468, df=3, p=0.002$). The Control Group ranked at 21.35; while Groups E1,E2 and E3 ranked at 34.83, 24.45 and 35.55, respectively (Table 4.13).
### Table 4.13. Chi-square and p-values from Kruskal-Wallis test

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>N</th>
<th>Mean Rank</th>
<th>$x^2$</th>
<th>Df</th>
<th>P</th>
</tr>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>Control</td>
<td>9</td>
<td>16.65</td>
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<td>Experimental 1</td>
<td>9</td>
<td>21.00</td>
<td></td>
<td></td>
<td></td>
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<td>Experimental 2</td>
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<td>15.83</td>
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<td></td>
<td></td>
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<tr>
<td>Experimental 3</td>
<td>9</td>
<td>25.50</td>
<td>13.134</td>
<td>3</td>
<td>0.003</td>
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<td><strong>Question Set B</strong></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Experimental 1</td>
<td>9</td>
<td>29.88</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Experimental 2</td>
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<td>20.46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental 3</td>
<td>9</td>
<td>24.17</td>
<td>15.463</td>
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<td>21.35</td>
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<td></td>
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<tr>
<td>Experimental 1</td>
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<td>34.83</td>
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<tr>
<td>Experimental 2</td>
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<td>25.45</td>
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</tr>
<tr>
<td>Experimental 3</td>
<td>9</td>
<td>35.33</td>
<td>14.468</td>
<td>3</td>
<td>0.002</td>
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</table>

#### Qualitative Exploration

Thirty-six students participated in draw and tell interviews before, during and after the intervention took place. As discussed in Chapter Three, prior to the intervention, student’s ITBS stanine scores were assigned by school administration into three levels: high, medium and low. Purposeful sampling resulted in a sample size of 36, with three from each ability level from the Control Group and Groups E1, E2 and E3. Each participant answered Question Set A (Appendix F), which uncovered their understanding of topics surrounding force and motion, particularly highlighting their conceptions of push and pull, and their understanding of how robotics could play a role in assisting them understand said topics.

Students were asked six questions which probed their prior understanding of topics surrounding push and pull. Their answers identified the level of their perception of an extension
of the Impetus Theory of Motion: the amount of motion is proportional to force, or the harder you push an object, the faster and farther it goes as well as the depth of understanding concepts of force and motion. Students from the Control Group did not use robotics during their treatment activity, and thus were not asked questions pertaining to robotics. These students were asked the same format of questions as the experimental group participants, except where robotics was discussed the researcher substituted the experiments from the 5E Learning Cycle Model lessons that were completed instead. The researcher chose to ask questions surrounding these topics prior to the treatment due to the nature of the experimental activity with the robots and in order to identify what conceptions the participants possessed.

Following the interview protocol (Appendix F), the researcher presented the questions in sequential order, allowing for emergent questions if needed. All interviews were voice recorded, downloaded into a computer and were manually transcribed into a word processing document. Using the coding framework based on Kenney’s books (2008) as well as Reiss and Tunnicliffe’s study (2001) a priori codes were established and used as the basis for coding. Draw and tell interview documents were analyzed in an effort to triangulate data collected from the drawing /survey analysis. The researcher began by broad brush coding in order to organize the answers into broad topic areas using a text search.

Once the topic areas were compiled, a deeper exploration occurred, where the researcher closely examined the data looking for specific indicators of the previously established a priori codes through word search and text frequency queries. Themes one and two quickly emerged and were based on the previously established theory a priori codes. In addition to text searches, each interview was voice recorded and transcribed. Through this process, the researcher
highlighted the transitions that occurred with the participants, particularly when topics surrounding themes three and four were discussed. These transitions assisted in the cutting and sorting technique (Barkin, Ryan, and Gelberg, 1999) used in order to solidify themes three and four for this research study.

The expressions or answers to the questions that appeared most frequently manifested into the four main themes for this research study which are later discussed in Chapters 5 and 6. These frequencies were compiled into matrix and demonstrated the most recurrent responses recorded throughout the interviews from the participants regarding their understanding of topics related to force and motion over the span of three interviews and are displayed in Table 4.14.

The answers that were provided during the first draw and tell interview assisted the researcher in assigning each participant with or without headings surrounding their understanding of the extension of the impetus theory of motion and/or concepts surrounding force and motion. These headings are: naïve beliefs (NB), preconception (P), prescientific conception (PSCI), misconception (MIS) or alternative conception (ALT). The heading for confusion (Conf) was also added. These terms are defined in Chapter 2, Table 2.2. Each participant’s heading is identified and are indicated with a “+” or “−” sign as seen in Table 4.15. The second draw and tell interview conducted during the treatment, further examined participants understanding of the concept while being exposed to activities which could assist in their understanding of concepts surrounding force and motion. Once again, students in the Control Group were not asked questions pertaining to robotics, but rather were questioned about the experiments conducted through the 5E Learning Cycle Model lessons completed in class.
Based on the participant answers during this second set of interviews, a new set of labels were assigned to each student based upon their current understanding of the impetus theory of motion in a similar manner as above. The final set of draw and tell interviews conducted one week following the close of the activity asked participants to further examine their understandings from the previous experiment. The answers provided with this last set of interview questions provided the researcher with information to label each participants understanding of the impetus theory of motion and concepts surrounding force and motion at this time. These results are shown for each student in Table 4.15.

All field notes and transcriptions of draw and tell interviews were explored through a coding technique of circling and highlighting sections of the texts that contain words or phrases thought to be meaningful (Saldaña, 2012). This open coding method was followed up with another analysis of transcriptions using a non-hierarchal axial coding approach (Saldaña, 2012) in order to sort themes and codes into an order or group (Table 4.14). Each code is further explained by the category listing in table 4.14. All descriptive coded field notes and draw and tell interview information assisted the researcher in gaining a deeper understanding of each student’s understanding of the overall experience. Each student who participated in the draw and tell interview was allocated an overall physical appearance participant description. These descriptions are located in Chapter 5 and the overview of participant information is located in Table 4.15. Triangulation of the data occurred following the completion of participant descriptions as well as a further review of resources for emerging themes, thus further supporting validity for the research. Analysis and discussion periods occurred concerning all draw and tell
interviews and codes applied, between the researcher and a co-educational researcher to better support precision as well as validate inter-rather reliability.

Table 4.14. Codes Derived from Interviews and Frequencies

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve Beliefs Pre-Activity</td>
<td>NB+</td>
<td>24</td>
</tr>
<tr>
<td>Pre-Conceived Understandings (impetus- if needed)</td>
<td>P</td>
<td>27</td>
</tr>
<tr>
<td>No Pre-Conceived Understandings</td>
<td>NPCI</td>
<td>18</td>
</tr>
<tr>
<td>Prescientific Conception</td>
<td>PSCI+</td>
<td>15</td>
</tr>
<tr>
<td>Misconception</td>
<td>MIS+</td>
<td>15</td>
</tr>
<tr>
<td>Alternative Conception</td>
<td>ALT+</td>
<td>17</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>EN</td>
<td>93</td>
</tr>
<tr>
<td>Constant force +Mass increase in object=decrease in distance traveled</td>
<td>CF+MI</td>
<td>82</td>
</tr>
<tr>
<td>Measurement Confusion</td>
<td>M-</td>
<td>73</td>
</tr>
<tr>
<td>Constant Force Confusion</td>
<td>CFC+</td>
<td>34</td>
</tr>
</tbody>
</table>

Many low ability labeled participants from the Control and Groups E1, E2 and E3 expressed variations of alternative conceptions, prescientific conceptions and misconceptions of Impetus theory of motion prior to the treatment. The medium and high ability participants from all four groups had fewer students with misconceptions, prescientific conceptions or alternative conceptions of the concepts. All groups showed more variations in answers during the second set of draw and tell interviews, while the third set of interviews had less variation among Groups E1, E2 and E3 and more variation among the Control Group. All student names are pseudonyms in the following discussion.

Chad (a high ability student) from Group E3 explained that before he conducted the experiment he thought the robot would push the load the same distance, but then he realized that what he thought wasn’t true and during the third interview when probed further he applied an example of the experiment to a real life situation. In this same interview he was asked if using the robot assisted him in understanding what happens when objects of changing masses are
pushed or pulled at a constant speed, he explained that using the robots was useful, but focused more on the motivation behind using the robots saying, “I learned that when we put the battery into the load thingy, because the mass was a ton more, the robot didn’t go as far on my ruler… but the best part about it was that I got to use the robot because its sweet and fun and I can’t wait to get my own robot for my house.”

Overall, the medium ability participants from the experimental groups did demonstrate misunderstandings of impetus theory of motion and topics surrounding force and motion prior to the intervention and most of these students showed an improved understanding of the concepts during the intervention. Very few medium ability leveled experimental group participants could link the use of robotics to assist them in further understanding the concepts of force and motion one week following the intervention; however the medium ability group participants outnumbered the low ability group in being able to discuss this concept.

Some medium and high ability participants from the Control Group demonstrated variations of impetus theory of motion and topics surrounding force and motion prior to the intervention and a few of these students did show a better understanding of the concepts during the activity. The majority of the high and medium ability leveled students from the Control Group had less retention of the material during the final interview. The majority of the low ability group participants from both the experimental and control groups demonstrated misconceptions, prescientific conceptions and alternative conceptions of impetus theory of motion before, during and after the activity took place.
Table 4.15. Participant Information

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Treatment</th>
<th>Ability Level</th>
<th>Understanding Before*</th>
<th>Understanding During*</th>
<th>Understanding After*</th>
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<td>+ALT</td>
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<td>-</td>
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<tr>
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<td>+P</td>
<td>-</td>
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</tr>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jahmaree</td>
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<td>+ALT</td>
<td>+ALT</td>
<td>+ALT</td>
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<td>C</td>
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<td>-</td>
<td>+MIS/Conf</td>
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<td>Trinity</td>
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<td>Low</td>
<td>+NB</td>
<td>-</td>
<td>+MIS</td>
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</table>

*Explanations of abbreviations are located in Table 4.14.
Comments from this group of participants included:

Keandra (E1):

When the robot in the picture pushes the loader really really hard, the thingy goes faster and faster. I did the robot too and the loader I did pushed faster and farther just like when I did it with you on Valentines party day.

McKenna (E2): All my favorite robots moved really fast and went really far in all my favorite experiments with my friends.

Tanner (E3): Your robot before had lighter load then my robot now… that’s why when I pulled your robot it went so so far far and my robot on the inch ruler didn’t go as far far as my favorite robot.

Trinity (Control Group): When I blew in the straw really hard the marble went further than the cotton ball. The cotton ball didn’t go as far because it has less mass.

All themes that emerged from the experimental groups throughout the experiment included using the robots along with the 5E activities was enjoyable and assisted learning, constant force applied to an object with increased mass decreases the distance traveled and measurement confusion (which includes mass and distance traveled). Themes which emerged from the Control Group included constant force confusion as well as measurement confusion. Further examination of these themes as well as other themes is discussed in Chapter 6.
CHAPTER 5
THE PARTICIPANTS

Introduction

This study is an embedded mixed methods design, which is defined by having qualitative data embedded within a quasi-experimental design. It took a two phase approach where the qualitative data from the draw and tell interviews came before, during and after the intervention occurred. The students who participated in the draw and tell interviews within the qualitative phase of this study are presented in this Chapter. Prior to the intervention, the ITBS stanine scores of participating second grade students were grouped into three levels high, medium and low, by an administrative procedure at the students’ school. As discussed in Chapters 3 and 4, a sample size of 36 was used for the qualitative component, with three from each ability level chosen from each of the research groups. The participant descriptions found within this chapter present descriptions of all 36 students, as well as synthesized information from students’ draw and tell interviews and quantitative assessments.

These 36 students were pulled three at a time from ancillary classes and participated individually in the draw and tell activity before, during and one week following the close of the intervention. Although there were three students pulled at one time, two of the students were placed with headphones on a computer, while one student worked with the researcher in an empty classroom to complete the draw and tell task. All draw and tell interviews were conducted and recorded in an empty classroom at the research site. Each interview lasted approximately 30-45 minutes in length. A group summary of the interviews is located at the close of this chapter.
Participant Descriptions

Each draw and tell interview participant is described here in order for the reader to better understand each student and what they learned about force and motion through the class activities they were exposed to as a result of this research. Participants were asked six questions which probed their prior understanding of topics surrounding push and pull. Their answers identified the level of their perception of an extension of the Impetus Theory of Motion: the amount of motion is proportional to force, or the harder you push an object, the faster and farther it goes as well as the depth of understanding concepts of force and motion. All participant descriptions are composed of field notes, observations, pretest and posttest data and each participant’s individual interview transcription. Each student is described below according to their assigned ability group, which treatment group they were placed in, as well as when each draw and tell interview took place.

High Ability Group

“Yahti”. Yahti, a high ability group student in Group E1, sat sullen across the table from me on our very first draw and tell interview together. He sulked the whole way to the interview room, plopped down into the chair and folded his arms while looking at me. His oversized Air Jordan Nike tennis shoes were untied and falling off of his feet. I explained to him that this interview was voluntary and he sighed “Yes ma’am,” his big brown eyes and wide toothed grin stared back at me and he continued, “I just don’t like missing PE but I guess this will be okay”. He glanced around the thirty feet by thirty feet classroom and at the two other students on the computers and shrugged his shoulders. At this first interview, he didn’t seem very interested in participating; however, once he warmed up he became very polite.
Yahti is eight years old and had been recently been screened for gifted accommodations. His current GPA is a 4.0 and he scored within the 98th percentile on the first grade ITBS assessment. He frequently used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is also an African American male and they are assigned to seats at the center of the computer lab. During the first interview Yahti did show signs of a pre-conceived idea of impetus theory of motion (Figure 5.1), specifically focusing on the amount of motion being proportional to the amount of force applied to an object; however, during the second draw and tell interview (Figure 5.2), which took place during the treatment he was able to correctly explain and illustrate the concepts. One week later when the interview was conducted again, he could still articulate the proper understanding of the concepts discussed during the robotics activity.

Figure 5.1: Yahti Draw and Tell Interview 1.

Yahti is a member of the high ability group in Group E1 and he scored within the top 25% on the Science Series Assessment 1. His pretest/posttest gain score was +2; of the 12 questions asked, he initially knew seven and after the lesson answered nine correctly. After the
second draw and tell interview he was asked if he thought that using the robot would help him remember the concepts of force and motion in the future and he agreed.

Yahti’s responses on the second and third interview strongly showcased his current grasp on the concept, whereas the first interview highlighted the confusion that was present surrounding impetus theory of motion and other topics of force and motion. During the third and final draw and tell interview he said:

I remember this now! It’s easy, peasy, lemon squeezy! A long time ago when we did this recording thingy, I thought the robot was going to move faster and farther because I programmed it to go… but then it didn’t and I got mad… but then when we did it in class I saw what you did- you tried to trick us with that heavy heavy loader thingy- but you didn’t fool me this time! I know that the robot won’t go that far because the loader thingy has more mass- so the robot can’t go as far!

Figure 5.2: Yahti Draw and Tell Interview 2.

“Zoa”. Zoa skipped down the hall to the classroom for each of the three draw and tell interviews. She was in Group E2 and in the high ability group. She hopped into the chair across the table from me and swung her legs under the table, grinning from ear to ear. Her dark brown
eyes and skin made the florescent colors on her bow glow on her hair. Her fingernails were painted neon orange and green to match the bow in her hair and her personality was as animated as her accessory choices had been for all three of our interviews. She glanced around the classroom throughout all three interviews, constantly turning around to look at the other two students on the computer, even though I assured her she would get a chance to play on the computer as soon as her interview as complete. The classroom was empty other than a few student desks, chairs and computers. A large kidney table was at the far right of the room surrounded by smaller student chairs. On the opposite side of the room four computers, with headphones, flanked the wall and faced the open grassy area behind the school. Rarely would staff or students cross past the windows due to the location of the classroom in the large building.

Zoa, an African American female, is seven years old and had the 504 accommodation of tests to be read aloud. She also had a 504 medical plan to receive medication at the elementary school. Her current GPA is a 3.8 and scored within the 97th percentile on the first grade ITBS assessment. She rarely used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a White female and they are assigned to seats at the front of the computer lab. During the first interview Zoa did not show signs of a pre-conceived conception of impetus theory of motion; however, during the second draw and tell interview, which took place during the treatment, she developed some confusion surrounding the concepts. This confusion consisted of inconsistencies in the information given in her answers; however, correct explanations could be given when consistently probed. One week later when the interview was conducted again, she still expressed the same confusion she had expressed during the second interview and her drawings supported this as well.
Zoa scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +3; of the 12 questions asked she initially knew five and after the lesson answered eight correctly. After the second draw and tell interview she was asked if she thought that using the robot would help her remember the concepts of force and motion in the future and she agreed. Zoa’s responses on the first interview indicated that she did not have any apparent confusion surrounding impetus theory of motion or concepts related to force and motion, whereas by the second and third interview she was confused and agitated when asked to draw arrows to indicate the forces. During the second interview, Zoa mentioned that her partner during the experiment was bothering her. She expressed that her partner caused the experiment to produce incorrect results, “I told her five hundred times that when you said the power has to be at 50% that’s what’s it’s supposed to be… but she didn’t listen to me so our whole project is wrong!” I assured her that the experiment was not incorrect; however, the more I examined her explanations and drawings from interviews two and three I realized that the issue in the computer lab did affect her ability to express understanding of the concept. The computer lab partners are assigned by the computer lab teacher, therefore I was unable to switch any students around. I do feel that had Zoa had a different computer lab partner to run the robotics experiment with she may have not exhibited signs of confusion in her second and third interview.

“Chad”. Upon entering the same classroom the other participants had conducted the interviews in, Chad took in a deep breath of air and exclaimed, “So this is where you are going to ask me all those questions?” His thick black glasses framed his tiny button-like face. He picked up the drawing utensils and beat them on the table like a drum set. To his left a sheet of faded green bulletin board paper hung down from the wall covering posters from the room’s previous
inhabitants. He pulled himself close to the kidney table and glanced around to check on the other two students at the computers. Above the windows more bulletin board paper hung askew from the wall, like a long octopus tentacle reaching down to the students on the computers below. I glanced around at the haphazard bulletin board display remains and considered pulling the paper down, but I am not sure who uses this room regularly, as it was available for all three of my interview dates and so I reserved it right away for all three sets of interviews. Some left over speech and reading manuals were stacked a foot high in the corner by the entrance way collecting dust.

Chad, a White male, is eight years old. His current GPA is a 3.9 and he scored within the 98th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a black male and they are assigned to seats in the back of the computer lab. During the first interview (Figure 5.3) Chad did show signs of some naïve beliefs surrounding topics of force and motion; however the second draw and tell interview (Figure 5.4), which took place during the treatment his understanding of the concepts became clearer. His arrows from the second draw and tell interview, along with his explanations, align with the correct concepts that were presented in the activity. One week later during the third and final draw and tell interview, Chad was again able to correctly articulate the same concept he had explained during our second interview.

Chad was a part of the high ability group in Group E3, and scored high on the Science Series Assessment 1. His pretest/posttest gain score was +4; of the 12 questions asked he initially knew seven and after the lesson answered 11 correctly.
Figure 5.3: Chad Draw and Tell Interview 1.

After the second draw and tell interview, Chad and I discussed using the robots again in the future and if he thought that using the robots could help him learn more about concepts of force and motion and he agreed. He even suggested modifying the original experiment so we could show the same concept, which proved he grasped the concept in a deeper way.

Figure 5.4: Chad Draw and Tell Interview 2.

Chad’s responses on the first interview indicated that he did have some confusion surrounding impetus theory of motion and a naïve belief was noted. The second and third
interview highlighted Chad’s new understanding of the topic and emphasized that through the activity with the robot as well as the way the lessons were presented (5E format) he was able to change his thinking about the concept. During his second interview he was able to connect one 5E activity to the robotics experiment to explain what he learned about the concept:

When we used the cotton balls and marbles I knew that it was the same as the robot because Speedy was set at 50% and I only blew in my straw a light breeze- not hard yet- so it was the same distance just like Speedy. Then when I blew in my straw on the marble I couldn’t do the same light breeze air- because the marble got more massive stuff in it- just like Speedy couldn’t push the heavy loader far because it’s got more massive stuff in it too- even if we turned up Speedy’s power he still wouldn’t push it far because of the massive stuff!

“Kale”. Kale slapped Yahti a high five as he slid into the chair across from me at the kidney table. “Yahti- keep my score on Mighty Guy high! I don’t want it going down again!” Kale’s big blue eyes watched the screen as Yahti plopped into the chair across from the computer and began rapping his fingers against the keyboard. Yahti turned and gave him a thumb’s up to ease Kale’s anxiousness about his score; Kale let out a sigh of relief and turned his attention back to me. “I’m ready now,” he said cracking his knuckles and placing his back firmly against the chair. He pushed his long blonde hair out of his eyes and pulled on his navy uniform shirt sleeve which was fraying around the edges. “It’s hot in here don’t you think?” he asked. It was warm, I checked the thermostat by the door and it read 71 degrees Fahrenheit. Even if I were to turn it down, it would never reach 68 degrees Fahrenheit, as these buildings are always too hot or too cold. However, I went ahead and turned the thermostat down to appease him. Walking back to the kidney table I caught Kale staring at the pink camouflage curtains that covered the window to the right of the door. All of the classrooms were required to have the window near the door covered in case of a lock down emergency and many of the teachers choose colors that match
their classroom theme. Presently, the pink camouflage didn’t match with anything in the room; however the room will be filled with another teacher next year, so maybe that teacher could find something to match with the current motif.

Kale, a White male, is seven years old. His current GPA is a 3.7 and scored within the 97th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White female and they are assigned to seats in the center of the computer lab. During the first interview Kale did show signs of some pre-conceived idea of impetus theory of motion; these beliefs remained constant throughout the second and third draw and tell interview. Kale was a part of the high ability group in Group E1 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew six and after the lesson answered seven correctly. After the second draw and tell interview, Kale and I discussed using the robots again in the future and if he thought that using the robots could help him learn more about concepts of force and motion and his response wasn’t clear and was focused more on playing with the robot and the interaction with his partner rather than the question I just asked him.

Kale’s responses on the first interview indicated that he had some confusion surrounding Impetus theory of motion; there was not an alternative conception noted, however his arrow drawings show some underlying confusion of the concept. The second and third interview emphasized again that Kale still seemed to hold his original alternative conception of a version of Impetus theory of motion in which he believed “that if the robot moved fast enough and pushed hard enough it would move the heavier load the same distance if not farther than it had
with the lighter load”. During his third interview, which took place one week after the treatment occurred, Kale explained his reasoning behind his belief of what really happened in the experiment:

Our robot was the fastest robot and it was the strongest too and we put the power on 50% and we didn’t use the heavy loader with the battery load so we won and ours went the farthest…. And people were mad mad because they didn’t win but we did.

“Ashton”. “Zoa and I have the same bow- only mine has One Direction on it! Do you like it?” Ashton’s long strings of blonde hair framed her oblong tan face as she hummed to herself. She stared up at the ceiling tracing the squares with her index finger pointing in the air. Following her finger I glanced up at the ceiling as well only to notice the dust bunnies gathering in the corner at the top of the built in wooden bookshelves that line the perimeter of the room. A few busted brown boxes were stacked on the very top of the shelves and some math manipulatives were shoved inside of the cubbies below.

Ashton, a White female, is eight years old. Her current GPA is a 3.8 and she scored within the 98th percentile on the first grade ITBS assessment. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a Hispanic male and they are assigned to seats in the back of the computer lab. Ashton frequently played with her hair during the second and third interview, she also replied to each question using many types of fillers such as “uh” and “um”. I noted that she seemed to be more fidgety and nervous after our first interview and typically students are more at ease during the later interviews, but not Ashton. During the first interview Ashton showed a misconception of force and motion that was noted in her drawings as well as in her explanation of the distance the heavier load would travel if the robot sped up exponentially before coming into contact with it.
Ashton’s second and third interview revealed her new understanding of the concept; her force arrows for her diagram were now placed in the correct places and she was able to articulate the correct concept she observed during the robotics activity.

Ashton was a member of the high ability group, in Group E2 and she scored high on the Science Series Assessment 1. Her pretest/posttest gain score was +4; of the 12 questions asked she initially knew seven and after the lesson answered 11 correctly. During the second draw and tell interview, Ashton and I discussed using the robots again in the future and if she thought that using the robots could help her learn more about concepts of force and motion and her response was positive.

Ashton’s responses on the first interview indicated that she had a misconception surrounding the concepts related to force and motion and this misconception was noted on the arrow diagrams in her drawings. The second and third interview revealed that Ashton had changed her understanding of the concept. In these later interviews, she indicated that as she manipulated the variables in the robot experiment she was able to see how her original thinking was incorrect. “When we made the time the robot traveled to two seconds instead of four… um… the robot was… um… faster but it like didn’t move the heavier loader thingy far far.”

When asked to continue her explanation she said, “Uh…just because the robot went fast fast it…uh…. didn’t push the heavier loader far….um….because going fast fast doesn’t matter when….uh… the loader is to too heavy.”

“Luke”. “My brother said to tell you hi, do you remember him? Y’all did the robots with him, too! I can’t wait to use them!” Luke’s overeager personality ran in his family; his brother had been the same way two years earlier. His sandy blonde hair covered his freckly forehead and
lightly touched the tips of his pink ears. He pulled his uniform pant leg up onto the chair to tie his multicolored shoe laces in a double knot. The oversized high top Nike Air Jordan shoes dwarfed his tiny hands as he pulled the tongue of his shoes straight up so he could tie the knot tighter.

Luke, a White male, is seven years old. His current GPA is a 3.7 and he scored within the 96th percentile on the first grade ITBS assessment. He does regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an African American female and they are assigned to seats in the center of the computer lab. Luke was very eager to talk during all interviews; he was especially expressive with his hands and had to be redirected to record his motions onto his drawings multiple times for all three interviews.

During the first interview (Figure5.5) Luke did show an alternative conception the concepts surrounding impetus theory of motion; this continued into his second and third interview. Luke consistently supported his belief which was consistent with Gilbert and Watts’ (1985) study which stated: “The amount of motion is proportional to the amount of force or faster moving objects are thought to have greater force” (Table 2.2b). During the second interview, I noted that Luke and his partner had disagreed during the robotics activity earlier in the day. Luke explained to me that his partner would not listen to him because she had read the ruler wrong. I read over my notes and noted that his partner had in fact read the ruler correctly, which showed that the heavier load did not travel the farther distance, and Luke continued to disagree with her even after they performed the experiment three more times to check for accuracy. Each time Luke insisted the load traveled the same distance, which indicates he was determined to maintain his belief on this topic.
Luke was a part of the high ability group in Group E3 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +2; of the 12 questions asked he initially knew eight and after the lesson answered ten correctly.

Figure 5.5: Luke Draw and Tell Interview 1.

Luke’s final interview (Figure 5.6) mirrored the same alternative conception he possessed during the first and second interview: that when a faster force (from the robot) was applied to the heavier load, it did in fact travel a farther distance than before. Even when the variables in the experiment changed where the mass of the load increased and the force from the robot remained the same Luke continued to argue with his partner stating, “I know that this is the heavier loader but it the robot went past the spot before. I know I am right because I measured it right every time. It did go far over there!” Luke’s responses are similar to those of students who have tenacious alternative conceptions of various scientific phenomena.
“Carly.” Carly fidgeted with her multicolored loom bracelets on her wrist while waiting for our first interview to start. Her ash brown hair was tied in a low pony tail and a few ringlets of hair framed her face. She stared at the large clock on the wall above our heads; I noted that during our interviews she frequently looked at the hands ticking around the clock. She seemed nervous, but was very polite and responded, “Yes ma’am” to almost every question asked before giving her response.

Carly, a White female, is eight years old. Her current GPA is a 3.9 and she scored within the 99th percentile on the first grade ITBS assessment. She has 504 accommodations for tests to be read aloud and extended testing time, as well as a 504 medical plan. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a black male and they are assigned to seats at the front of the computer lab.

During the first interview Carly did show some naïve beliefs of some concepts surrounding impetus; however, on her second and third interview these beliefs were not present. When asked if she thought that she could use robotics to assist her in understanding other concepts surrounding force and motion she agreed stating that, “It wasn’t just the robots—those
were fun - but the other stuff too helped me learned more stuff!” Carly was a part of the high ability group in Group E1 and she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +3; of the 12 questions asked she initially knew eight and after the lesson answered 11 correctly.

Carly’s final interview indicated her new understanding of the concepts where she could clearly articulate the differences in the experiments that she and her partner conducted in order to make clear the different concepts surrounding force and motion. I noted her support of the 5E activities; she seemed to refer back to those more than the use of the robots. The gallery walk was an activity she consistently went back to in order to explain the concepts. She said:

When we made our poster to show our experiment….we showed the class that the sheep jeep in the book was going really fast but that wasn’t going to help it push the heavy rock out of the way. We showed everyone that when our robot went slow at the same speed and power the loader didn’t go any farther because it was heavy- then when we sped the robot up it didn’t matter either- just like in the book. It does not matter how fast or how much muscle you put the heavier thingy won’t move far far then before. That’s what our poster showed everyone.

“Jazzy.” Jazzy’s tiny frame reached over and snatched a pencil out of the drawing utensils cup. She twirled it in her long slender fingers like a tiny baton; her eyes squinted behind her purple rimmed glasses. Her hair was pulled into a high bun atop her bullet shaped head. The Peter Pan collar of her white uniform shirt was stained with syrup from breakfast. On this first interview she put the collar into her mouth multiple times as if she was trying to suck every last morsel of the remaining sugary substance. Her pink sparkly lip gloss was smeared across her chocolate brown cheek from the shirt chewing. Handing her a tissue I asked her to wipe the lip gloss from her face before we began our first interview.
Jazzy, an African American female, is seven years old. Her current GPA is a 3.7 and scored within the 96th percentile on the first grade ITBS assessment. She does regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a White male and they are assigned to seats at the back of the computer lab.

During the first interview Jazzy did not show any misconceptions of any topics surrounding force and motion. She spoke very slowly and quietly when explaining all of her answers, as if she was in deep thought every time she opened her mouth. Similar to her first interview, her second and third interview didn’t reveal any incorrect conceptions either. Jazzy appeared to be very absorbed in all of the activities. I noted that during the robotics activity she took her time walking through each step more than the required procedures, she insisted she wanted to be thorough. During the second interview, I asked Jazzy if she thought using the robots assisted her in understanding the concepts better and she quietly agreed, nodding her head yes. Jazzy was a part of the high ability group in Group E2 and she scored high on the Science Series Assessment 1. Her pretest/posttest gain score was +4; of the 12 questions asked she initially knew seven and after the lesson answered 11 correctly.

Jazzy’s second and final interview revealed positive responses. She was able to indicate correct concepts using the arrows and articulate various aspects of the experiment very clearly. When asked to choose an experiment she conducted and explain what the findings were, Jazzy quietly cleared her throat and stated:

When Matt and I put the heavier loader in front of Shaq, we left the power and seconds traveled the same…. Because the experiment had to be fair……Shaq wasn’t pushing faster or harder against the loader. We made sure six times and Shaq didn’t go far at
all….so we learned that Shaq didn’t push the loader as far because it was heavier than the other loader.

“Jenna.” Jenna stretched her arms high above her head, reaching to the ceiling and yawning loudly. Pieces of her short brown, bob hair cut fell into her eyes. She quickly removed the slim yellow headband from her hair and replaced it back into its correct spot just behind her ears, adjusting the tiny lace bow gently. Glancing around the room, Jenna bit at her nubby fingernails. Specks of glitter from her blue fingernail polish gathered at the edge of the table in little piles. Every few minutes Jenna would sweep these pieces under the table to hide the evidence of her fingernail chewing. I noted that she repeated the same finger chewing rituals in all three of our interviews and appeared nervous, but seemed happy to discuss her experience.

Jenna, a White female, is seven years old. Her current GPA is a 3.6 and she scored within the 97th percentile on the first grade ITBS assessment. She has 504 accommodations for extended time, as well as a 504 medical plan. She also attends speech regularly for language processing remediation. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a Hispanic female and they are assigned to seats in the center of the computer lab.

During the first interview (Figure 5.7) Jenna showed some preconceptions of some concepts surrounding force and motion; however, on her second and third interview these beliefs weren’t expressed. When asked if she thought that she could use robotics to assist her in understanding other concepts surrounding force and motion she shook her head in agreement. Jenna was a part of the high ability group in Group E3 and she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +2; of the 12 questions asked she initially knew seven and after the activities answered nine correctly.
Jenna’s final interview (Figure 5.8) revealed her now corrected understanding of force and motion concepts; whereas in her first interview she had expressed some confusion about the concepts surrounding force and motion. In her first interview I indicated strong confusion surrounding the way her force arrows were drawn; while in her second and final interviews I noted her improved understanding through her correctly drawn arrow diagrams.

Jenna was one of the only students in the high ability group who relied more on her drawings to assist her in explaining the experiments. Many of the medium ability group students displayed this behavior. During her final interview, I asked if she could explain the concept she felt she now knows the most about. Jenna pointed towards her drawing and said:
The robot moved this way [pointing to her arrow indicating forward] and it pushed the load the same way. Then when we made the load have more mass inside, Juan bet me the loader would go farther because the robot is so so strong, but I knew that Juan was gonna be wrong, and he was wrong, and I was right. I knew that we didn’t change the power of the robot or how fast he was going, so he wouldn’t be able to push that more massive load farther down here [pointing to the arrow with the X on it] because the loader was too heavy and pushing back on our robot [pointing to her arrow facing the robot].

“Nicholas.” Nicholas slumped across the table from me on our first interview. He yawned and stretched his arms above his freshly shaven head. His navy sweatshirt was covered in grits residue from breakfast and it had started to harden. He rose walking across the room to get a tissue. He blew his nose loudly, causing the other students on the computer to glare in his direction. He laughed as he threw the snot-filled tissue into the trash can and squirted a half-dollar sized amount of hand sanitizer into his hands. As Nicholas sauntered back to his chair, he flung the hand sanitizer off of his hands violently, allowing the smell of alcohol to permeate the empty classroom.

Nicholas, an African American male, is seven years old. His current GPA is a 3.7 and he scored within the 90th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is also an African American male and they are assigned to seats in the center of the computer lab. During the first interview Nicholas showed signs of naïve beliefs surrounding some concepts of force and motion and Impetus theory of motion. These beliefs were not evident in his second interview; however, some misunderstandings were found in his final interview.

In his first interview, when asked to explain and draw force arrows on a picture where a truck is pushing an object with more mass he explained that the only force was from the truck and the truck was larger so it should be able to push the object out of the way. He did not draw
any other force arrows. He then took the toy truck and sand containers on the table and began to manipulate them trying to explain his drawing; however, his explanation using these props didn’t add to the accuracy of his original answer. His second interview (Figure 5.9) showed his improved understandings of the concepts, while his force arrow drawings were not completely accurate; there was some improvement from our first interview. He was more excited to explain his view on the activities and was equally excited that he had learned something different than he knew before.

![Image of a drawing with numbers 1, 2, 3, 4, 5, 6, 7, 8]

Figure 5.9: Nicholas’ Draw and Tell Interview 2.

Nicholas was a part of the high ability group in the Control Group, and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +2; of the 12 questions asked he initially knew five and after the activities answered seven correctly. Nicholas’ final interview (Figure 5.10), conducted one week following the 5E Learning Cycle Model lessons, indicated some prescientific conceptions had formed. He struggled with the concept of force, particularly if constant force was applied when conducting the experiments. He was unsure of the location of the force arrows and began to second guess his answers. His demeanor during the final interview was different in that he wasn’t as confident as he had been a week ago to explain the concepts to me.
I noted the uncertainty in his voice when I asked him to explain what he felt he learned most from our experiment. He said:

The um… experiment that we did with the straw and the cotton ball. I um… think what happened was the marble wasn’t supposed to go, um… as far as the cotton ball because we didn’t blow into the straw as hard. Maybe that’s right or maybe that’s wrong…um… the marble has more mass though.

“DiMajay.” DiMajay pushed his black and white framed glasses to the bridge of his tiny brown nose. In his first interview, I noted he frequently looked around the room and appeared to be nervous. His eyes darted back and forth, stopping to stare at the students on the computers, then to the windows facing outside. “Are they cutting the grass today? It looks like they might cut it today because it’s nice outside.” He folded and unfolded his hands in his lap while staring at me to answer the grass cutting question. Smiling, I quickly responded I was unsure and began to explain the interview directions.

DiMajay, an African American male, is eight years old. His current GPA is a 3.8 and he scored within the 89th percentile on the first grade ITBS assessment. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a black female and they are assigned to seats in the front of the computer lab. During the first interview DiMajay showed signs of preconceptions surrounding concepts of
force and motion. Similar to many students in the Control Group, his misunderstandings were not noticeable in the second interview; however, some form of misunderstanding appeared in the final interview.

It was evident that DiMajay had little previous interaction with concepts related to force and motion. Most of the answers to my questions were incomplete or he refused to answer them at all. When asked to draw force arrows to show the force applied when a truck pushes a less massed object, DiMajay drew one long line across the paper. When asked to explain his drawing he responded with, “I don’t know what to draw. I don’t know how to draw a force arrow or any arrow so I drew a line because the air is right there.” I recorded his eyes filled up with tears and noted his uncomfortableness; therefore, I didn’t push him to elaborate any further on any of the other questions.

DiMajay’s second interview was much more positive. Here he was able to draw some of the force arrows in the correct positions and could effectively communicate concepts discussed during the 5E Learning Cycle Model lessons. He elaborated on the drawing of his experiment:

During the gallery walk we showed all of our class that we could do the experiment correctly. We made sure it was fair when we blew into the straw and when we pushed the truck. We saw what we were supposed to learn! Which was when you have a big massive object it won’t go as far as a little massive object. We used the measuring tape in centimeters and inches and we saw that!

DiMajay was a part of the high ability group in the Control Group, and he scored high on the Science Series Assessment 1. His pretest/posttest gain score was +4; of the 12 questions asked he initially knew six and after the activities answered ten correctly.

His final interview, conducted one week following the 5E Learning Cycle Model lessons, uncovered evidence of a misconception that was not apparent in his second interview. Consistent
with most of the Control Group participants, DiMajay’s final interview indicated issues with understanding the concept of constant force. He could still correctly articulate understanding of the main concept from the lessons: as the mass of an object increases, the distance it travels decreases as long as the force remains constant. However, his explanation and examples of constant force were shaky. His force arrows for this final interview were similar to his second interview; however the explanations were lacking concrete evidence of understanding. When asked to explain how he and his partner applied constant force to the containers of sand using the truck, his response was, “We pushed hard each time… then we stopped then pushed some more and the container with more mass didn’t go as far as the one with less mass.”

“Asia.” Asia smoothed the hem of her khaki uniform jumper near her shins. She pulled on her white ankle socks tightly, making sure they were not slouching. Her hair was tied back with tiny light brown braids, affixed at the ends with pink and white beads. She shook her head back and forth letting the beads clack around her head, smiling. For this first interview, she seemed interested in taking part in this project; I noted this due to her attentiveness and eagerness to please. She was also very polite answering most of her questions with “Yes ma’am.”

Asia, an African American female, is eight years old. Her current GPA is a 3.8 and she scored within the 94th percentile on the first grade ITBS assessment. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the back of the computer lab. Asia was one of three students in the Control Group who did not display any misunderstandings prior to the 5E Learning Cycle Model lessons. During the first interview, Asia did not show signs of any misconceptions surrounding concepts of force and motion or
Impetus. Her force arrow drawings and explanations were 80% correct; however, she did struggle through some explanations of why she drew her force arrows applying force in certain directions. Her second interview showed the same correct understandings as before, and she was once again able to correctly articulate the concepts discussed during the 5E Learning Cycle Model lessons as well as indicate the correct force arrow drawings on her recording sheet.

Asia was a part of the high ability group in the Control Group, and she scored high on the Science Series Assessment 1. Her pretest/posttest gain score was +3; of the 12 questions asked she initially knew seven and after the activities answered ten correctly. Asia’s final interview, conducted one week following the 5E Learning Cycle Model lessons identified some prescientific conceptions. When asked to draw the force arrow drawings to recall their experiment from one week prior, Asia partially correctly placed the arrows. I sensed her trepidation when it came to elaborating on her arrows and noted that her brow was furrowed. She responded:

Last week when we did the experiment it was fun! I learned a lot about using my push and pull to move less masses stuff far and more masses stuff not that far. I used my tape measurer to measure too and recorded it in my chart. I drew three small arrows to show when I blew the air into the straw three times to push the marble and one arrow to show when I blew the air into the straw to push the cotton ball.

She further explained that she knew it was a fair experiment because she did the same amount of breaths for each object and she stressed that she knew she would have to push more air into the straw for the marble than the cotton ball because it has more mass.

Medium Ability Group

“Craig.” Craig crossed and uncrossed his arms multiple times throughout our first interview. He mumbled when he answered almost all of his questions which made his interviews
the most difficult to transcribe. He was tall for a second grader; the tallest in his class and his uniform shirts appeared to be a size too small. The sleeves of his navy shirt pulled at the chest and shoulder areas; two buttons were missing by the collar and a small hole had appeared where the seams had worn away in the neck area.

Craig, an African American male, is eight years old. His current GPA is a 3.0 and he scored within the 88th percentile on the first grade ITBS assessment. He has a 504 behavior modification plan. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White male and they are assigned to seats in the back of the computer lab.

During the first interview (Figure 5.11) Craig did show misconceptions of some concepts surrounding force and motion and impetus and these beliefs remained throughout his second and third interview. I noted that during the second interview he expressed two views of the experiment that conflicted. At one point he stated his robot was able to push the heavier load a farther distance, which he indicated using the force arrows. Later in the same interview he gave a contradictory response to his previous explanation, stating that the robot was not able to push the “more massive load farther”. In his drawings he indicted this change in his explanation by the placement of an X on the first arrows. When asked if he thought using robotics in the future could help him to understand other topics surrounding force and motion his response was mainly focused on using the robots for enjoyment and his answer was unclear.
Craig was a part of the medium ability group in Group E1 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +3; of the 12 questions asked he initially knew four and after the activities answered seven correctly.

Craig’s final interview indicated that he maintained the same misconceptions surrounding force and motion as in his first and second interview. Throughout all of the interviews Craig seemed distracted and uncomfortable; I noted that this may have caused his inability to effectively express his understanding of the concepts. In his final interview he focused heavily on the enjoyment he gained from using the robots, which may have also aided in the distraction issue. Craig described the most important thing he learned from using the robots to conduct the experiment as, “When we used the robots it was fun…sometimes they worked and sometimes they didn’t.” When prompted to elaborate on his response he said, “We used the robot move fast to push this heavy battery load and then it moved far…this one time and then it didn’t.” A closer inspection of Craig’s notebook from the experiment shows that he and his partner conducted the experiments correctly and the distance of the more massive load did not increase. Although, Craig did express seeing this he still showed confusion on the concept overall.
“Daniel.” Daniel slumped over in the chair across from me. His eyes darted back to the students on the computers and back to me. Strands of his long dirty blonde hair fell into his eyes; he frequently shook his head violently to remove the hair from his gaze in order to see the paper to continue his drawings. Rain lightly pitter pattered on the windows outside; creating a zigzag pattern showing the paths of raindrops cascading down the building. Daniel announced, “I am so happy I am in here with you today because I hate rainy days for PE!”

Daniel, a White male, is seven years old. His current GPA is a 3.3 and he scored within the 80th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an African American female and they are assigned to seats in the front of the computer lab.

During Daniel’s first interview a preconception was noted surrounding ideas of Impetus; however there was no evidence of this in his second or third interview. His first interview showed signs of informal ideas he had created before instruction on the topic. For example, when asked if he thought a truck moving at a faster speed could move an object with more mass he responded by shrugging his shoulders and saying, “I guess so…maybe….yes?” I noted his answers were followed with a question back to me asking if his answer was in fact the correct answer. I also noted that he would use his hands to “act out” what would happen before drawing the force arrows to show what he thought would happen.

Daniel was a part of the medium ability group in Group E2 and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew two and after the activities answered three correctly. During the second
interview, I asked Daniel if he thought using robotics in the future could help him in understanding other topics surrounding force and motion and his response was positive.

The final interview conducted with Daniel did not contain any indications of the preconceptions he had within his first interview. His second and final interview showcased his understanding of the concepts discussed; this was seen in his arrow drawings as well. His confidence in what he learned during the experiments was also noted during the gallery presentations. Daniel described what he learned the most from the experiment as:

We used Monster Machine to make a force field and push the massive load- but we didn’t change the powerful push the Monster Machine had. We did it four times and each time Monster Machine still didn’t push the more massive load far- so this means that when we switched the little load to the massive massive load that Monster Machine’s force field wasn’t more it just couldn’t push the load far because it was too massive.

“Axavier.” Axavier traced his name multiple times on his paper, outlining each letter carefully with the pencil. Once finished, he sat back in his chair and admired his work. He sneezed loudly and then quickly crossed the room to the small round table near the door where the box of tissues was located. As he walked back to the kidney table I noticed his uniform pants were a few inches too short. The hem of his khaki pants grazed the tops of his tiny coffee colored ankles. He sat carefully in his chair, moving it closer to the table before we began our first interview.

Axavier, an African American male, is eight years old. His current GPA is a 3.4 and he scored within the 85th percentile on the first grade ITBS assessment. Axavier has 504 accommodations for repeated directions and tests read aloud. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a Hispanic female and they are assigned to seats in the center of the computer lab.
During Axavier’s first interview, a naïve belief was noted surrounding ideas of force and motion. It seemed as if he impulsively responded to the questions asked, rather than think deeply about his answers or interact with the objects offered. When drawing his arrows he haphazardly scribbled answers and was quick to dismiss my questions.

Axavier was a part of the medium ability group, was in Group E3 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +4; of the 12 questions asked he initially knew six and after the activities answered ten correctly. During the second interview, I asked Axavier if he thought using robotics in the future could help him in understanding other topics surrounding force and motion and he nodded his head in agreement. In this interview Axavier also discussed the issues he was having with his partner during the experiment. He said:

I kept trying to tell Gabriella that the robot had to start at the black tape each time or the experiment would not be fair because it has to start at the same place each time. We had the wrong answers for one of the runs because of her….it made me mad.

I had noted during the experiment that he and his partner had issues; however, I wasn’t sure of the details.

The final interview conducted with Axavier did not contain any indications of the naïve beliefs he had within his first interview. With this interview he demonstrated correct understanding of the concepts presented during the activities and was able to indicate this through the force arrows he drew. I asked Axavier to elaborate on his experience using the robot and to explain what he learned through the activities. He said:

I learned that I didn’t know that robots were so strong! The experiment was fun and I learned that when you do a fair experiment then start the robot at the same place each time…if you make the load have more mass with the battery, then the robot won’t push
the load farther. The space it moves isn’t as far when you make it heavier but nothing else changed [he pointed to the robot], the robots push power and timer stayed the same.

“Jayden.” When Jayden sat upright in his chair he was almost as tall as I was. His tall, muscular frame filled the seat and while most second graders feet barely touched the floor when sitting in the chair his feet were planted firmly on the ground. He adjusted the straight-billed navy Cubs baseball cap on his head and assured me he had received a “Hat Pass” to wear his hat all day. I noticed his socks matched his hat; both had the Cubs emblem and were navy and red. He was definitely a Cubs fan.

Jayden, an African American male, is eight years old. His current GPA is a 3.6 and he scored within the 87th percentile on the first grade ITBS assessment. Jayden has 504 accommodations for a behavior modification plan. He does regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White male and they are assigned to seats in the back of the computer lab.

During Jayden’s first interview (Figure 5.12), a naïve belief of impetus was noted. He didn’t seem confident in his answers and appeared to be confused when answering the questions. His force arrows were randomly placed and had multiple scratch outs. Jayden was a part of the medium ability group in Group E1 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +3; of the 12 questions asked he initially knew seven and after the activities answered ten correctly.

During the second interview, I noted that the naïve belief that was previously present in the first interview was not expressed again in the second interview. Jayden was able to accurately describe concepts surrounding force and motion and indicate the correct force arrows in his
drawings. He referred to the extension activity featured in the 5E lesson where the students used cotton balls and straws to make the connection to the robotics experiment.

Figure 5.12: Jayden Draw and Tell Interview 1.

I noted he was the second student to make this connection. When asked if he thought using robotics in the future could help him in understanding other topics surrounding force and motion and his response was positive.

In the final interview (Figure 5.13) Jayden was able to express his understanding of the concepts clearly again.

Figure 5.13: Jayden Draw and Tell Interview 3.
He vividly remembered details from the experiment and was able to again draw the force arrows to indicate where force was applied in the correct places. Jayden said:

Using the robot was a lot of fun but the other stuff was fun too! I learned that when we used the robot we could show that it doesn’t matter how hard you push or how fast you go…. if what you are pushing has too much mass it’s not gonna go any farther.

“Kristen.” Kristen’s shoulder length brown hair was pulled into two braided pigtails. She pulled the ends of her hair, flattening them onto her shoulders and then fanning the pieces out. Her pony tail holders matched her neon pink nail polish and her zebra and neon pink light up shoes. She bounced in her seat while waiting for us to get started. I noted she had a lot of energy and was eager to talk.

Kristen, a White female, is seven years old. Her current GPA is a 3.2 and she scored within the 85th percentile on the first grade ITBS assessment. Kristen has 504 accommodations for repeated directions, tests read aloud and extended time. She also has a 504 medical plan. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the front of the computer lab.

During Kristen’s first interview, some alternative conceptions surrounding concepts of force and motion were noted. For instance, when asked to explain what would happen if we were to increase the mass of an object and push it using the same force if the distance the object moved would increase, decrease or stay the same, Kristen insisted the distance the object would travel would increase. Her force arrows were incorrect and she adamantly insisted that she had seen a TV show where the same experiment was conducted and the object traveled farther
because they “pushed it harder and faster.” These same beliefs were also seen in her second and final interviews.

Kristen was a part of the medium ability group in Group E2 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +1; of the 12 questions asked she initially knew three and after the activities answered four correctly. In the second and then again in the final interview Kristen’s alternative conception remained. I noted she was extremely fixated on making the connection between her previous understandings constructed from watching the TV show and the robotics activities. She continuously referenced her previous interaction throughout the interviews and during her experiment with her partner. I noted her partner began to disagree with her over the measurements they took. When I asked her about this she chortled, “Kevin was wrong when he took the measurements. I told him we were using centimeters and not inches- the more massive load traveled farther each time.” I noted that even after Kevin repeated the correct information to her, she refused to believe that it was true. Kristen continued to try to convince everyone around her that her erroneous belief was correct.

“Shelby.” Shelby’s long, stringy blonde hair stopped just above her shoulders. She reached back and put it in a ponytail, took it down again only to put it back into a half pony tail. The ends stuck straight atop her head; she looked like a small statue of liberty wearing the crown so proudly. Her green eyes scanned the room and then stopped at the computers, “Will I get to use the computers too?” Every child asks about the computers even though I assure them before the interview starts that they will get to play on the computers as soon as the interview is over. Shelby didn’t seem satisfied with my response, as she crossed her arms and continued to stare at the computers. I noted at this first interview, she didn’t seem too excited to participate.
Shelby, a White female, is eight years old. Her current GPA is a 3.4 and she scored within the 84th percentile on the first grade ITBS assessment. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is also a White female and they are assigned to seats in the center of the computer lab.

During Shelby’s first interview, some preconceptions surrounding Impetus were noted. Shelby didn’t appear to have any interactions with concepts related to force and motion prior to this interview. Her responses were underdeveloped, which was fitting seeing as she didn’t display any prior knowledge of the material. Shelby was a part of the medium ability group in Group E3 and she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +4; of the 12 questions asked she initially knew five and after the activities answered nine correctly.

In her second interview, Shelby didn’t display any of the preconceptions previously shown; she was able to clearly articulate her understandings from the experiment. I also noted that she appeared excited to share what she had learned by using the robot. She expressed she had never gotten to change the settings for the power or time for the robot before, so she was very happy that she was able to be the programmer position for her team. Her excitement continued in her final interview as well when she could again express understanding of the concepts discussed through the experiments and the 5E activities. She stated:

I got to program the robot last week! I made it go 50% power for only four minutes [the actual time unit was seconds] and I saw that when we changed the object to have more massive stuff inside of it then left the power the same it didn’t push it as far. Even when I made the power go up to 60% it still didn’t push it because more power doesn’t mean that the object will go farther.
“Jordan.” Jordan furrowed her brow as she concentrated on drawing her force arrows during our first interview. She sighed as she turned the paper sideways to get a better look at where to place her next arrow. Her curly, dirty blonde hair hung in ringlets framing her cherub face. She seemed very serious during our first interview, but in the second and third interview she opened up much more.

Jordan, a White female, is eight years old. Her current GPA is a 3.2 and she scored within the 88th percentile on the first grade ITBS assessment. She does regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the back of the computer lab.

During Jordan’s first interview (Figure 5.14), some preconceptions surrounding concepts of force and motion were noted. Jordan did not exhibit any solid understanding of the concepts of force and motion presented during her first interview. Even though she appeared to be in deep thought as to where to place her arrows, her eyes constantly watched my face as if I were going to indicate where she should place her next mark on the paper. Her responses to the questions were splintered and random. Jordan was a part of the medium ability group in Group E1 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +2; of the 12 questions asked she initially knew six and after the activities answered eight correctly.

In her second interview (Figure 5.15), Jordan’s previously shown preconceptions were not evident. Jordan was able to express her excitement for using the robots to help her “learn more about how things can move.” She was able to better articulate her understandings from the experiment after the day’s activities had been completed.
I noted that there were some measurement issues with Jordan and her partner. The measurement units had been changed midway through the experiment; thus causing Jordan to have some confusion on the actual distance the loader had traveled. I pressed her for more of an explanation as to what happened with this and she explained the confusion which was measurement related. Furthermore, she was able to clearly articulate that the robot’s power and time didn’t change so the distance the less massive loader traveled was farther than the more massive loader had.
Jordan’s third and final interview evidenced similar results to her second interview. She struggled making a concrete connection to using the robots outside of school to help her better understand force and motion; however, she was able to express a correct understanding for the experiment. When asked to explain the most important thing she learned from all of the activities she said:

When we did the gallery walk we showed everyone our experiment was right! They thought we measured it in inches but we showed them it was in centimeters and our robot did NOT go as far with the more massive loader. We were right!

“Nathan.” Nathan blinked several times before stating his name into the voice recorder. He rubbed his eyes and yawned before responding to the next question. I noted his sluggish body language was possibly an indication of his level of exhaustion. He could barely keep his eyes open for all of our interviews. I inquired about his constant yawning and he replied, “We just got a baby sister and all she does is cry all night long. I am so tired of the crying!”

Nathan, an African American male, is seven years old. His current GPA is a 3.0 and he scored within the 84th percentile on the first grade ITBS assessment. Nathan has 504 accommodations for extended time and tests read aloud. He does regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is also an African American male and they are assigned to seats in the center of the computer lab.

During Nathan’s first interview, some preconceptions surrounding concepts of Impetus were present. For example, Nathan’s responses to the questions were very simple; it was evident he had not been in contact with information similar to this before. His drawings contained multiple scratch outs and extraneous doodles. During his second interview his understanding of the concepts had shifted. I made a note to change his label to prescientific conception due to his
ability to somewhat explain some of the scientific topics we had discussed, but his explanations were still not on a solid foundation just yet. This lack of confidence in the correctness of his answers was also seen in his force arrow drawings from the second interview.

Nathan was a part of the medium ability group in Group E2 and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew five and after the activities answered six correctly. Nathan’s second and third interview indicated that he had retained the same prescientific conceptions that he started with. He could clearly articulate some of the pieces to the experiments surrounding force and motion, but there were still major parts missing. For example, in Nathan’s third interview he drew large arrows showing force being applied from the robot to the loader with less mass. He explained:

The first time we ran the robot it pushed more power that’s why I put those arrows there-wait no it didn’t push more power then I think… because we left the power at 50% so it wasn’t more power then…. But it did go far….farther than it did the next time with the massive loader.

Here he could articulate that the distance with the loader with less mass went farther, but he seemed to confuse the amount of power or force applied to make the loader move.

“Makenzie.” Makenzie towered over me as we walked from the gym to the classroom to conduct our first interview. Her flamingo like legs put her a full walking stride ahead of me; she could have been the tallest second grader I had ever seen. Her purple and zebra striped bow added at least an inch or two to her height, not that she needed it. As she sat in the chair across from me I watched as she unsuccessfully attempted to scoot the chair under the table. I helped her pull the chair to my side of the kidney table so she could stretch her legs before we began our first interview.
Makenzie, an African American female, is eight years old. Her current GPA is a 3.3 and she scored within the 83rd percentile on the first grade ITBS assessment. Makenzie attends speech intervention services. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an Asian male and they are assigned to seats in the back of the computer lab.

During Makenzie’s first interview, some naïve beliefs were evident. For instance, when I began asking the questions she didn’t wait for me to finish before responding. I noted that her first drawings contained random force arrows, pointing in many different directions. It was apparent she had not had any previous interactions with subject matter pertaining to force and motion. Makenzie was a part of the medium ability group in Group E3 and she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +4; of the 12 questions asked she initially knew six and after the activities answered ten correctly.

Makenzie’s second and third interview did not reveal any naïve beliefs from her first interview. I also made note that Makenzie had relied heavily on the force arrows to assist her in explaining her understanding for both the second and third interviews. She also was one of the few students who could apply our activities and experiments to an event outside of school. This understanding was showcased in her third interview where she was able to accurately place the force arrows and explain her knowledge gained from the activities. Makenzie explained:

The experiment with the robot…. It’s like… like… when you use a rubber band to pop something.” I probed her to explain this farther and her response was surprising. “One time my brother and I were using… we were using this rubber band to move these cars…. the cars they were small and we were trying to see how far we could make the cars go just by plucking them with the rubber band. Then we took bigger cars… they were heavier…metal cars… and we… we used the same rubber band to move them but those cars did go as far. That’s like what happened with our robot.
At this point she stopped to point to the force arrows she had drawn, one from the robot to the loader and the other from the loader to the robot. She went on:

    Do you see here? I drew it for you….When we did the... the…first robot experiment the load was not having that much mass. You knew that and then that second time you tried to fool us! But we…we were too smart! We knew that the mass of the second loader was more so the robot couldn’t push it as far.

    “Javier.” Javier pulled his chair close to the kidney-shaped table. His feet grazed the floor as he swung them back and forth. He adjusted the neck of his white uniform shirt pulling on the threads of the missing two buttons near the collar. His fingers tapped silently against the table as he waited for our first interview to start. I noted nervous energy during this first meeting, he also mumbled his answers, making his interview difficult to transcribe.

    Javier, a Hispanic male, is eight years old. His current GPA is a 3.2 and he scored within the 88th percentile on the first grade ITBS assessment. Javier has a 504 medical plan and has accommodations for tests read aloud and extended time. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an African American male and they are assigned to seats in the back of the computer lab.

    During Javier’s first interview, no misunderstandings of concepts surrounding force and motion were apparent. He correctly placed his force arrows on his drawings and also correctly articulated his understandings from the photos. Although he seemed to take a longer time explaining his answers they were correct; I noted his mumbled speech five times throughout this first interview and asked him to repeat his answers many times. His second interview was similar to the first, he was again able to articulate the concepts correctly and indicate understanding as seen in his force arrow drawings. The second interview he seemed to enjoy explaining his reasoning behind his experiments more; I noted his excitement level was higher with this
interview compared to our first meeting. Javier was a part of the medium ability group in the Control Group and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +3; of the 12 questions asked he initially knew six and after the activities answered four correctly.

The final interview (Figure 5.16) with Javier did not reveal any new misunderstandings. He once again answered his questions correctly and placed the force arrows in the proper place. Javier was the only student from the Control Group who did not display any misunderstandings during the final interview.

![Figure 5.16: Javier Draw and Tell Interview 3.](image)

When asked to elaborate on his experience during the activities his response was:

I liked working with my partner to solve the challenges! It was fun! I really liked when we got to present our information to the class and use the truck to push the less massed object across the floor. I told my partner to push it the same each time- that makes the push fair- and each time it went the far distance.

“Jahmaree.” My first interview with Jahmaree was the shortest interview I conducted for all of the students in the Control Group. He fidgeted with his long dreadlocks during the interview; weaving the long brown pieces of hair through his index and middle fingers. His eyes
were glassy and the answers to his questions were short and abrupt. I noted his disconnected state and was sure to check my notes again on his medical information.

Jahmaree, an African American male, is seven years old. His current GPA is a 3.3 and he scored within the 87\textsuperscript{th} percentile on the first grade ITBS assessment. Jahmaree has a 504 medical plan and has accommodations for tests read aloud, extended time and repeated directions. He also has a behavior modification plan. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White male and they are assigned to seats in the front of the computer lab.

Jahmaree’s first interview revealed an alternative conception surrounding concepts of Impetus. For example, when asked to draw force arrows indicating force located in a photo containing a truck pushing an object with more mass, Jahmaree drew a person running and pushing the truck. His arrows he drew from the person to the truck were large and plentiful; he explained:

I ran and pushed the truck really really hard. Then the truck was so strong it pushed the big massive rock far far away! When you run and push something really hard you always have it move far even if it has a lot of mass- you can make it go far.

I tried pushing him to explain more but he crossed his arms and refused. The remaining portions of his first interview were in yes or no answers. His force arrows were random and he could not provide a correct explanation other than the first response he gave. He kept repeating that he had already given me the answer to my question. Jahmaree was a part of the low ability group in the Control Group and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew one and after the activities answered three correctly.
Jahmaree’s second and third interview revealed the same alternative conception that was present in our first interview. These interviews lasted somewhat longer than our first interview; however, he continued to refer back to his first answer as his final answer for all questions. During his second interview he expressed his frustration during the experiment with his partner. Looking back through my field notes I had recorded there were multiple issues between Jahmaree and his lab partner. When his partner attempted to redirect Jahmaree to the correct answer he became annoyed and refused to listen. Jahmaree could not compromise with his partner when the portion of the experiment asked the participants to apply constant force to the truck. I noted Jahmaree playing with the truck and driving it all over the room, instead of applying constant force to gather the measurements for the assignment. When it came time for his group to present during the gallery walk they did not have all of the information and instead of Jahmaree getting upset he began defending his actions stating, “I did the right thing. Each time I did push the truck faster and faster to make the object go far far. We did ours right and all of you are wrong!”

The final interview indicated the same alternative conception shown from the first interview. Jahmaree continued to refer back to his very first explanation in our first interview in order to explain his understanding of the concepts he observed during the experiment. All of his force arrows were placed in the incorrect locations and when I asked him to explain his reasoning he became defensive and clammed up, stating he had already given me the correct answer. Jahmaree was one of many students in the Control Group who struggled with the concept of applying constant force throughout the 5E Learning Cycle Model experiment.
“Chloe.” Chloe sat at the kidney-shaped table examining the drawing tools and paper. She traced her finger along the perimeter of the paper and hummed to herself. Pink glasses framed her saucer shaped eyes and her reddish-brown hair was pulled back into a high pony tail atop her head. Throughout all of our interviews Chloe was very polite and timid. I noted she was shy, even when working with her partner through the experiments.

Chloe, a White female, is seven years old. Her current GPA is a 3.5 and she scored within the 80th percentile on the first grade ITBS assessment. Chloe has a 504 medical plan. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the front of the computer lab.

The first interview with Chloe did not reveal any misunderstandings of Impetus or topics surrounding force and motion. She took her time in answering the questions and the answers were correct. The majority of the force arrows drawn were located in the correct places. Although she was not overly confident, her answers were correct, which I assured her of. The second interview, which took place during the experiment, also did not reveal any misunderstandings of concepts surrounding force and motion. She elaborated on her experiences during the 5E Learning Cycle Model lessons:

I learned that um…. You have to make experiments fair…um… and when you push the same force for each time you do the experiment that…. Um.. makes it fair. When we did the gallery walk I made sure that everyone saw that we got the right measurements in centimeters and inches because we made sure we did the experiment fair with the pushing each time.

During the lessons I recorded in my field notes that Chloe and her partner were extremely attentive to detail. Chloe was a part of the medium ability group, was in the Control Group and
she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +3; of the 12 questions asked she initially knew seven and after the activities answered ten correctly.

Chloe’s final interview (Figure 5.17) took place one week after we had completed the 5E Learning Cycle Model lessons. Although in her first two interviews she appeared reserved, her answers were consistently correct; however, the final interview revealed some foundational understanding issues. I recorded her to have confusion and/or a misconception surrounding the application of constant force.

For instance, when asked to explain a correctly drawn force arrow facing from the marble to the straw she hesitated. She began to scratch through her drawing and draw the truck experiment instead. When I asked her why she decided to change her drawing she said she understood this experiment better. Looking back at my notes from the two experiments from the 5E Learning Cycle Model lessons I could not locate any major differences other than the materials used. After she drew the new representation she could correctly explain the concepts; however when I pushed her back to the original drawing she explained, “We didn’t do that experiment right.. um… we didn’t make it fair. This part wasn’t fair [pointing to the straw], like um… we didn’t blow the same.” Examining my field notes I located that Chloe and her partner
did have a disagreement over the amount of air pushed through the straw for that experiment. This conflict appeared to prohibit her from understanding the concept for this experiment.

Low Ability Group

“Murry.” My first interview with Murry lasted longer than any of my other interviews. Murry was a child of few words and the words he did speak were sentence fragments and mumbles of barely coherent speech, making his interviews difficult to transcribe. I noted that he seemed shy or sluggish due to the delay in response for his answers. He had a Mohawk shaved into his hair, which is against school policy, but it wasn’t overly noticeable. He frequently reached down to retie his red and black Air Jordan tennis shoes. He would tie a double knot and then untie it only to retie it over again. He did this multiple times throughout all of our interviews.

Murry, an African American male, is eight years old. His current GPA is a 2.0 and he scored within the 65th percentile on the first grade ITBS assessment. Murry attends speech intervention services for language processing. He also has a 504 medical plan and has accommodations for tests read aloud and extended time. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White female and they are assigned to seats in the center of the computer lab.

During Murry’s first interview, an alternative conception surrounding Impetus was apparent. For example, when he gave his answers he seemed to be fixated on a video he viewed on You Tube which assisted him in explaining the reasoning behind why the truck and/or robot pushed the less massed loader farther. Some of his force arrows were correct; however he
couldn’t piece together exactly what he thought would happen and he began to just give random reasoning surrounding the video as to why he thought his answers were correct.

Murry was a part of the low ability group in Group E1 and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +2; of the 12 questions asked he initially knew two and after the activities answered four correctly. Murry’s second and third interview revealed the same alternative conception that was present in our first interview. These last two interviews did not last as long as our first interview and he continued to mumble and speak in broken sentences throughout both interviews. During his second interview he expressed his frustration during the experiment with his partner. Looking back through my field notes I had recorded there were multiple issues between Murry and his computer lab partner. When his partner attempted to redirect Murry to the correct answer he became extremely agitated and refused to listen to her. His notebook and recordings from the experiments indicated multiple measurement issues. When I examined his partner’s notebook she took the measurements and correctly calculated the answers. Thus it appears that Murry mainly struggled with the measurement portion of the activity.

The final interview (Figure 5.18) indicated the same alternative conception shown from the first interview. Murry continued to refer back to the video he had seen in order to explain his understanding of the concepts he observed during the experiment. All of his force arrows were placed in the incorrect locations and when I asked him to explain his reasoning he became defensive. I attempted to redirect his attention to highlight the enjoyment he had shown while using the robot, his response wasn’t overly enthused. His response was:

When I used the robot my partner didn’t listen to me. I told Kasey that we needed to do like the video and put the power up high to push the first load but she didn’t listen to me
so my answers were all wrong. I told her that just like in the video our robot needed to push both loaders hard hard and fast fast to make them move the farthest then everyone else’s.

Figure 5.18: Murry Draw and Tell Interview 3.

“Matt.” Matt clung to his copy of Diary of a Wimpy Kid book and stared out the windows at the back of the room. The edges of the book were worn and discolored; he mentioned many times that this was his favorite book and he had read it five times. The jacket of the book matched his belt which was green and navy stripes and much too long for such a small boy. I recorded he was very polite and responded “Yes ma’am” to all questions.

Matt, a White male, is seven years old. His current GPA is a 2.2 and he scored within the 68th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an Asian female and they are assigned to seats in the back of the computer lab.

During Matt’s first interview, a prescientific conception was seen. When prompted with questions his explanations contained some scientific basis. For example, when I asked him to explain why an object with more mass would travel less distance if pushed at the same force and speed, his response was, “Just because you push something hard or fast that doesn’t mean its
going to go far. It just depends.” With this explanation I noted that he had some understanding
of certain aspects surrounding force and motion but a solid foundation was lacking. Matt was a
part of the low ability group in Group E2 and he scored low on the Science Series Assessment 1.
His pretest/posttest gain score was +1; of the 12 questions asked he initially knew three and after
the activities answered four correctly. Matt’s second and third interview revealed the same
prescientific conception that was present in our first interview.

The second interview showed Matt’s confusion regarding the measurement aspects of the
experiment. He confused the measurement units four times throughout the interview and he
continued to refer to the units traveled by the two loaders as yards and feet. The directions were
explicit with the use of metric units only; therefore there shouldn’t have been confusion on
which measurement unit to use. I noted during the class portion of the experiment that he had
tried to move the tape measurer in order to demonstrate the loader going farther than it actually
had. His partner quickly corrected Matt and adjusted the tape measurer back into its place.

Matt’s final interview again demonstrated his prescientific conception of force and
motion. When asked to explain his understanding of the experiment, I recorded he had to be
reminded to draw his force arrows. He didn’t seem to use them much in any of the interviews.
His explanation of the experiment contained some correct information and some inaccuracies.
Matt explained:

The robot sometimes needs more power to push the less massed loader forward… it just
depends on your experiment. When we redid the experiment we did the power at 50% and it pushed
the less massed loader far but that didn’t work each time … so that’s why I
don’t think it’s right all the time.

“Julia.” Julia’s first interview was the shortest interview I conducted out of all the
participants. She sat across the table from me and rapidly drew her force arrows. Her pencil-
straight blonde hair dusted her shoulders. Her purple headband sat cocked to the side in her hair, she pushed it back tight to her scalp. All of her responses were direct and to the point.

Julia, a White female, is seven years old. Her current GPA is a 2.7 and she scored within the 69th percentile on the first grade ITBS assessment. She has 504 accommodations and receives tests read aloud and repeated directions. She did not regularly use science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the center of the computer lab.

During Julia’s first interview, a misconception was apparent. For instance, her responses were extremely inconsistent and she often contradicted herself. She couldn’t correctly express any scientific basis for her thoughts and her force arrows were all incorrect. When I pressed her to give me further explanation she became agitated and her replies went to yes or no answers. Julia was a part of the low ability group in Group E3 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +3; of the 12 questions asked she initially knew four and after the activities answered seven correctly. Julia’s second and third interview revealed the same misconception that was present in our first interview.

The second interview revealed Julia’s issues with her partner during the experiment. She also struggled with the measurement portion of the experiment. I noted her arguing with her partner concerning mass. Her partner tried multiple times to explain to her that the first loader didn’t have as much mass as the second loader; but Julia kept insisting that the distance difference was due to the weight. Even though, I intervened and gave Julia a mini-lesson on mass and weight, reinforcing concepts we had previously covered, she continued to be confused. Her issues with her partner may have aided in her frustration with the experiment as a whole. She
asked to go to the restroom three times during our experiment that day, which I took as evidence that she was trying to avoid dealing with her partner.

Julia’s final interview again revealed her misconception of force and motion which was the belief that the amount of motion is proportional to the amount for force applied. When asked to explain her understanding of the experiment, she sat quietly for a few moments and drew her force arrows first (all were incorrect again). She sighed as she spoke:

I didn’t like using the robots because Jamir wouldn’t let me program anything. He was mean to me and I couldn’t have a different partner. All I remember from the experiment was that the robot went the farthest when it was pushing fast and hard.... sometimes but not all the time.

“Keandra.” Keandra’s braided hair beads clacked as she shook her head back and forth. The beads were pink, white and purple; they matched her tiny purple glasses. She pushed her glasses onto her nose and adjusted the post of her diamond stud earrings. I taught Keandra’s brother two years earlier, Jeremiah and they both have the same close-set brownish green eyes. She pulled her chair close to the table and leaned into the voice recorder as we began our first interview.

Keandra, an African American female, is eight years old. Her current GPA is a 2.2 and she scored within the 62nd percentile on the first grade ITBS assessment. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is also an African American female and they are assigned to seats in the back of the computer lab.

During Keandra’s first interview (Figure 5.19), an alternative conception surrounding force and motion was noted. This was seen in her reasoning for her answers which were based on a previous experience she had with her first grade teacher’s force and motion experiments. She
explained, “In first grade we did an experiment with roller coasters and cars. That’s where I learned that you need to push the race car fast to make it go far far.” When I asked her to explain if the race cars were all the same or were they different she claimed they were different. Keandra was a part of the low ability group in Group E1 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +0; of the 12 questions asked she initially knew five and after the activities answered five different questions correctly.

Figure 5.19: Keandra Draw and Tell Interview 1.

Keandra’s second and third interview did not reveal the original alternative conception that was present in our first interview. Her second interview disclosed her new understanding of the concepts. She was able to clearly articulate her new understanding; however, she did continue to have some issues with correctly drawing the force arrows. This second interview, during the experiment, exposed her issues with measurement. She expressed frustration when trying to calculate the difference between the distance traveled by the less massed loader and the more massed loader. She said she didn’t record the right numbers, but I had recorded in my field
notes that she had asked her partner three times to tell her what the measurements were because she wasn’t sure.

Keandra’s final interview again revealed her new understanding of the concepts examined during the experiment. When asked if she thought she could use robotics again to help her understand force and motion her response was positive. She couldn’t give me an example of how she could do so, but she was excited about trying to find another way to use the robots to help her understand more about force and motion. She explained the most important thing she learned during the experiment:

Me and Asia made Hungry Man have the most powerful force field! We made him have power at 50% and push the more massed loader not that far but the less massed loader moved far! Remember when we did our presentation… ours was the best!

“McKenna.” McKenna twisted the red and black loom bracelet on her arm. She adjusted the baseball necklace tighter around her neck. The necklace and bracelet matched her baseball stud earrings. McKenna’s brother, who I taught a year earlier, also was very active in sports—especially baseball. McKenna said, “I have a game today. We practiced for three hours last night…. It was long and I’m tired.” She put her head down and her chin length dirty blonde hair splayed all over the table before she sat straight up to begin our first interview.

McKenna, a White female, is seven years old. Her current GPA is a 2.1 and she scored within the 65th percentile on the first grade ITBS assessment. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is a White male and they are assigned to seats in the front of the computer lab.

During McKenna’s first interview, a prescientific conception surrounding force and motion was noted. It focused on the amount of motion being proportional to the amount of force
applied to the object. I noted some of her force arrows were correct; when asked to explain her drawings she thought for a moment and responded, “The lighter object will move farther because it weighs less…. That’s why I drew the arrows pointing that way. The truck pushing it won’t make a difference in how far it goes.” I noted that while she appeared confident in her answers there were still some holes in her understanding and that her explanations did have some scientific backing. McKenna was a part of the low ability group in Group E2 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +2; of the 12 questions asked she initially knew six and after the activities answered eight correctly.

McKenna’s second and third interview did showcase similar prescientific conceptions that were present in our first interview. During her second interview she expressed her frustration in using metric units for the experiments. I reexamined my field notes and saw that she asked her partner four times to assist her in measuring the distance traveled. Her partner did assist her in taking a closer look at the measuring tape; he even went as far as to count out the measurement with her. Although she outwardly appeared as though she understood the concepts; I could tell there were still holes in her understanding.

The third interview revealed that McKenna still was holding onto some misunderstandings based upon her prescientific conception of the topics discussed. When asked to explain what she learned in the experiment she motioned to her force arrow drawings and said, “When we put the robot on 50% power it pushed the lighter loader 10 more inches farther.” She continued to confuse mass and weight as well as the units of measurement. Her force arrow drawings were correct; however, she still demonstrated signs of misunderstanding.
“Jacob.” Jacob pushed his oversized black rimmed glasses back to his nose. I don’t believe they were prescription glasses; they must have been an accessory. The large frames magnified his brown eyes and long black eyelashes. “Do you like my new glasses?” he leaned in to pose the question. I nodded and pushed the papers to him across the kidney table and began to explain the instructions for our first interview. He stood to adjust his black leather belt tighter around his waist then plopped back into the chair.

Jacob, an African American and White male, is eight years old. His current GPA is a 2.0 and he scored within the 60th percentile on the first grade ITBS assessment. He has 504 accommodations for repeated directions and tests read aloud. He also has a 504 medical plan. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is a White male and they are assigned to seats in the back of the computer lab.

All three of Jacob’s interviews indicated a misconception surrounding topics of force and motion surrounding the amount of motion being proportional to the amount of force applied to an object. His first interview’s answers were extremely inconsistent and appeared random. I reviewed my participant information and saw that he does have an ADHD diagnosis and his medicine is irregularly administered. I watched his mannerisms closely and I could see attention becoming an issue. I repeated the directions multiple times and even rephrased the directions and his arrows continued to be inconsistent. His responses were the exact opposite of the concepts of force and motion we were discussing; therefore I labeled his first interview with a misconception heading.
Jacob was a part of the low ability group in Group E3 and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew four and after the activities answered five correctly. Jacob’s second and third interview both highlighted the same misconception that appeared in his first interview. During our second interview, I prompted Jacob to explain his force arrows. His responses, similar to our first interview, were random and didn’t have much, if any, scientific backing. The arrows were scattered across his paper, there were multiple scratch outs. The second interview also allowed him to express to me his frustrations with his partner. I noted that during the experiment I had to visit Jacob and his partner twice in order to mediate an argument. Jacob’s main complaint was his partner was being “bossy.” I recalled the partner trying to assist him in reading the measurements and dealing with a programming issue, this was interpreted by Jacob as being “bossy.”

Jacob also had trouble using the metric units for measurement. His science notebook and experiment recording sheets were scribbled with drawings and nonsensical explanations. The papers inside of his notebook were also disorganized and out of order so it was difficult to pinpoint which notes he took on what date. During the second interview he explained he wanted more time during the experiment with the cotton balls and straws. He felt that if he had more time to experiment with these tools he would have understood the concepts better. I did note that during this portion of the activity he was more focused, and had he received more time during this activity, he may have understood the concepts better.

The third and final interview (Figure 5.20) indicated the same misconceptions seen in the first and second interview. Jacob’s arrows were again randomly placed on his paper. When
explaining the force arrows he said, “The robot would have pushed the more massed loader farther if Jude would have let me use more power, but it did push it farther that one time, it went farther when it was in inches not centimeters.” I asked him what his favorite part of the experiment was and if he thought he could use the robots to help him understand topics of force and motion in the future and he nodded his head in agreement. “The robot was really fun and cool! I think if Jude wasn’t my partner I would like to use the robots again.”

Figure 5.20: Jacob Draw and Tell Interview 3.

“Emily.” Emily tapped her feet under the chair. She pulled her glittered pink and green tennis shoes onto the chair. The shoe lit up as the heel rapped on the seat. “Do you like my new shoes? They are my two favorite colors! I love pink and green!” Emily smiled a huge gap-toothed smile. Her ashy brown hair was in two high pigtails atop her head. I noted she appeared to be excited to participate in the interview. This excitement continued throughout all three of our interviews.

Emily, a White female, is seven years old. Her current GPA is a 2.2 and she scored within the 62nd percentile on the first grade ITBS assessment. She has 504 accommodations for
tests read aloud. She also has a 504 medical plan. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is also a White female and they are assigned to seats in the center of the computer lab.

Emily’s first interview did not reveal any misunderstandings concerning Impetus or any topics surrounding force and motion. She answered all of her questions without any hesitation and they happened to be correct. She was one of the only students in the low ability group who didn’t show any indications of any misunderstandings concerning force and motion. She was also the only student who got all of her force arrow drawings correct. I noted also that during her second and third interviews she relied heavily on the 5E activities to support her understandings of the concepts.

Emily was a part of the low ability group in Group E1 and she scored average on the Science Series Assessment 1. Her pretest/posttest gain score was +4; of the 12 questions asked she initially knew six and after the activities answered ten correctly. Emily’s second and third interview did not indicate any misunderstandings concerning force and motion. In the second interview Emily expressed her happiness of working with her partner and using the robots, “It was so much fun working with Lori! We programmed the robot to go so far and it was so much fun.” This second interview revealed Emily did have confusion about the measurement units. She explained, “When we used the tape measurer I wasn’t sure which side was inches or centimeters or what to use to measure how far the loader went.” She then stopped for a moment and continued:

But I remember that when we did that cotton ball experiment it did go far so when we used the less massed loader I knew it would go far and then because the marble had more mass it didn’t go as far. Remember?
Her third and final interview did not reveal any misunderstandings about concepts surrounding force and motion. Emily correctly placed her force arrows and could recall events from the previous week. She also responded positively to using the robots again in the future and having them assist her in understanding objects of force and motion. She explained:

The gallery walk we showed we knew what was going on. Lori and I showed that we could use the robot to show that the more mass something has it won’t travel far- but you gotta keep the power and time the same because if you change it its not a fair experiment.

“Tanner.” Tanner shook his head from side to side. He stared at the other students on the computers while tapping his fingers on the table as if he was playing an imaginary piano. His white uniform shirt was stained pink, probably from the strawberry milk served at breakfast. He began to wipe at the stain with his fingers; licking his index and thumb and scrubbing away. I asked him to get some hand sanitizer before we began our interview and he begrudgingly agreed. I noted his attitude was less than enthusiastic about being in this first interview. It was during his normal ancillary time so he most likely was unhappy about missing it. I asked if everything was okay and he replied, “It’s the bus. I hate my bus driver.” I nodded and made note to talk to his homeroom teacher about this. I assured him I would talk to someone about the issues on his bus and we began our first interview.

Tanner, a white male, is seven years old. His current GPA is a 2.3 and he scored within the 68th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an African American male and they are assigned to seats in the front of the computer lab. Tanner’s first interview revealed an alternative conception surrounding concepts of Impetus. For instance, when prompted as to explain his force arrows, which were 85% incorrect, he responded:
The faster you push something the farther it’s going to go. And if you push something hard it will go far, far, too. I know this is true because one time I pushed something that was really heavy really far.

When I asked him to elaborate on this he refused and simply insisted that he knew he was correct.

While his first interview revealed a prominent alternative conception surrounding Impetus, the second and final interview indicated otherwise. The previous alternative conception from the first interview was not apparent in the second interview. His force arrows for this second interview were correct and his explanations for the concepts discussed were also correct. He did discuss having issues with his partner but he assured me they worked it out. There was also a measurement issue with Tanner as well; his science notebook and recording sheets indicated some confusion surrounding using the metric form of measurement. His recordings switched between standard and metric units. When I asked him about it he was hesitant to explain, stating he was having trouble measuring how far the different loaders went.

Tanner was a part of the low ability group in Group E2 and he scored average on the Science Series Assessment 1. His pretest/posttest gain score was +3; of the 12 questions asked he initially knew seven and after the activities answered ten correctly. His third and final interview revealed correct understandings of the concepts discussed. Tanner was very positive in his descriptions of his partner as well as his experiences during the experiment and activities. His response was positive when asked if he would use robotics again to help him better understand topics of force and motion. He explained the most important thing he learned was, “When Jacolby and I used the robot we learnded together that the more massive object won’t move as far and the robot pushes with this little arrow but the massed loader pushes with this big arrow.”
“Madison.” Madison’s green and zebra glasses sat far down on her nose. She pushed them back on the bridge of her tiny, narrow nose. Her brown naturally curly hair was pulled back in small braids affixed to her scalp. Green rubber bands tied the ends of each braid that skimmed the tops of her shoulders. Her khaki jumper was embroidered with her initials over the heart. She pulled the drawing utensils closer to her inventorying her supplies. I noticed she intently studied all of the materials on the table. She appeared to be an intense child, very serious with her answers, but polite.

Madison, an African American female, is eight years old. Her current GPA is a 2.1 and she scored within the 64th percentile on the first grade ITBS assessment. She regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is also an African American female and they are assigned to seats in the center of the computer lab. Madison’s first interview revealed a misconception surrounding concepts of force and motion. For instance, when asked to explain her reasoning behind her force arrows, which were randomly placed and pointed to the sky, she had varying answers. She said, “The force field from the magnets push on the robot to push the box along.” There were no magnets present in picture or mentioned during the demonstration. When probed to explain further she went on, “That’s what makes things move. The magnets- they are everywhere. That’s why we move, because our legs push against the magnets.”

Madison was a part of the low ability group in Group E3 and she scored low on the Science Series Assessment 1. Her pretest/posttest gain score was +1; of the 12 questions asked she initially knew four and after the activities answered five correctly. Even though her first interview indicated a misconception surrounding topics of force and motion, in the second and
final interview this misconception was not noted. The second interview (Figure 5.21) highlighted her excitement about using the robots and getting to present her new understanding to the class with the gallery walk. She was very positive about using the robots in the future to assist her in understanding topics of force and motion. Madison elaborated on this during the second interview, “The best part about the whole experiment was getting to show everyone I learned how to use the robot to show everyone something! I can’t wait to do it again soon!” The final interview with Madison again did not reveal the misconception seen in her first interview. Her force arrows were correct and she was able to clearly articulate and remember the experiment from the previous week.

When asked to explain the thing she felt most important that she learned she elaborated:

I know that I learneded a whole bunch of science stuff. I know that when we used the robot to push the less massed load it went really far (pointing to the arrow going away from the robot). Then when you tried to play a trick on us and make us use the more massed load it didn’t go as far because it had more mass (pointing to the arrow going towards the robot). It was cool because you tried to trick us and it didn’t work!

“Connor.” Connor’s first interview was one of the longer interviews I conducted with the Control Group students. He frequently stopped to think before answering the questions; this
think time took longer than most students. The responses to most of the questions were incomplete and he frequently attempted to change the subject in order to avoid answering the questions. While I adjusted the volume for another student at the computer Connor sighed and crossed his arms in front of his chest. He pushed his long shaggy brown hair from his forehead, pulling the pieces down in front of his eyes then pushing them back again. I noted his demeanor appeared to be agitated.

Connor, a White male, is seven years old. His current GPA is a 2.3 and he scored within the 60th percentile on the first grade ITBS assessment. He did not regularly use science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is also a White male and they are assigned to seats in the front of the computer lab. Connor’s first interview revealed an alternative conception surrounding Impetus. For example, when asked to draw force arrows indicating force in a photo which featured a truck pushing an object with less mass he drew multiple, large arrows facing the object. He then drew the arrows extending off the page coming from the truck and the object. He explained, “The truck is really strong and drives really fast. It can push that little thing far, far away.” When asked to draw the force arrows on the second photo that featured the same truck and an object with more mass he drew the same arrows. He explained again, “I just told you that the truck is really big and strong so it doesn’t matter if the rock is bigger. The truck was driving so fast that it pushed the rock far, far.”

Connor was a part of the low ability group in the Control Group and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +2; of the 12 questions asked he initially knew three and after the activities answered five correctly. The same alternative
conception seen in the first interview was seen in the second and third interview as well. I noted during the 5E Learning Cycle Model lessons that Connor had many disagreements with his partner. I attempted to diffuse the arguments; however, Connor was very opinionated in his views on why the experiments were or were not working. He refused to allow his partner to push the truck at the same speed each time; this caused his partner to become upset and eventually he redid the whole experiment alone. Following the experiments I collected their notebooks and noted that both Connor and his partner had measurement inaccuracies, particularly pertaining to metric measurement. It is possible that these disagreements caused both students to make incorrect measurement recordings.

During the gallery walk Connor insisted that, “it didn’t make a difference in the distance traveled with each trial because you could push the truck at whatever speed you wanted”. His third and final interview revealed the same misunderstandings from the first two interviews. He drew photos of the experiments that took place during the 5E Learning Cycle Model lessons and the arrows were incorrect again. When I attempted to test his understanding of the concepts, or get him to further explain his viewpoints he became extremely agitated and continued to repeat his original viewpoint, “I told you already. It doesn’t matter how much mass the object has. If you push fast enough it will move it.”

“Julio.” Julio stared at the students on the computers. “Will I have enough time to play on the computers too?” I nodded and continued to clear off the table from my previous interview. His attention turned back to the computers. “My teacher never gives us enough time to use them. We never get time for AR or anything.” In this first interview he appeared to be very interested in using the computers, therefore, his answers were short and abrupt. He wore a navy uniform
shirt and khaki uniform shorts. His belt matched his shoelaces; both were neon green and blue. Even though he seemed to rush through his answers, I recorded that he appeared to be a happy child who was eager to please.

Julio, a Hispanic male, is eight years old. His current GPA is a 2.5 and he scored within the 68th percentile on the first grade ITBS assessment. He regularly used science notebooks in the classroom and has used the robots before in computer lab. His computer lab partner is an African American male and they are assigned to seats in the center of the computer lab. Julio’s first draw and tell interview uncovered a naïve belief surrounding concepts of force and motion, particularly focusing on the amount of motion being proportional to the amount of force applied to an object. His answers and force arrows were impulsive and random; it was apparent he had not had much interaction with concepts of force and motion. His second interview (Figure 5.22) unveiled a different understanding. He was able to more correctly articulate concepts discussed during the 5E Learning Cycle Model lessons. I noted that Julio’s science notebook contained many measurement discrepancies, especially when changing from metric to standard forms of unit measurement. Although there were some moments in the interview where I noted he looked to me before answering, the majority of his answers were correct. There was a definite improvement in understanding of concepts from our first interview. Julio was a part of the low ability group in the Control Group and he scored low on the Science Series Assessment 1. His pretest/posttest gain score was +1; of the 12 questions asked he initially knew six and after the activities answered seven correctly.
The final interview with Julio revealed his misunderstanding had reappeared. I labeled this misunderstanding as a prescientific conception due to his responses when explaining his force arrows. It was evident he had gained partial understanding of the scientific concepts discussed in the previous week’s 5E Learning Cycle Model lessons; however, retention of these concepts was lacking. The correctness of his force arrows had declined, not by much, but a decrease in accuracy was noted. When asked to elaborate on his force arrow drawings he said, “When we blew in the straw we pushed the air on the cotton ball and on the marble but they went the same distance. I can’t remember what happened next though.” I then redirected him to remember the truck experiment that was similar to the straw experiment. He shook his head and responded:

I think we pushed it the same and got the same distance- but I don’t think that’s right because I know we pushed this way [points to arrows facing towards the less massed object] but if it has less mass it should go farther but I don’t think we did it right.

“Trinity.” Trinity played with the drawing tools and papers on the kidney-shaped table. She scattered the pencils in front of her and attempted to pluck the pencils off the table with her index finger. She pulled on the long, blonde pony-tail that extended down her back. A large red and blue chevron printed bow sat atop her head. Her eyes squinted as she attempted to pluck
another pencil from off the floor. Snatching the pencils off of the table and out of her reach, I captured her attention quickly and began to explain the directions.

Trinity, a White female, is seven years old. Her current GPA is a 2.2 and she scored within the 64th percentile on the first grade ITBS assessment. She has a 504 medical plan and a 504 behavior modification plan. She also receives extended time and repeated directions on tests. Trinity regularly used science notebooks in the classroom and has used the robots before in computer lab. Her computer lab partner is an African American male and they are assigned to seats in the front of the computer lab.

Trinity’s first interview uncovered a naïve belief surrounding force and motion focusing on the amount of force applied to an object is proportional to the distance the object will travel. Her force arrows were haphazardly strewn across her paper and her explanations were equally as flippant. She laughed while explaining her answers; this appeared to be due to her uncertainty and nervousness. Her second interview, which took place during the 5E Learning Cycle Model activities, produced more promising results. Although the force arrows drawn during our second interview weren’t completely correct, Trinity was able to correctly explain her reasoning for the location force arrows, which was an improvement from our first interview. She elaborated on what she learned from the experiments:

We explained in the gallery walk that when you have something with less mass that it goes farther and with more mass it doesn’t go as far. But I think I didn’t write that down with numbers- I just drew the arrows on my paper I think.

Trinity’s recording sheet during the experiments did not contain any actual measurements; however, her partner’s did contain some correct measurement recordings. I noted that during the
experiment I had redirected her to record her measurements three times on her paper, she must have assumed recording the force arrows were a substitute for the actual measurements.

Trinity’s final draw and tell interview revealed issues with her foundational understanding of the topics. I labeled her answers as misconceptions due to the randomness of her responses which included “the cotton ball went farther than the marble because I blew air slowly” and “the object with less mass travels not far because I didn’t push it hard.” Our final interview was similar to our first interview in that she was very agitated and appeared to be bothered when I probed her to explain her answers more. The force arrows she recorded had returned to inconsistent locations. She giggled multiple times when I asked her to explain her drawings. Through her laughter she elaborated, “Sometimes you can push heavy stuff far- it just depends on how hard you push.” When I reminded her of our conversation a week prior where she had correctly explained the concept to me she looked down to the floor. I noted her facial expression appeared to be guilt, but I was unsure of how she felt. She responded, “I think I copied off of my partner on some stuff… I can’t remember what we did. I am sorry.”

**Group Summary**

All participants were chosen through a selection process that took place prior to the intervention. As discussed in Chapter 4, the type of purposive sampling that was utilized in this study was criterion sampling. This sampling technique is used when the researcher is searching for cases that contain extreme, typical, or multiple perspectives in relation to the phenomenon one is studying (Creswell & Clark, 2011). The ITBS stanine scores were grouped into three levels: high, medium and low. This provided a sample size of 36 with three from each ability
level within the experimental (Groups E1, E2 and E3) and Control Groups. All participants were pulled from ancillary to participate in the interviews.

Ten of the 36 participants were Caucasian females and seven were African American females. Ten of the thirty-six participants were African American males, seven were Caucasian males and two were Hispanic males. All participants were second grade students and were either seven or eight years of age (Table 4.17). Many participants in both the control and experimental groups labeled as having low ability possessed a variant of misunderstanding of concepts of force and motion or impetus, which remained throughout all three interviews. Few of the high and medium participants revealed misunderstandings of force and motion concepts and/or impetus before, during and after the treatment occurred. Understanding of the concepts seemed to be influenced by their interaction with their lab partner and their previous interactions and understandings of measurement units. Retention of concepts discussed appeared to be lacking in all ability levels from the Control group. These students also appeared to express issues with understanding the concept of constant force. These topics as well as the four main themes are discussed later in Chapter 6. All observations, draw and tell coded interview transcripts, and descriptions located inside this chapter assisted the researcher in developing an overall picture of each participant.
CHAPTER 6
FINDINGS, DISCUSSION AND CONCLUSIONS

Introduction

Through analysis of both quantitative and qualitative data as a concurrent embedded mixed methods design, the following questions were answered:

How does the utilization of robotics instruction embedded within the 5E Learning Cycle Model assist students in gaining a deeper understanding of force and motion?

In what ways have the robotics instruction utilized in this study empowered students of different ability levels to retain these newly developed conceptions over a period of time?

The specific purpose of this study was to investigate the development of rural elementary students’ conceptual understanding for force and motion as a result of robotics instruction immersed within the 5E Learning Cycle Model. Elementary rural students’ experiences and understandings were examined through assessments and draw and tell interviews. Chapter 6 begins with a summary of the overall study; it then presents the common patterns and themes that emerged during data analysis. Following the data analysis are conclusions from the study and recommendations for future research.

Summary of the Study

The focus of this study was to make use of constructivist teaching practices (5E Learning Cycle Model Lessons) accompanied with robotics instruction as a means to assist students in addressing their understandings of force and motion topics. Through an embedded mixed methods study these selected practices were applied within a classroom setting for rural elementary students in order to determine how this teaching style (5E Learning Cycle Lessons) affected their understanding.
Ninety-five students participated in this mixed methods study, which used a control baseline comparison group (n=24 for Control Group) and three experimental groups (n=23 for Group E1, n=24 for Group E2, and n=24 for Group E3) and a draw and tell activity and the answers from the short answer questions encompassed the qualitative data. The Science Series Assessment 1, a quantitative assessment, was administered to all participants as both a pretest and a posttest. Participants took the pretest two weeks prior to the intervention, participated in the intervention, and then took the Science Series Assessment 1 immediately after the intervention was complete to assess for knowledge retention of force and motion understanding (Posttest 1). The same posttest, containing 12 force and motion type questions was administered one week after the intervention to test for the effect of the instructional activities over time (Posttest 2). The draw and tell data collection was employed before, during and one week after the intervention. The draw and tell data interview contained Likert-type scale questions and short answer questions.

Prior to the intervention, the ITBS stanine scores were grouped into three levels: high, medium and low, and provided a sample size of 36, three from each ability level from the experimental and control groups. This criterion sample of 36 students were pulled three at a time from ancillary classes and participated individually in the draw and tell activity before the intervention, during and one week following the close of the intervention. Analysis of the draw and tell interviews as well as observations and field notes generated four themes which were then compared to qualitative data sources. The four themes were: using the robots along with the 5E activities was enjoyable and assisted learning, constant force applied to an object with increased
mass decreases the distance traveled, measurement confusion (which includes mass and distance traveled), and constant force confusion.

**Findings**

**Pilot Study**

An examination of the quantitative data collected from the pilot study revealed mixed results among groups. Eighty percent of students (n=93) displayed a version of misunderstanding in topics pertaining to force and motion and/or impetus. Draw and tell interviews prior to the treatment revealed only five of the 36 students interviewed possessed alternative conceptions on topics surrounding force and motion. Three of these five did not display the same alternative conceptions during or one week following the treatment. Two of these three were identified as having medium ability and in Group E3, while one was identified as having low and in Group E1.

Eighty percent of all participants (n=93) displayed a variation of misunderstanding in reference to topics surrounding force and motion and/or impetus prior to the treatment. These students varied across ability levels as well as in the Control and Groups E1-E3. During the treatment this number decreased to 50%. Groups E1 and E3 had little variations among the second and third interview. Many students in these two groups (E1 and E3) who had displayed correct understanding during the treatment expressed the same correct understanding one week following the treatment. The majority of the students in the Control Group and Group E2 who displayed incorrect understanding during the treatment displayed the same incorrect understanding one week following the treatment.
Only 12 participants displayed the same misunderstanding or a variation of a previously expressed misunderstanding throughout the whole treatment process. Of these 12 participants, six were located in the Control Group. Within these six, three were identified as having low ability and three were identified as having medium ability. The Control Group had very few participants (33%; n=24) who retained information one week following the treatment. Group E1 contained three participants who were identified as having low ability. Group E3 also had three participants who expressed misunderstandings throughout the whole treatment process; these students were identified as having low ability.

An analysis of the data from the Pilot Study suggests that the majority of the low ability identified students in all experimental groups (Groups E1-E3) benefitted from interacting with robotics instruction immersed within the 5E Learning Cycle Model lessons; however, an inspection of the qualitative data suggests that the majority of the low ability group did not display a deeper understanding of concepts of force and motion during or following interactions with robotics instruction immersed within 5E Learning Cycle Model lessons. The Control group’s quantitative data reveals a small gain in results directly following the activity; however, an examination of the data from Posttest 2 shows a decrease in retention of knowledge. This is mirrored in the qualitative data from the Control Group and is especially evident in the students identified as having low ability level (Table 6.1).

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<th>Table 6.1. Means for Pretest and Posttests</th>
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Twelve students who typically receive the accommodation of tests read aloud and extended time were not given those accommodations in the Pilot Study due to researcher error. These students were distributed across the four groups as follows: four students were located in Group E1, three students were in Group E3, two students were in Group E2 and two students were in the Control Group. Eighty-three percent of these students displayed poor scores (70% and below) on the quantitative portion of the study; however, the majority of these same students demonstrated average to high understanding during the qualitative portion of the study. Participants in the pilot study were not given the option to hand record their answers for the Science Series Assessment 1, as it was an online assessment. Multiple students in all four groups expressed concern that the computer didn’t record the answer they had entered.

The draw and tell interviews prior to the treatment allowed participants the opportunity to describe their current understanding of concepts of force and motion and the impetus theory of motion. These interviews were structured so that students could express their knowledge by answering questions posed aloud by the researcher and accompanying those answers with a drawing or drawings to illustrate their answers. These answers and drawings were coded by the researcher.

Themes one and two quickly emerged and were based on the previously established theory a priori codes. In addition to text searches, each interview was voice recorded and transcribed. Through this process, the researcher highlighted the transitions that occurred with the participants, particularly when topics surrounding themes three and four were discussed. A change in voice tone and multiple pauses were noted for 81% of low ability participants across all groups when explaining the concept of measurement. When Control Group participants of
varying ability levels were prompted to further explain their understanding of constant force, 72% of participants paused or had a voice change. These transitions assisted in the cutting and sorting technique used in order to solidify themes three and four for this research study. The expressions or answers to the questions that appeared most frequently manifested into the four main themes for this research study.

In Groups E1-E3, participants identified as having ability levels of high and medium produced three themes. The first theme identified from Groups E1-E3 and across all ability levels of participants was “using the robots along with the 5E activities was enjoyable and assisted learning”. Participants in Groups E1, E2 and E3 expressed their excitement and understanding of why they used the robots alongside the 5E Learning Cycle Model activities. This was chosen as the first theme because it was the most prevalently expressed during all three interviews among the participants not only in Groups E1, E2 and E3, but also in the Control Group. Control Group participants expressed a similar enjoyment of the 5E Learning Cycle Model activities. Draw and tell interviews conducted with these students during the activities indicated that many high or medium ability participants enjoyed the activity and demonstrated understanding of concepts discussed.

Draw and tell interviews conducted during and one week following the activity set showed that participants expressed enjoyment of as well as knowledge growth through both the 5E Learning Cycle Model activities and the robotics instruction. Kristen from Group E2 elaborated on the experience of the activities stating:

The whole time I was working with my partner and we were using the robots to learn about making the loader with different masses move far. Then we got to show everyone what we learned by making a poster, using the robot and the other materials. It was fun!
Jacob from Group E3 said the gallery walk was “Really fun and helpful because we got to see how everyone else’s groups did on their robot project” and “The robot helped me see that you have to keep the power and speed the same- so its fair- and then you can change the loader to have more or less mass to see how far it will go.” The experiment was “awesome! She [the teacher] tried to trick us by putting the more massed loader down but when we did the experiment we saw that the distance went less when the mass of the loader was more” was a comment from Jayden in Group E1. Julio in the Control Group commented, “My favorite part was when we got to show everyone what we learned from the straw and marble experiment. It was so much fun showing everyone we knew what to do!”

The participants from Groups E1, E2 and E3 identified as having low ability also responded positively to the use of robotics and the 5E Learning Cycle Model lessons. Many participants responded that the activities were fun and they learned more information about how changing the mass of an object can affect the distance it travels. For instance, McKenna explained, “The cotton ball and marble experiment was like the robot experiment because we saw that the less mass an object has inside it- it’s going to go farther when you keep the power [force] the same.” Madison, who had scored five out of 12 points on the pretest and answered ten out of 12 questions correctly on the posttest, elaborated:

I thought the experiments were cool and so much fun! Some of the stuff was like challenge work because we had to use our brains to really think about what was making the second loader move less far. Then we used the balance scales and saw that it was the mass stuff that makes it move less far- the more you have the less the robot can push you.

Among Groups E1, E2 and E3, one other theme emerged, which was “if force remains constant and the mass of the object increases, the distance the object travels will decrease”. This theme emerged as second due to its prevalence in draw and tell interviews two and three where
many participants correctly articulated an understanding of the force and motion concepts that were discussed throughout the lessons. The high ability group participants from Groups E1, E2 and E3, expressed these themes more frequently than the medium ability group participants. Some of the low ability students in Groups E1-E3 demonstrated little retention of content knowledge one week following the activities; while 75% of the low ability leveled students in the Control Group demonstrated little retention of content knowledge following one week of activities. Many of the low ability leveled participants from all four groups illustrated force arrow drawings demonstrating incorrect understanding of force and motion concepts discussed during and one week following the experiment.

The majority of the students in Groups E1, E2 and E3 identified as having high or medium ability levels (64%) expressed in the draw and tell interviews during and one week following the activity that using the robots along with the 5E Learning Cycle Model activities helped them learn more about pushes, pulls, moving objects with different masses and showed them that some of the beliefs they had displayed during our first draw and tell interview were incorrect. The majority high or medium ability leveled participants from the Control Group (64%) also expressed during and one week following the lessons their interest in continuing activities similar to the constructivist lessons.

Almost all of the participants from Groups E1, E2 and E3 (91%) commented they enjoyed using the robots and the 5E Learning Cycle Model lessons in order to learn more about topics related to force and motion. The low ability students’ from all four groups responses indicated that although they enjoyed the activities, their inability to apply basic measurement principles prohibited them from grasping the concepts presented fully. Some of these students
expressed agitation and annoyance when elaborating on their experience during and following
the activity.

An examination of the draw and tell interviews and drawings one week following the
activities revealed that 70% of the interviewed participants from Groups E1, E2 and E3 that had
medium or high ability levels had good retention of the concepts surrounding force and motion.
These students’ force arrow drawings also supported their explanations of the concepts
discussed. Control Group students identified as having high or medium ability levels displayed
inconsistencies in accurate retention of knowledge. Some of these students expressed
inconsistent explanations of constant applied force; this specific issue was not seen as much with
any of the participants in experimental groups. The force arrow drawings from these students
also mirrored their inconsistent explanations. Some students did show improvement in
understanding the concepts; however it was not as many as the students in the experimental
groups.

Some of the Groups E1, E2 and E3 low ability students draw and tell interviews and
drawings conducted one week following the activity indicated the lack of deep conceptual
understanding pertaining to the concepts discussed. Keandra, a low ability student in Group E1,
responded that the experiment was “too hard sometimes because I couldn’t figure out how to
read the tape measurer in centimeters.” Julia from Group E3 responded that the experiment
irritated her and when the researcher asked her to elaborate she said, “I didn’t know how to find
the mass of the loaders and my partner wasn’t helping me so I didn’t learn how to do it and I still
don’t know how to do it.”
The third theme emerged from the low ability students in Groups E1, E2 and E3, that of a confusion in how they should collect measurement data, particularly surrounding the understanding of mass and the application of using metric or standard units of measurement to find the distance an object traveled. This third theme, was also expressed from the Control Group low ability students. Groups E1, E2 and E3’s low ability participants had fewer students express themes one and two; however, theme three’s responses were very similar across seventy percent of the control and experimental groups low ability leveled students.

An examination of the field notes recorded during the constructivist activities indicated that many of the students in Groups E1, E2 and E3 who were identified as having low ability levels expressed frustration and confusion with the portion of the activities pertaining to measurement. This was also seen in four of the low ability students in the Control Group. Researcher notes highlighted many low ability students in Groups E1, E2, and E3 also experienced agitation when asked to measure the distance the loader traveled in each trial run. Six students in Groups E1, E2 and E3 having medium ability levels displayed the same measurement issues and no students having high ability levels indicated any measurement issues. Seven participants from the Control Group and Groups E1, E2 and E3 across all ability levels questioned the reasoning behind the use of the metric form throughout the experiment. Five of these participants also experienced conflict with their partner over measurement confusion and were of a low ability level.

Disagreements over measurement units were also noted during the Control Group activities, particularly from students identified as having low ability levels. These students also displayed similar frustration when asked to measure the distance their object traveled in metric as
well as standard units of measurement. Researcher notes indicated that when students were asked if they had been exposed to measurement activities such as these the student responses varied. Five participants from the Control Group and Groups E1, E2 and E3 across ability levels expressed they had not interacted with any measurement type activities involving varying unit forms.

Interview notes showed that four participants from Groups E1, E2 and E3 having medium and high ability levels expressed they had participated in measurement activities with varying units; however, it was not in depth and was taught in passing through dailies. Researcher notes indicate this data could contribute to why so many participants struggled with this concept and this theme became prevalent in students of varying ability levels. Observation notes indicated a handful of participants in the study who were identified as having medium or high ability levels expressed issues with their partners during the experiments, but none of the abovementioned conflicts were due to measurement confusion.

The fourth and final theme emerged from the Control Group and was revealed in the draw and tell interviews conducted one week after the 5E Learning Cycle Model activities. Students across all ability levels in the Control Group only, began to vary on retention of knowledge and many expressed confusion surrounding constant force applied during the experiments conducted; therefore the fourth and final theme of constant force confusion materialized.

Seventy percent of the Control Group’s low ability students also expressed lack of deep conceptual understanding one week following the 5E Learning Cycle Model activities. As previously mentioned, many of the participants across all ability levels in the Control Group
expressed difficulties in understanding the concept of constant force. This affected their explanations of their force arrows as well as their authentic understanding of the 5E Learning Cycle Model experiments they participated in. Connor explained, “I guess we pushed the same amount each time on the truck… maybe we did… I can’t remember if that made the object with less mass go far or not because I don’t think we pushed the same amount each time.” Trinity, who was also in the Control Group and was identified as having medium ability level, elaborated, “When I blew into the straw I didn’t blow hard, but my partner did so our numbers were different in how far the marble went.”

**Full Research Study**

In the full research study, the majority of the participants were males (53%), African American ethnicity (48%) and at a medium ability level (41%). The Kruskal-Wallis test was conducted to determine if there were statistically significant differences in change scores between each of the four groups within the Full Study. The researcher found that the distribution of question set scores were similar among groups; however, the median question set scores were significantly different between groups. A post hoc analysis revealed statistically significant differences in median question set scores between all groups with regard to Question Set A ($\chi^2(3) = 13.134, df=3, p=0.003$), Question Set B($\chi^2(3) = 15.463, df=3, p=0.001$) and Question Set C($\chi^2(3) = 14.468, df=3, p=0.002$). Statistical significance between all four groups was determined through the use of an ANCOVA test. First grade ITBS scores were used as the covariate and $p$-values were examined from a pairwise comparison using the post hoc Bonferroni adjustment. All statistical tests had an alpha level set at .05, with the Bonferroni correction accounting for alpha inflation.
An examination of Posttest 1 data indicates that the Control Group is significantly different from Groups E1 and E3. Posttest 1 data also indicated no significant difference between experimental Groups E1 and E3 and a significant difference between Group E2 and Groups E1 and E3. Posttest 2 showed significant differences between the Control Group and all treatment Groups E1, E2 and E3 as seen in Table 4.7. Improvement was shown in all treatment groups from the Pretest to Posttest 1. As discussed in Chapter 4, Group E3 had the highest average Pretest score and the Control Group had the lowest average Pretest score. Based on the quantitative data, incorporation of robotics instruction immersed within 5E Learning Cycle Model lessons appears to be valuable in assisting students in understanding and retaining topics related to force and motion.

The qualitative data produced four main themes:

- **Theme 1**- using the robots along with the 5E activities was enjoyable and assisted learning.
- **Theme 2**- constant force applied to an object with increased mass decreases the distance traveled
- **Theme 3**- measurement confusion (which includes mass and distance traveled)
- **Theme 4**- constant force confusion

Themes 1-3 were reported by all treatment groups and theme four surfaced mainly in the Control Group. These themes are discussed in depth later in this chapter. Draw and Tell interviews conducted prior to the treatment identified each participant’s understanding of force and motion and/or impetus. High scorers from this first set of interview questions did not demonstrate multiple misunderstandings or no misunderstandings pertaining to concepts of force
and motion. Low scorers from Question Set A (Appendix F) demonstrated some or multiple misunderstandings of concepts of force and motion. These participants had the majority of force arrows incorrect and/or gave inconsistent explanations.

The Likert-scale results from the draw and tell interviews during and after the treatment indicated high scorers had proper use of force arrows and provided the correct scientific explanation. High scorers were also able to elaborate further on how the experiment assisted them in understanding topics related to force and motion. Low scorers interviews during and after the experiment showed improper use of force arrows and inconsistent scientific explanations. These participants were more likely to express measurement confusion (Theme 3) and constant force confusion. In addition to this, these participants were also less likely to make connections where the experiment was enjoyable and assisted them in understanding the topics of force and motion further (Theme 1).

Each participant across the treatment and control groups expressed enjoyment of the activity; however, some (4%) low ability leveled participants could not express enjoyment in addition to mastery of the concept discussed. High scores from the medium and high ability participants across the experimental and control groups were expected; interestingly three of the low ability students from Groups E1, E2 and E3 were also able to correctly illustrate force arrows and clearly explain topics pertaining to force and motion. The Control Group did not have as many low ability participants correctly indicate force arrows or clearly explain topics pertaining to force and motion (Theme 2).

**Control Group (Only 5E Learning Cycle Model).** Students in the Control Group were provided only 5E Learning Cycle Model lessons. Administered by the researcher, these lessons
contained five stages: engage, explore, explain, elaborate and evaluate. Within each stage of the lesson participants interacted with literature, conducted experiments without the robotics component to showcase their understanding of force and motion, and created a display with which they presented their understandings of the concepts discussed. In the lessons the students were asked to provide constant force to an object of varying masses and then measure the distance it traveled.

Many students (70%) voiced frustration when attempting to apply constant force to move an object (Theme 4), this percentage was the highest out of all groups across the study. DiMajay said, “I am not sure if our answers are right because she was pushing it way too fast one time and then the next time she pushed it slow.” Javier expressed moderate excitement about the lessons but says, “I learned that when you do an experiment with partners you can talk in front of people, and when you push something with a lot of mass at the same speed it won’t go as far.” Many of this group’s draw and tell high scorers expressed moderate (~score of 2.5 on Table 4.2) understanding of the concepts during and after the 5E Learning Cycle Model Lessons. In addition to this, 90% of Control Group participants expressed enjoyment from participating in the 5E Learning Cycle Model activities (Theme 1).

Based on their scores from Posttest 1, the use of the 5E Learning Cycle Model activities did assist them in gaining knowledge on concepts surrounding force and motion (Theme 2). A statistically significant difference was noted between this group and Groups E1, E2 and E3 (see Table 4.7). Posttest 2 scores showed the highest mean decrease from all four groups and indicated the Control Group did not retain a complete understanding of the concepts presented. Out of the nine participants interviewed, eight ended with a variation of a misunderstanding of
concepts related to force and motion. Six students identified as low or high ability ended with a misunderstanding and two of the three medium ability students also had misunderstandings.

Two of the nine Control Group students who participated in the draw and tell interview were identified from the first interview as having an alternative conception. These two students retained their alternative conceptions throughout the study. After the first interview, six of the nine Control students were identified as having naïve beliefs, preconceptions or prescientific conceptions. An analysis of the transcribed interviews during the study indicated that only two of the nine Control Group students showed misunderstandings surrounding force and motion concepts. The final draw and tell interviews indicated eight of the nine students from this group continued to display a variation of misunderstanding pertaining to concepts of force and motion.

Throughout all three interviews, Control Group participants frequently expressed measurement confusion (Theme 3). This theme was more prevalent among low ability participants in this group (62%). An examination of the data would suggest the 5E Learning Cycle Model lessons may increase short term retention of force and motion concepts; however, it appears that participants may need additional reinforcement activities to retain concepts of force and motion for a long period of time. The data would also suggest that while the 5E Learning Cycle Model lessons did have a short term effect on those students whose misunderstandings were less severe; the long term positive effects were lacking.

**Experimental Group 1 (Group E1: Robotics + 5E).** The ANCOVA pretest results (Table 4.7) showed no significant difference between experimental Groups E1 and E3. A significant difference was found between Group E1 and E2 and Group E1 and the Control Group with respect to knowledge retention as determined from the gain scores the day of the activity. Group
E1 did show significant difference from the Control Group with respect to long term retention; however it did not show a significant difference than any of the other treatment groups (Table 4.7).

Utilizing the robots alongside 5E Learning Cycle Model activities proved to be enjoyable for Group E1 students (Theme 1). This group had 100% of participants labeled as having a variation of misunderstanding pertaining to force and motion during the first draw and tell interview. The second and third draw and tell interview showed that only 33% of participants continued to retain a misunderstanding and one student labeled as having an alternative conception. Group E1’s students only had three of nine students remaining with confusion pertaining to concepts of force and motion one week following the lessons. Six of nine students in Group E1 were able to clearly articulate understandings of force and motion concepts as well as correctly illustrate force arrows to do so. An examination of this group’s draw and tell statements indicates that few of the students in this group had measurement confusion (Theme 3) and ninety percent of the students enjoyed the activity as well as retained the concepts discussed (Themes 1 and 2).

Jordan commented, “This was so much fun! Using the robots helped us learn too! We got to show everyone that we could use the robot to push the same push and move stuff with less mass far far.” Keandra identified as having low ability explained what she learned from the activities:

The best part was using the robot because we could show how powerful it was to push the loaders with more mass- it didn’t push them far though- it was still fun to use the robots. I can’t wait to use them again.
It appears that the majority of the students in this group enjoyed the activity and retained long term knowledge (85%). Results for Group E1 suggests that through the use of the robot, these students were able to see how constant force can be applied to effect the movement of objects with varying masses. In addition to this, the data would also support that using robotics does have a positive effect on correcting misunderstandings pertaining to force and motion, particularly with students of high and medium ability levels.

**Experimental Group 2 (Group E2: Robotics + 5E).** This group received the same robotic instruction alongside 5E Learning Cycle Model activities as the other two treatment groups (Groups E1 and E3). Students were instructed to program the robot through procedures in order to showcase how applying constant force can affect the distance an object of varying masses travels in addition to participating in the 5E Learning Cycle Model activities.

As with Groups E1 and E3, this group of students also expressed enjoyment of the activities (91%); however Group E2 had the largest decrease in long term knowledge out of all of the experimental groups as well as had the highest percentage of students that were identified as having low ability. Prior to the treatment, 7 of the 9 (77%) students were identified as having a misunderstanding related to concepts of force and motion, two of these possessed alternative conceptions. During the treatment, this percentage dropped to 44%; however in the final interview it rose to 56%. Out of the nine students who participated in the draw and tell interview five students retained a variation of a misunderstanding of concepts related to force and motion and one of these students possessed an alternative conception throughout the treatment.

The medium and low ability participants from Group E2 performed the most poorly compared to Groups E1 and E3 on both the posttests as well as on all three draw and tell
interviews. Many students from these two ability levels expressed measurement confusion (6= number of students) as well as incorrectly illustrated force arrows and concepts during the draw and tell interviews (Theme 3).

Zoa commented:

The robots were fun to use and I worked good with my partner to do our stuff. We did our robot with the right power and saw that it pushed the less massed loader far. Some people didn’t understand though and were fighting with their partners and they didn’t use the tape measurer right.

Kristen elaborated:

The robots were fun but what we had to do was hard. I didn’t know what the mass was for the loaders because my teacher didn’t teach us about mass yet- or using the centimeters so our whole gallery walk was wrong and it was bad.

As previously discussed in Chapter 4, Group E2 had the largest decrease in long term knowledge retention of all of the treatment groups. In comparison to Groups E1 and E3, this group (E2) had the largest percentage of low ability students; therefore, with respect to long term retention of knowledge for low ability leveled students this method appears to not be as effective.

**Experimental Group 3 (Group E3: Robotics + 5E).** Students in this group participated in 5E Learning Cycle Model lessons alongside the robotics component. Like students in the other treatment groups, this group also expressed enjoyment of the activities. This group had the highest percentage of students classified as having a high ability level and the lowest percentage of students classified as having a low ability level. Similar to Group E1, this group of students had the smallest decrease in long term retention of knowledge as shown on Posttest 2 (Table 4.7). Group E3 had statistically significant difference in long term retention of concepts compared to the Control Group.
The majority of students in Group E3 also expressed an enjoyment of the activities (Theme 1). Participant responses pertaining to concept retention were similar to responses from Group E1. Prior to the treatment 100% (9 out of 9) of students in Group E3 were labeled as having a variation of misunderstanding pertaining to concepts of force and motion. Out of the nine students in the draw and tell interviews, only three students retained their misunderstanding of concepts related to force and motion one week following the activities and only one student retained their alternative conception for the duration of the treatment. Jenna commented, “Using the robots was so cool! We learned that when you make the robot go forward for a certain amount of time with the same power how far something goes can change. Me and my partner showed everyone we understood that.” Few students reported measurement confusion in this group and overall the partner communication was very positive among students in Group E3.

Madison elaborated:

Sometimes it was hard because I couldn’t figure out how to make the robot go for the same amount of time and then I couldn’t remember how to use my tape measurer right. But my partner helped me and we sort of figured it out- well he figured it out for me and then told me so we could do the experiment right.

An analysis of the data from this group indicates that as with Group E1, high and medium ability student’s benefit from using robotics immersed within the 5E Learning Cycle Model lessons and show improved short and long term retention of knowledge pertaining to concepts of force and motion.

**Compilation of Interview Themes.** Ninety-five percent of participants across treatment groups often expressed their enjoyment of using the robots while participating in the 5E Learning Cycle Model lessons to better understand concepts of force and motion. Four themes emerged from interview transcriptions, which included all groups elaborating on the enjoyment of the activities,
high scorers from the experimental groups expressing a correct understanding of the force and motion concepts being examined, low scorers from the experimental and control groups believing their confusion of measurement units prevented them from fully understanding the concepts, and Control Group participants expressing difficulty in understanding the application of constant force.

Using the Robots Along with the 5E Activities was Enjoyable and Assisted Learning.

Examination of the qualitative codes from all groups during and after the treatment occurred indicated 93% of all participants enjoyed the activities. The students from the Control Group expressed the same amount of excitement as had the students from the Groups E1-E3 based on the transcribed interviews. The students who were classified as having low ability expressed enjoyment; however, there was also more frustration expressed from this group of students as well, particularly dealing with the measurement portion of the activities in both the control and experimental groups.

The Control Group’s draw and tell transcripts indicated that more students expressed enjoyment from the gallery walks, rather than the actual act of conducting the experiment. Seven out of nine participants articulated their excitement about engaging with their peers in order to explain their learning from the activity. Ninety-five percent of the draw and tell participants from Groups E1, E2 and E3 expressed their enjoyment and engagement during the use of the robots. With these three groups, the highest rating of enjoyment was recorded during the second draw and tell interview, which was conducted during the treatment. The level of articulation and illustration of the concepts was also heightened during the second draw and tell interview from
ninety-two percent of participants across Groups E1-E3 and within the Control Group. This was particularly seen in the high and medium ability students.

Similar to Groups E1-E3, the Control Group participants had the most correct responses during the second set of interviews; their level of enjoyment was highest during the 5E Learning Cycle Model activities. Not surprisingly, the third draw and tell interview (conducted one week following the activities) had fewer students express as high a level of enjoyment as they had during their second interview; however, 93% of the participants, across the Control Group and Groups E1-E3, expressed their interest in doing the activities again. The level of understanding had also decreased across all groups (Control and E1-E3) as well with the final interview. This was particularly seen in Julio, a low ability student from the Control Group. Julio’s first interview revealed he had some naïve beliefs concerning force and motion; however, in his second interview he could articulate the correct concepts more clearly. In this second interview, Julio elaborated on his experiences from the activities:

Doing the gallery walk to show what we know is good! I liked reading the books too—everything was fun. I learned a lot from the straw experiment too, that when you apply the same push to the object that has less mass it goes far!

In the final interview, Julio lacked a concrete understanding of the concepts; however, he still expressed enjoyment from the activities overall. “I can’t remember what we did with the marble- if it went far or not- but I could try to do it again and get the answer. It was fun- so let me do it with my partner again.” Julio was not the only student who expressed difficulty retaining information learned from a week prior and he was not the only student who in spite of being unsure of his answers was willing to redo the experiment again.
Constant Force Applied to an Object with Increased Mass Decreases the Distance Traveled.

An analysis of the draw and tell interview data from all four groups indicated that eighty-five percent of the participants in the treatment groups who were identified as having a medium or high ability level expressed understanding of this concept related to force and motion. This theme appeared in interviews conducted primarily during and following the robotics instruction and 5E Learning Cycle Model activities.

Few students expressed this theme prior to the treatments in both the Control Group and treatment groups (E1-E3). Three of the students classified as having high ability, two students identified as medium ability and only one identified as having a low ability level articulated this theme prior to the activities (Table 4.17). Only three students from the entire group of draw and tell participants (n=36) expressed this theme in all three interviews throughout the study. These students were from each of the ability levels and represent Groups E1, E2 and the Control Group.

As previously stated, this theme was found more often in the interviews conducted during and following the activities. For example, Yahti, a high ability student from experimental Group E1, did not express understanding of this concept prior to the activities; however during and following the activities Yahti scored very high on the Likert scale from the draw and tell interviews and was one of the students who could correctly articulate the concept in his group overall. Another student, Chad from Group E3, scored poorly on the draw and tell interview before the treatment; however, during and following the treatment he was able to express the concepts of force and motion. Daniel and Axavier, medium ability students from Groups E2 and E3 respectively, expressed understanding during and after the treatment as well.
This theme was not as prevalent with students who were labeled as having a low ability level. During the treatment only one low ability student, Tanner, from Group E2 expressed a correct understanding of this concept. There were two low ability students from the Control Group, Julio and Trinity, who were also able to correctly articulate this concept. The draw and tell interview conducted one week following the activities only identified four low ability students, Keandra, Emily, Tanner and Madison who could correctly articulate the concepts. These four students were in Groups E1-E3. There were no low ability Control Group students who were able to correctly express this concept during their final draw and tell interview.

**Measurement Confusion.** This theme was expressed across all groups, particularly from students identified as having low ability levels and it was expressed mainly in the second interview which occurred during the 5E Learning Cycle Model activities. Some participants who expressed measurement confusion also expressed difficulty interacting with their partners. An analysis of transcribed interviews revealed that seventy percent of students who had difficulty understanding how to correctly use metric and standard units of measurement to determine the distance traveled also had some negative interaction with their partners. It was noted that most partners tried to assist the struggling partner, but some students did not receive the feedback positively. There was also an issue with recording the mass of the objects.

Eighty percent of low ability students had difficulty identifying what the mass of the objects was; therefore, an understanding the basic concept being examined was extremely difficult for them. For example, Murry, Matt and Julia (all identified as low ability students from Groups E1, E2 and E3), expressed measurement confusion as well as had negative partner interactions. These three students also possessed a variation of misunderstanding of the concept
before, during, and after the treatments had occurred. Murry’s draw and tell interview revealed a strong alternative conception that was present throughout all of the interviews. His inability to transform his beliefs surrounding the force and motion concept hindered him in accepting the correct concept, in addition to the alternative conception he also had problems understanding how to take the proper measurements. He explained, “I couldn’t figure out when to use metric or how to read the tape measurer so I just quit because I knew my answer wasn’t going to be right anyway and my partner was going to be mad.”

This experience was similar to Matt’s, whereas he also gave less effort during the experiment because he was frustrated in understanding how to use the tape measurer. Matt elaborates:

I was going to use the inches but my partner told me not to because it was wrong- we were using the centimeters this time. I still couldn’t figure out the mass part either- how am I going to know if the mass is different? What’s the mass anyways? I got annoyed because no one could help me.

This same confusion was also expressed by three low ability students from the Control Group, Connor, Julio and Trinity. All three students expressed measurement confusion and two of the three expressed negative partner interaction. Similar to Murry, Connor also had an alternative conception that stayed with him throughout all of the interviews. He also struggled with the measurement portion of the activity and had very negative interactions with his partner. All of the students who expressed measurement confusion during the second interview expressed the same confusion during the final interview. Many of these same students did not correctly articulate the concepts of force and motion being examined either.

**Constant Force Confusion.** This theme was found only within the Control Group and not in any of the other groups. This theme was prevalent mainly in the third and final draw and tell
interview; however, it also appeared in the second interview as well. It was also seen across ability levels in the Control Group and appeared to be an underlying issue for the students in understanding the concepts being examined throughout the 5E Learning Cycle Model activities. A closer examination of the transcripts revealed many students who felt as though they had applied constant force called their experiments “fair.” This translated into each student performing the same actions for each time the trial of the experiment occurred. Many of the participants in the Control Group appeared to have an issue understanding what it means to apply constant force to an object in order to conduct a “fair” experiment.

For example, Nicholas and Dimajay, both were classified as high ability students through the student placement protocol procedure; however, during their final interview their explanations of why they understood the concepts being examined contained inconsistencies. Both had trouble remembering if they had applied constant force when blowing the air into the straw (5E Learning Cycle Model experiment 1) and when pushing the truck (5E Learning Cycle Model experiment 2). Neither boy could draw accurate force arrows during the third draw and tell interview, whereas a week earlier their force arrows were more consistent and correct. Jahmaree and Chloe, both medium ability students also expressed frustration in the application of constant force during the experiments. Jahmaree revealed an alternative conception during our first interview and used this same alternative conception throughout all of our interviews in order to explain why he didn’t need to use constant force to complete the experiment. He explained, “I didn’t need to push it the same amount each time because I ran three steps and pushed hard so it went far no matter how much mass the loader had.”
Connor, Julio and Trinity, all low ability students, exhibited a lack of understanding of constant force that prevented them from expressing an accurate understanding of the concept. During our second draw and tell interview, Trinity expressed confusion as to whether or not she applied constant force to the object used for the experiment. She said:

I can’t remember how far the cotton ball went because we didn’t blow the same each time and I know it’s supposed to go far, but I don’t think my answers showed that because I copied off my partner because I didn’t know if she blew really hard each time or not.

**Gains in Knowledge Overall.** This study examined which teaching method, 5E Learning Cycle Model Lessons or 5E Learning Cycle Model Lessons with Robotics, produced the greatest amount of knowledge retention at varying time intervals, as well as examined students’ perception of the activity they participated in before, during and after the activities were conducted. An examination of the draw and tell interview Likert-type scale results indicate that the participants from the Control Group gained short term understanding of the concepts discussed, while Groups E1, E2 and E3 had more of a long term gain of knowledge across ability levels. The difference appears to be correlated with their identified ability group and their classified variation of misunderstanding of the concept of force and motion and/ or impetus.

**Conclusions, Discussion and Recommendations**

The students who successfully displayed long term retention of accurate force and motion concepts support the hypothesis that the utilization of robotics instruction embedded within 5E Learning Cycle Model lessons can have a beneficial impact on student understanding. An examination of the pilot data as well as the full research data suggests that robotics instruction immersed within 5E Learning Cycle Model lessons does assist students of all ability levels with less severe misunderstandings in better understanding concepts of force and motion; however
particularly with respect to long term retention of knowledge, this study also indicates that students identified as having a low ability level would greatly benefit from the use of robotics to assist them in better understanding concepts of force and motion as well.

**Conclusions**

The success of students who utilize robotics instruction immersed within 5E Learning Cycle Model lessons supports the initial hypothesis of the positive effect robotics instruction embedded within 5E Learning Cycle Model lessons having a beneficial impact on students effectively retaining correct concepts of force and motion. Accomplishments of students of different ability levels who utilize embedded robotics instruction within 5E Learning Cycle Model lessons also aligns with the initial hypothesis of robotics instruction alongside 5E Learning Cycle Model lessons empowers students to retain force and motion concepts over time. A significantly higher percentage (85%) from medium or high ability students who participated in 5E Learning Cycle Model lessons with the robotics component consistently showcased long term understanding of concepts related to force and motion than those in the Control Group (85% versus 13%).

Based on the findings from this study, it appears that medium or high ability leveled students who did not utilize robotics instruction were less likely to have accurate long term retention of concepts related to force and motion (13%) and were more likely to return to their original misunderstandings of said topic (25%). More of the low ability participants who utilized the robotic component were able to retain knowledge pertaining to force and motion (7%) compared to the low ability participants who did not use the robotics component (0%) suggesting
that a combination of these two methods is beneficial in assisting students understanding of force and motion concepts.

Results showed that allowing students to program the robot to produce constant force which is then applied to objects of varying masses has more beneficial effects on the long term understanding of concepts of force and motion for students of all ability levels (85%). Additionally, students who possessed less severe variations of misunderstandings prior to using the robotics component alongside the 5E Learning Cycle Model lessons (87%), showed vast improvements over the course of the study. Participants who were identified as having high or medium ability levels with less severe misunderstandings of physics concepts were more accurate in their verbal explanations as well as their illustrations of the experiments that were conducted with the robot.

The qualitative data assisted the researcher in better understanding the importance of the added robotics component. Students who were identified as having a low ability who used the robotics component alongside the 5E Learning Cycle Model lessons, verbally expressed more understanding of the concepts, than what was indicated on their pretest and posttests. Although these students frequently demonstrated measurement confusion, the majority of the students (90%) did not display constant force confusion. The interviews and drawings provided profound insight as to what factors assisted in helping or hindering students of varying ability levels understand the topics of force and motion. The drawing component of this study proved to be a key aspect to each participant demonstrating their understanding of the concepts at different points throughout the study. The progression of how each drawing changed after each interview was critical in assisting the researcher in determining how the participants’ understanding of the
concepts changed or remained the same over time, providing the researcher with a different perspective of the participants in the study.

A mixed methods approach for this study was necessary in order to better understand how robotics coupled with 5E Learning Cycle Model lessons can affect students of varying ability levels understanding of force and motion concepts over time. Collection and analysis of quantitative data gave insight to the retention and amount of knowledge gained; while the qualitative data gave insight as to how students of varying ability level comprehend and process the activities conducted. The combination of qualitative data gathered from draw and tell interviews, field notes, observations and quantitative data from pretest and posttest assessments indicates that it appears as though students with varying ability levels who utilize a robotics component immersed within 5E Learning Cycle Model lessons will retain knowledge of physics concepts over time.

Their previous understandings of concepts of force and motion or measurement units may affect how they understand experiments or activities during class. Their pre-determined ability level grouping can also affect how they comprehend the abovementioned concepts. The use of technological tools to demonstrate consistent examples of concepts related to force and motion also affects their understanding of the topic as a whole. The depth of their misunderstanding is also a factor pertaining to their ability to fully understand a concept. An examination of both the qualitative and quantitative data indicates that measurement confusion was correlated with having low ability levels and a consistent severe misunderstanding of the concept. The data also suggests that interaction with a technological tool which demonstrates constant force to move
objects with varying masses was correlated with more consistent understanding of concepts pertaining to force and motion across ability levels.

**Discussion and Future Research**

Based on the literature review regarding science misunderstandings, the 5E Learning Cycle Model, constructivism, constructionism and robotics instruction in the classroom this study addresses a gap in the literature by providing the quantitative and qualitative data that shows the importance of immersing robotics into 5E Learning Cycle Model lessons as a means to assist students of various ability levels in addressing their understandings of physics concepts. This research supports the results of Wandersee, Mintzes and Novak’s (1994) study that highlighted the importance and support of students utilizing metacognitive strategies as a means to tackle their own scientific misunderstandings. All participants in this study utilized metacognitive strategies such as self-analysis and self-regulation during the 5E Learning Cycle Model lessons in order to better understand physics concepts being presented. Evidence of this was particularly noted in the second set of draw and tell interviews among participants in the Control Group as well as Groups E1-E3.

This research also supported Posner, Strike, Hewson and Gertzog’s (1982) research regarding the application of disequilibrium to approach students’ misunderstandings in order to identified flawed understandings. Throughout the study, participants across the Control and Groups E1-E3 were asked to challenge their previous and current thinking through conducting experiments. Many students across all groups, were faced with the realization that their previous understandings of certain physics concepts were flawed; thus having to examine an alternative explanation to the topic being examined.
This study is also aligned with Mauch’s (2001) study and Archambault, Tsai and Crippen’s (2011) study, both of which supports the utilization of LEGO Mindstorms Robots in a constructivist format as a means to further support students understanding of STEM concepts; however, this study not only provided evidence that motivation and enjoyment were present, it also showed that utilizing the robotic component within the 5E Learning Cycle Model would assist students in retaining knowledge of certain scientific topics. While technology continues to be a growing presence in the classroom, the researcher is aware that there are multiple ways to approach teaching the concepts of force and motion. Most often these approaches involve a real life context setting where students can apply concepts discussed to authentic life situations. While these approaches have proven to be beneficial, educators who have access to robotics use would be providing their students with a different lens to examine concepts with which for some students can make a marked impact on their long term knowledge retention of a topic.

Only utilizing the 5E Learning Cycle Model lessons (Control Group) were beneficial with respect to short term knowledge and this could have been due to the approach with which this model employs. This model highlights a structured way to conduct inquiry-based experiments, which supports Bybee’s (1997) research on the success of the 5E Learning Cycle Model. The reason only utilizing the 5E Learning Cycle Model lessons (Control Group) produced less long term knowledge retention when compared to the groups which utilized the robotics component (Groups E1-E3) may be due to the technological component (providing measurable constant force and motion) robotics has to offer. As stated in Chapter 2, utilizing robots with age-appropriate materials yields positive results, particularly when involving inquiry-based thinking concepts applied to science situations (Liao & Bright, 1991; Clements & Battista,
1990; Resnick, 2003); hence, the robotic component immersed within the 5E Learning Cycle Model lesson provides students with an outlet to accurately demonstrate scientific concepts in order to address their understandings of concepts.

Although this study had limitations, the results indicate that there is a need to further investigate the effect of the use of robotics immersed within a 5E Learning Cycle Model format on students of various ability levels to address their understandings of science topics. Combining quantitative test scores with qualitative draw and tell interviews provides a more complete picture as to how the utilization of robotics within a 5E Learning Cycle Model format can better assist students in further understanding topics of force and motion. Employing a mixed methods design provided deeper insight to each student who participated in this study. The isolation of quantitative or qualitative data would not have provided as much information to the study as a whole.

As mentioned in Chapter 2, as technology becomes more prevalent in elementary classrooms it would be advantageous for educators to conduct more research in order to further investigate how the combination of robotics instruction and the 5E Learning Cycle Model can benefit students’ understandings in the science classroom. Areas of future research might include:

- Applying this study’s model (5E Learning Cycle Model +Robotics) to address another area of elementary student science confusion pertaining to physics concepts. Does using a robotics component immersed within the 5E Learning Cycle Model assist students in better understanding friction, lift, weight, thrust and other topics related to mechanics and physics?
• Adding a measurement component which utilizes robotics to this study’s model (5E Learning Cycle Model +Robotics). Would a precursor activity focusing only on utilizing the robot to make measurements increase the effectiveness of using this study’s model?

While retention of force and motion concepts is difficult for elementary students of varying ability levels to achieve, the incorporation of a robotics component into a 5E Learning Cycle Model format can be practical and provide assistance to students in order to better explain and understand the world around them.
REFERENCES


of heat and temperature concepts. *Journal of Maltese Education Research, 4*(1), 64-79.


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Appendix A

Next Generation Science Standards: Core Idea PS2: Motion and Stability Kindergarten

K-PS2 Motion and Stability: Forces and Interactions

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Students who demonstrate understanding can:

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. [Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.] [Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.]

K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.* [Clarification Statement: Examples of problems requiring a solution could include having a marble or other object move a certain distance, follow a particular path, and knock down other objects. Examples of solutions could include tools such as a ramp to increase the speed of the object and a structure that would cause an object such as a marble or ball to turn.] [Assessment Boundary: Assessment does not include friction as a mechanism for change in speed.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices
Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1)

Analyzing and Interpreting Data
Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2)

Connections to the Nature of Science
Scientific Investigations Use a Variety of Methods
- Scientists use different ways to study the world. (K-PS2-1)

Disciplinary Core Ideas
PS2.A: Forces and Motion
- Pushes and pulls can have different strengths and directions. (K-PS2-1, K-PS2-2)
- Pushing or pulling on an object can change the speed or direction of the motion and can start or stop it. (K-PS2-1, K-PS2-2)

PS2.B: Types of Interactions
- When objects touch or collide, they push on one another and can change motion. (K-PS2-1)

PS2.C: Relationship Between Energy and Force
- A bigger push or pull makes things speed up or slow down more quickly. (secondary to K-PS2-1)

ETS1.A: Defining Engineering Problems
- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. (secondary to K-PS2-2)

Crosscutting Concepts
Cause and Effect
- Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS2-1, K-PS2-2)

Connections to other DCIs in kindergarten:

Articulation of DCIs across grade levels:

Common Core State Standards Connections:
ELA/Literacy -
W.K.1 Write prompts and support, ask and answer questions about key details in a text. (K-PS2-2)
W.K.2 Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-PS2-2)
SL.K.3 Ask and answer questions in order to seek help, get information, or clarify something that is not understood. (K-PS2-2)
Mathematics -
NP.2 Reason abstractly and quantitatively. (K-PS2-1)
K.MD.A.1 Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-PS2-2)
K.MD.A.2 Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. (K-PS2-1)

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APPENDIX A
NEXT GENERATION SCIENCE STANDARDS: CORE IDEA PS2: MOTION AND STABILITY GRADE 3

3-P52 Motion and Stability: Forces and Interactions

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Students who demonstrate understanding can:

3-P52-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. [Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to the motion of objects as a force that pulls objects down.]

3-P52-2. Make observations and measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. [Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such as period and frequency.]

3-P52-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. [Clarification Statement: Examples of electric force could include the force on hair from an electrically charged balloon and the electrical forces between a charged rod and pieces of paper; examples of a magnetic force could include the force between two permanent magnets, the force between an electromagnet and steel paperclips, and the force on a compass needle by a magnet.] [Assessment Boundary: Assessment is limited to forces produced by objects that can be manipulated by students, and electrical interactions are limited to static electricity.]

3-P52-4. Define a simple design problem that can be solved by applying scientific ideas about magnetism. [Clarification Statement: Examples of problems could include constructing a latch to keep a door shut and creating a device to keep two moving objects from touching each other.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices

- Asking Questions and Defining Problems
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Developing and Using Models
- Planning and Carrying Out Investigations
- Eliciting/Collaborating
- Refining/Improving
- Communicating
- Evaluating/Revising

Disciplinary Core Ideas

P.S2.A: Forces and Motion
- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it. If they add to give zero net force on the object, forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, not quantitative application of forces is used at this level.)

P.S2.B: Types of Interactions
- Objects in contact exert forces on each other.
- Electric and magnetic forces between a pair of objects do not require that the objects be in contact.

Crosscutting Concepts

Patterns
- Patterns of change can be used to make predictions. (P.S2-3)
- Cause and effect relationships are routinely identified. (P.S2-1)

Connections to Engineering, Technology, and Applications of Science

Intergenerational of Science, Engineering, and Technology
- Scientific discoveries about the natural world often lead to new and improved technologies, which are developed through the engineering design process. (P.S2-4)
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APPENDIX C
LOUISIANA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD APPROVAL

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

Applicant, please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please send the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://sites01.lsu.edu/wp/urod/human-subjects-screening-committee-members/.

A Complete Application Includes All of the Following:
(A) A copy of this completed form and a copy of parts B thru F.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
(C) Copies of all instruments to be used.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://php.niobrination.com/users/login.php)
(F) IRB Security of Data Agreement (https://sites01.lsu.edu/wp/urod/files/2013/07/Security-of-Data-Agreement.pdf)

1) Principal Investigator: Blanca Delliberto
   Dept: Education
   Ph: 225-636-2156
   E-mail: blonder18@tigers.lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each.
   *If student, please identify and name supervising professor in this space.
   Dr. Blanchard
   Associate Professor
   College of Education
   578-2997
   Ph.D. @ LSU
   E-mail:

3) Project Title: Robotics and inquiry: Addressing the Impact on Alternative Conceptions of Physics Concepts from Rural Elementary Students through Robotics Instruction Immersed within the SE learning Cycle Model

4) Proposal? (yes or no) ☐ No ☑ Yes, LSU Proposal Number

   Also, if YES, either
   □ This application completely matches the scope of work in the grant.
   OR
   □ More IRB Applications will be filed later.

5) Subject pool (e.g. Psychology students) ☐ Children ages 7-9
   *Circle any "vulnerable populations" to be used: (children < 18, the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature
   Blanca Delliberto
   Date 10/4/13 (no more signatures)

** I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ☑ Not Exempted ☐ Category/Paragraph ____________

Signed Consent Waived?: Yes ☐ No ☑

Reviewer: S. Kim MacGregor Signature: 10/4/2013
Parental Permission Form

Project Title: Robotics and Inquiry: Addressing the Impact on Alternative Conceptions of Physics Concepts from Rural Elementary Students through Robotics Instruction Immersed within the 5E learning Cycle Model

Performance Site: Rollins Place Elementary School 225-658-1940

Investigators: Bianca Deliberto

Purpose of the Study: The purpose of this study is to examine the teaching of force and motion concepts through the utilization of the Lego Mindstorms Robotics NXT kit, specifically examining the incorporation of robotics instruction and the 5E learning cycle model as a means to address students' alternative conceptions.

Inclusion Criteria: Second Grade rural elementary students ranging in age from 7 to 9 years.

Exclusion Criteria: Children who do not meet the age requirements, or are not enrolled in second grade.

Description of the Study: Over a period of one month, four 60 minute force and motion 5E model type activities with robotics lessons will be facilitated by the lead investigator. One week prior to the start of the project, a pretest will be administered; the same test will be employed immediately after the intervention is complete. There will also be another posttest administered four weeks after the intervention is complete to test for the effect of the instructional activities over time.

Students will also keep a science notebook throughout this time which will be examined by the lead investigator. In addition to this, through the draw-and-tell technique students will be able to journal, sketch and explain their interpretation of the force and motion concepts being presented. These writings will also assist in coding their alternative conceptions of force and motion topics. To assess this qualitative portion of the study, student understanding of force and motion will be examined through student drawings and individual interviews.
Benefits: Subjects will have the opportunity to gain a deeper understanding of force and motion concepts through robotics instruction. The study may identify themes that may arise when elementary educators are utilizing robotics in the science classroom. The subjects will also benefit from having one on one interaction with STEM topics through this study.

Risks: There are no known risks.

Right to Refuse: Participation is voluntary, and a child will become part of the study only if both child and parent agree to the child's participation. At any time, either the subject may withdraw from the study or the subject's parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: The school records of participants in this study may be reviewed by investigators. Results of the study may be published, but no names or identifying information will be included for publication. Subject identity will remain confidential unless disclosure is required by law.

Financial Information: There is no cost for participation in the study, nor is there any compensation to the subjects for participation.

Signatures:
The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigator. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I will allow my child to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Parent's Signature: __________________________ Date: ______________

The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent form to the parent/guardian and explained that by completing the signature line above he/she has given permission for the child to participate in the study.

Signature of Reader: __________________________ Date: ______________

STUDY EXEMPTED BY:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
130 David Boyd Hall
225-578-8692 / www.lsu.edu/irb
Exemption Expires: 10/9/2016
Child Assent Form

I, ______________________________, agree to be in a study to find ways to help children better understand science concepts. I will go to a special robotics class four times for an hour with another science teacher. I have to follow all the classroom rules, even when I am working with another teacher that isn’t my homeroom teacher. I can decide to stop being in the study at any time without getting in trouble.

Child's Signature: __________________________  Age: _____  Date: ______________

Witness* ___________________________  Date: ______________

* (N.B. Witness must be present for the assent process, not just the signature by the minor.)

STUDY EXEMPTED BY:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
130 David Boyd Hall
225-578-8692 / www.lsu.edu/irb
Exemption Expires: 10/9/2016
APPENDIX E
PILOT PRE AND POST TESTS

Robotics and Inquiry: Addressing the Impact on Student Understanding of Physics Concepts (Force and Motion) from Select Rural Louisiana Elementary Students through Robotics Instruction Immersed within the 5E Learning Cycle Model

PILOT: PRE and POST TESTS

Directions: Listen to the questions your teacher reads aloud. Use the computer and follow the directions to complete the tasks below.
Robotics and Inquiry: Addressing the Impact on Student Understanding of Physics Concepts (Force and Motion) from Select Rural Louisiana Elementary Students through Robotics Instruction Immersed within the 5E Learning Cycle Model

PILOT: PRE and POST TESTS

Directions: Listen to the questions your teacher reads aloud. Use the computer and follow the directions to complete the tasks below.
APPENDIX F
FULL RESEARCH STUDY: PRE AND POST TESTS

Robotics and Inquiry: Addressing the Impact on Student Understanding of Physics Concepts (Force and Motion) from Select Rural Louisiana Elementary Students through Robotics Instruction Immersed within the 5E Learning Cycle Model

Directions: Listen to the questions your teacher reads aloud. Use the computer and follow the directions to complete the tasks below.
FULL RESEARCH STUDY: PRE AND POST TESTS

Robotics and Inquiry: Addressing the Impact on Student Understanding of Physics Concepts (Force and Motion) from Select Rural Louisiana Elementary Students through Robotics Instruction Immersed within the 5E Learning Cycle Model

Directions: Listen to the questions your teacher reads aloud. Use the computer and follow the directions to complete the tasks below.
APPENDIX G
DRAW AND TELL INTERVIEW QUESTIONS
QUESTION SET A: PILOT AND FULL RESEARCH STUDY

1. What could you do with this play dough? Could you push or pull on this play dough?

2. Can you explain what it means to push or pull on an object?

3. Using these drawing pencils, draw a picture of how you pushed or pulled on the play dough. Draw arrows to show how you pushed or pulled on the play dough. Explain what you did with the play dough.

4. Do you know what a force is? Look at this truck and this container filled with sand. If you used the truck to apply a force or push the container slowly at the same speed would the container travel a far distance? Try it and see what happens.

5. Using these drawings pencils, draw a picture of how you used the truck to apply the force of a push to move the container filled with sand. Draw arrows to show the force you applied and explain.

6. What if I increased the amount of sand inside of the container? Would the container travel farther if you used the same truck and applied the same force? Draw arrows to show the force you applied and explain.
DRAW AND TELL INTERVIEW QUESTIONS
QUESTION SET B: PILOT AND FULL RESEARCH STUDY CONTROL GROUP

1. I am going to ask you to create four drawings. If at any time you want to stop its okay, no one will be mad at you and you will not be in trouble. Do you understand?

2. First, please draw a picture of the science experiment we did today involving the straw. Please tell me about your drawing and if you enjoyed the experiment we did today.

3. Please draw a picture of what happened when you used the straw to move the cotton ball.

4. Please draw an arrow(s) to show how the forces acted on the cotton ball. Please explain your reasoning for the placement of the arrow(s).

5. Please draw a picture of what happened to the marble when you used the straw.

6. Please draw an arrow(s) to show how the forces acted on the marble. Please explain your reasoning for the placement of the arrow(s).

7. Please draw a picture of the science experiment we did involving the truck.

8. Please draw arrow(s) to show how the forces acted upon container A. Please explain your reasoning for the placement of the arrow(s).

9. Please draw a picture of what happened to container B when you used the truck.

10. Please draw arrow(s) to show how the force acted upon container B. Please explain your placement of the arrow(s).

11. Choose one of the experiments. Can you indicate (circle) which factors made it easier or harder to push the object forward?

12. Please tell me about the factors you circled.

13. Please explain if anything happened differently to the straw when the object you applied force to changed.
14. Please explain if anything stayed the same with the straw when the object you applied force to changed.

15. Please explain if anything happened differently to the truck when the object you applied force to changed.

16. Please explain if anything stayed the same with the truck when the object you applied force to changed.

17. Take a look at this robot. Do you think you could use this robot to find out more information about applying force to the objects we used today? Is there anything else you would like to add?
DRAW AND TELL INTERVIEW QUESTIONS
QUESTION SET B: PILOT STUDY EXPERIMENTAL GROUPS

1. I am going to ask you to create four drawings. If at any time you want to stop its okay, no one will be mad at you and you will not be in trouble. Do you understand?

2. First, please draw what you did during the science experiment today and if you enjoyed the experiment we did today.

3. Please tell me about your drawing.

4. Can you indicate (circle) which factors made it easier or harder to push the object forward?

5. Please tell me about the factors you circled.

6. Please draw a picture of what happened to the robot when it pushed container A.

7. Please draw an arrow(s) to show how the forces acted on container A.

8. Please explain your reasoning for the placement of the arrow(s).

9. Please draw a picture of what happened to the robot when it pushed container B.

10. Please draw an arrow(s) to show how the forces acted on container B.

11. Please explain your reasoning for the placement of the arrow(s).

12. Please draw a picture of what happened to the robot when it pushed container C.

13. Please draw an arrow(s) to show how the forces acted on container C.

14. Please explain your reasoning for the placement of the arrow(s).

15. Please explain if anything happened differently to the robot when the container of sand changed.

16. Please explain if anything stayed the same with the robot when the container of sand changed.

17. Is there anything else you would like to add?
DRAW AND TELL INTERVIEW QUESTIONS
QUESTION SET B: FULL RESEARCH STUDY EXPERIMENTAL GROUPS

1. I am going to ask you to create four drawings. If at any time you want to stop its okay, no one will be mad at you and you will not be in trouble. Do you understand?

2. First, please draw what happened in the experiment when you used the robot and container A.

3. Explain what happened.

4. Please draw an arrow(s) to show how the forces acted on container A.

5. Please explain your reasoning for the placement of the arrow(s).

6. Please draw a picture of what happened to the robot when it pushed container B.

7. Please draw an arrow(s) to show how the forces acted on container B.

8. Please explain your reasoning for the placement of the arrow(s).

9. Please draw a picture of what happened to the robot when it pushed container C.

10. Please draw an arrow(s) to show how the forces acted on container C.

11. Please explain your reasoning for the placement of the arrow(s).

12. Please explain if anything happened differently to the robot when the container of sand changed.

13. Please explain if anything stayed the same with the robot when the container of sand changed.

14. Choose a picture to focus on. Can you indicate (circle) which factors made it easier or harder to push the object forward?

15. Please tell me about the factors you circled.

16. What was your favorite part about the experiments we did?

17. Is there anything else you would like to add?
DRAW AND TELL INTERVIEW QUESTIONS
QUESTION SET C: PILOT AND FULL RESEARCH STUDY CONTROL GROUP

1. I am going to ask you to create four drawings. If at any time you want to stop its okay, no one will be mad at you and you will not be in trouble. Do you understand?

2. Do you remember the science experiments we did last week? First, please draw a picture of the science experiment we did today involving the straw. Please tell me about your drawing and if you enjoyed the experiment we did today.

3. Please draw a picture of what happened when you used the straw to move the cotton ball.

4. Please draw an arrow(s) to show how the forces acted on the cotton ball. Please explain your reasoning for the placement of the arrow(s).

5. Please draw a picture of what happened to the marble when you used the straw.

6. Please draw an arrow(s) to show how the forces acted on the marble. Please explain your reasoning for the placement of the arrow(s).

7. Please draw a picture of the science experiment we did involving the truck.

8. Please draw arrow(s) to show how the forces acted upon container A. Please explain your reasoning for the placement of the arrow(s).

9. Please draw a picture of what happened to container B when you used the truck.

10. Please draw arrow(s) to show how the force acted upon container B. Please explain your placement of the arrow(s).

11. Choose one of the experiments. Can you indicate (circle) which factors made it easier or harder to push the object forward?

12. Please tell me about the factors you circled.
13. Please explain if anything happened differently to the straw when the object you applied force to changed.

14. Please explain if anything stayed the same with the straw when the object you applied force to changed.

15. Please explain if anything happened differently to the truck when the object you applied force to changed.

16. Please explain if anything stayed the same with the truck when the object you applied force to changed.

17. Take a look at this robot. Do you think you could use this robot to find out more information about applying force to the objects we used today? Is there anything else you would like to add?
1. I am going to ask you to create four drawings. If at any time you want to stop its okay, no one will be mad at you and you will not be in trouble. Do you understand?

2. Do you remember the experiments we did with the robots? First, please draw what happened in the experiment when you used the robot and container A.

3. Explain what happened.

4. Please draw an arrow(s) to show how the forces acted on container A.

5. Please explain your reasoning for the placement of the arrow(s).

6. Please draw a picture of what happened to the robot when it pushed container B.

7. Please draw an arrow(s) to show how the forces acted on container B.

8. Please explain your reasoning for the placement of the arrow(s).

9. Please draw a picture of what happened to the robot when it pushed container C.

10. Please draw an arrow(s) to show how the forces acted on container C.

11. Please explain your reasoning for the placement of the arrow(s).

12. Please explain if anything happened differently to the robot when the container of sand changed.

13. Please explain if anything stayed the same with the robot when the container of sand changed.

14. Choose a picture to focus on. Can you indicate (circle) which factors made it easier or harder to push the object forward?

15. Please tell me about the factors you circled.

16. What was your favorite part about the experiments we did?

17. Is there anything else you would like to add?
APPENDIX H
EXPERIMENTAL GROUP
LESSON PLANS

Lesson Plans: Utilizing NXT LEGO Mindstorms Robot to explore concepts of force and motion in a 5E Learning Cycle Model Format

Student Learning Goal: To gain a deeper understanding of concepts of force and motion through the use of robotics instructions embedded in the 5E Learning Cycle Model and retain these understandings over time.

Objectives:

The Learner will:

1. Explain the concept of pushing
2. Identify the forces acting upon objects
3. Describe the concept of mass and how it relates to force

Timespan: Due to rotating ancillary schedule at proposed test site (rural elementary school), lesson 1 will span two consecutive days and lesson 2 will span two consecutive days.

Lesson 1: Introduction to concepts surrounding force and motion using robotics and 5E Learning Cycle Model format.

Engage:

Begin by reading the book Sheep in a Jeep by Nancy Shaw. Ask the students to give you a thumbs up or thumbs down when they hear an example of force and motion in the book. Once you read the story have the student’s record examples of force and motion on sticky notes. Have the students place them on a class t-chart which displays each student’s examples of force and motion from the book. Ask the students guiding questions such as: What is a force? What can
forces do? What is motion? Go through the students written examples on the class t-chart and have them provide the motion for the provided force and vice versa.

**Explore:**

Tell the students that today they will be using the LEGO Mindstorms NXT robots to explore concepts of force and motion. Provide the students with the tape measurer, recording sheets, stop watch, robot and container A filled with sand. Demonstrate how to connect the LEGO Mindstorms NXT robot to the computer to program it to push the container for 4 second at 50% power. Be sure the students have moved in their groups to their areas near the masking tape on the floor (Figure K1.1). Before the students begin discuss how the students should measure the distance traveled in the allotted time. Also, discuss with the students how when scientists are conducting an experiment they take multiple measurements during the experiment for variability purposes; therefore, for this experiment we will run the robot 4 times and record the distance traveled each time, keeping the force provided for the robot the same each time. Have the students complete the experiment, making sure they are recording their observations on the recording sheet. Informally evaluate students by discussing their observations and asking questions such as: How is the robot similar to the jeep in the story? Do you think we could make the robot push the container faster or slower? What would we have to change?

**Explain:**

The students will make a poster to showcase their understanding of the experiment. They do not need to use correct terminology here, they are simply explaining to the class how they interpreted the data collected from the experiment. After the students have completed their posters they will go on a gallery walk to examine all groups’ data and discuss how the data they collected is alike
and different. The teacher will remind students of the definition of mass and ask students how
the mass of their container is important to the experiment. Also, discuss the concept of force
again; ask students if the force of the robot remained the same throughout the experiment and
how it relates to the experiment. Pass out the force and motion cards to the students. Have the
students use these cards to make sentences to explain and share what they just experienced in the
experiment. Discuss concepts of force and motion learned in the experiment and expand upon
terminology from the cards.

**Elaborate:**

Ask the students to think of how they can use what they just learned from their experiment to
conduct their own experiment using a small toy car and a large dump truck. Ask the students to
determine whether it will take a big push or a small push to make the truck travel the same
distance as the car. Have the students record their experiments on the recording sheet. Once they
are done with their experiments have them share their findings. Be sure to emphasize the
difference between big and small pushes on the truck versus the car in comparison to the distance
traveled and highlight the terms mass, force, motion and acceleration to tie the student designed
experiments to the terminology discussed today.

**Evaluate:**

Have the students create their own exit ticket quiz covering concepts of force and motion
discussed today. The quiz must have five questions pertaining to mass, force and acceleration.
Students then exchange the quizzes with their classmates to check for understanding. Discuss
which quiz questions the student’s felt were most appropriate to test their understanding of the
experiment.
Figure K1.1: A pair of students using the robot to push container A
Lesson 2: Extension of concepts surrounding force and motion using robotics and 5E Learning Cycle Model format

Engage:

Begin by reading the book, Motion: Push, pull, fast and slow by Darlene Stille. Have students give thumbs up each time they see evidence of force and motion. Once you are finished have the students discuss ways in which the story relates to the experiment from yesterday. Have the students record ways in which the story connected to the experiment on sticky notes to place on the class schema chart. Have groups stand and explain their understandings of the connections.

Explore:

Tell the students that again today they will be using the LEGO Mindstorms NXT robots to explore concepts of force and motion. Provide the students with the tape measurer, recording sheets, stop watch, robot and containers B and C filled with sand (K1.2; K1.3). Review how to connect the LEGO Mindstorms NXT robot to the computer to program it to push the container for 4 second at 50% power. Be sure the students have moved in their groups to their areas near the masking tape on the floor. Review how the students should measure the distance traveled in the allotted time. Also, review with the students how when scientists are conducting an experiment they take multiple measurements during the experiment for variability purposes; therefore, for this experiment we will run the robot 4 times and record the distance traveled each time, keeping the force provided for the robot the same each time. Have the students complete the experiment, making sure they are recording their observations on the recording sheet. Informally evaluate students by discussing their observations and asking questions such as: How is the robot similar to the situations in the story? Do you think we could make the robot push the
container faster or slower? What would we have to change? How is this experiment different from yesterday’s experiment?

**Explain:**

The students will make a poster to showcase their understanding of the experiment and compare their findings from today to those of yesterday. After the students have completed their posters they will go on a gallery walk to examine all groups’ data and discuss how the data they collected is alike and different. The teacher will remind students of the definition of mass and ask students how the mass of their container is important to the experiment. Emphasize how today’s experiment differed from that of the day before due to the mass of containers B and C and what happened when the mass of the sand inside of the containers increased, while the force and acceleration of the robot stayed the same. Reinforce the concept of force again; ask students if the force of the robot remained the same throughout the experiment and how it relates to the experiment. Pass out the same force and motion cards from yesterday to the students. Have the students use these cards to make different sentences from yesterday to explain and share what they just experienced in the experiment. Discuss concepts of force and motion learned in the experiment and expand upon terminology from the cards and highlight the differences between the two experiments.

**Elaborate:**

Ask the students to think of how they can use what they just learned from their experiment to conduct their own experiment using straws, cotton balls and marbles. Ask the students to determine whether it will take a big push of air or a small push of air to make the marble travel the same distance as the cotton ball. Have the students record their experiments on the recording
sheet. Once they are done with their experiments have them share their findings. Be sure to emphasize the difference between big and small pushes of air on the marble versus the cotton ball in comparison to the distance traveled and highlight the terms mass, force, motion and acceleration to tie the student designed experiments to the terminology discussed today.

**Evaluate:**

Have the students create their own skit where they act out the big ideas from this lesson: mass, force and acceleration. Students are encouraged to be creative and use scenario cards provided by the teacher to guide them into situations where an examination of mass, force and acceleration can be conducted. They can use labels on people if necessary to indicate force, mass and acceleration during the skit. After the skit the students will explain the big ideas of the lesson to the class. Groups will be assessed using a rubric.
Figure K1.2: Two students using the robot to push container B
Figure K1.3: Two students examine the distance the robot pushed container C
CONTROL GROUP
LESSON PLANS

Lesson Plans: Explore concepts of force and motion in a 5E Learning Cycle Model Format

Student Learning Goal: To gain a deeper understanding of concepts of force and motion through the use of the 5E Learning Cycle Model and retain these understandings over time.

Objectives:

The Learner will:

1. Explain the concept of pushing
2. Identify the forces acting upon objects
3. Describe the concept of mass and how it relates to force

Timespan: Due to rotating ancillary schedule at proposed test site (rural elementary school), lesson 1 will span two consecutive days and lesson 2 will span two consecutive days.

Lesson 1: Introduction to concepts surrounding force and motion using robotics and 5E Learning Cycle Model format.

Engage:

Begin by reading the book Sheep in a Jeep by Nancy Shaw. Ask the students to give you a thumbs up or thumbs down when they hear an example of force and motion in the book. Once you read the story have the student’s record examples of force and motion on sticky notes. Have the students place them on a class t-chart which displays each student’s examples of force and motion from the book. Ask the students guiding questions such as: What is a force? What can forces do? What is motion? Go through the students written examples on the class t-chart and have them provide the motion for the provided force and vice versa.

Explore:
Ask the students to think of how they can use what they just learned from the story to conduct their own experiment using various containers filled with different masses of sand and a large dump truck. Ask the students to determine whether it will take a big push or a small push to make the truck move the varying masses of sand in the containers. Provide the students with tape measurers so they can take measurements each time. Have the students record their experiments on the recording sheet. Discuss with the students how when scientists are conducting an experiment they take multiple measurements during the experiment for variability purposes; therefore, for this experiment we will push the truck 4 times and record the distance traveled each time, keeping the force provided for the truck the same each time. Once they are done with their experiments have them share their findings. Be sure to emphasize the difference between big and small pushes on the truck in comparison to the distance traveled and highlight the terms mass, force, motion and acceleration to tie the student designed experiments to the terminology discussed today. Informally evaluate students by discussing their observations and asking questions such as: How was your pushing the truck to move the containers similar to the jeep in the story? Do you think we could make the truck push the container faster or slower? What would we have to change?

**Explain:**

The students will make a poster to showcase their understanding of the experiment. They do not need to use correct terminology here, they are simply explaining to the class how they interpreted the data collected from the experiment. After the students have completed their posters they will go on a gallery walk to examine all groups’ data and discuss how the data they collected is alike and different. The teacher will remind students of the definition of mass and ask students how
the mass of their container is important to the experiment. Also, discuss the concept of force again; ask students if the force of the push on the truck remained the same throughout the experiment and how it relates to the experiment. Pass out the force and motion cards to the students. Have the students use these cards to make sentences to explain and share what they just experienced in the experiment. Discuss concepts of force and motion learned in the experiment and expand upon terminology from the cards.

**Elaborate:**

Tell the students to use what we just learned in our experiment to try this concept again. Take a plastic straw and cut a piece off the end about 5 cm long. Blow a sunflower seed out of it and see how far it goes. Try blowing a sunflower seed out of a regular straw and observe how far the seed goes. Use the tape measurer and measure the distance in centimeters and in inches. Have the students predict what will happen and record their results after conducting the experiment 4 times. Next, have the students color one seed blue and one seed red try the experiment again and see if it made a difference. Have them record their results and share their findings. Explain to the students it’s the blowing force that makes the seeds move. In the larger tube, the force acts for a longer time. Hence the seed continues to accelerate, builds up more speed, and goes farther. Have the students discuss how this relates to our terms and the experiment we just conducted.

**Evaluate:**

Have the students create their own exit ticket quiz covering concepts of force and motion discussed today. The quiz must have five questions pertaining to mass, force and acceleration. Students then exchange the quizzes with their classmates to check for understanding. Discuss
which quiz questions the student’s felt were most appropriate to test their understanding of the experiment.

**Lesson 2:** Extension of concepts surrounding force and motion using the 5E Learning Cycle Model format.

**Engage:**

Begin by reading the book, *Motion: Push, pull, fast and slow* by Darlene Stille. Have students give thumbs up each time they see evidence of force and motion. Once you are finished have the students discuss ways in which the story relates to the experiment from yesterday. Have the student’s record ways in which the story connected to the experiment on sticky notes to place on the class schema chart. Have groups stand and explain their understandings of the connections.

**Explore:**

Ask the students to think of how they can use what they just learned from the story to conduct their own experiment using straws, cotton balls and marbles. Ask the students to determine whether it will take a big push of air or a small push of air to make the marble travel the same distance as the cotton ball. Give the students tape measurers, reminding them to make measurements in metric and standard units. Have the students record their experiments on the recording sheet. Review with the students how when scientists are conducting an experiment they take multiple measurements during the experiment for variability purposes; therefore, for this experiment we will use the straw 4 times and record the distance traveled each time, keeping the force provided from the straw the same each time. Once they are done with their experiments have them share their findings. Be sure to emphasize the difference between big and small pushes of air on the marble versus the cotton ball in comparison to the distance traveled and
highlight the terms mass, force, motion and acceleration to tie the student designed experiments to the terminology discussed today. Informally evaluate students by discussing their observations and asking questions such as: How is the experiment we did today similar to the situations in the story? Do you think we could make the air coming from the straw push the marble or cotton ball faster or slower? What would we have to change? How is this experiment different from yesterday’s experiment?

**Explain:**

The students will make a poster to showcase their understanding of the experiment and compare their findings from today to those of yesterday. After the students have completed their posters they will go on a gallery walk to examine all groups’ data and discuss how the data they collected is alike and different. The teacher will remind students of the definition of mass and ask students how the mass of their container is important to the experiment. Emphasize how today experiment has differed from that of the day before. Reinforce the concept of force again; ask students if the force of the air pushed through the straw remained the same throughout the experiment and how it relates to the experiment. Pass out the same force and motion cards from yesterday to the students. Have the students use these cards to make different sentences from yesterday to explain and share what they just experienced in the experiment. Discuss concepts of force and motion learned in the experiment and expand upon terminology from the cards and highlight the differences between the two experiments.

**Elaborate:**

Tell the students to use what we just learned in our experiment to try this concept again. Pass out the same containers used from the previous experiment and a smaller dump truck. Ask the
students to determine whether it will take a big push or a small push to make this truck move the varying masses of sand in the containers. Provide the students with tape measurers so they can take measurements each time. Have the students record their experiments on the recording sheet. Discuss with the students how when scientists are conducting an experiment they take multiple measurements during the experiment for variability purposes; therefore, for this experiment we will push the truck 4 times and record the distance traveled each time, keeping the force provided for the truck the same each time. Once they are done with their experiments have them share their findings. Be sure to emphasize the difference between big and small pushes on the truck in comparison to the distance traveled and highlight the terms mass, force, motion and acceleration to tie the student designed experiments to the terminology discussed today. Informally evaluate students by discussing their observations and asking questions such as: How was your pushing the truck to move the containers similar to the experiment with the straw and the marble? Do you think we could make the truck push the container faster or slower? What would we have to change? How is this experiment different than the previous experiment we conducted with the larger dump truck?

**Evaluate:**

Have the students create their own skit where they act out the big ideas from this lesson: mass, force and acceleration. Students are encouraged to be creative and use scenario cards provided by the teacher to guide them into situations where an examination of mass, force and acceleration can be conducted. They can use labels on people if necessary to indicate force, mass and acceleration during the skit. After the skit the students will explain the big ideas of the lesson to the class. Groups will be assessed using a rubric.
VITA

Bianca R. Deliberto was born in 1983 in West Palm Beach, Florida. She graduated from Louisiana State University with a Bachelor of Science degree in Education in 2005. The following year she earned a Master’s degree in Curriculum and Instruction from Louisiana State University. She began her teaching career in West Feliciana Parish, and then later transferred to the Zachary Community School system where she has been employed for the past nine years. While teaching second and third grade students, she earned multiple awards, honors and fellowships including: Presidential Awards for Excellence in Mathematics and Science Teaching, Louisiana State Elementary Math Finalist; National Board Certification, Middle Childhood Generalist; Louisiana Science Teachers Association Most Outstanding Science Teacher of the Year 2011; ZULA International National Science Teachers Association Early Science Educator Award; NASA/LaSPACE Michoud Education Fellows Program and Louisiana Association of Teachers of Mathematics Finalist for Outstanding Teacher of the Year 2010. During this time she also presented at numerous national and regional/local conferences and accumulated $7,750 in grant funding.

Bianca has been married for five years to her husband, Michael. In August 2011, she became a doctoral student under Dr. Pam Blanchard at Louisiana State University. She earned an Education Specialist degree in August 2013 and a Ph.D. in Curriculum and Instruction in December 2014. She has taught elementary math, science, and social studies since 2008. Through these efforts, Bianca hopes to provide meaningful opportunities to fellow educators and students within the community. She plans to continue teaching at the elementary level upon completion of this dissertation.