The Effects Of The 5e Learning Cycle Model On Students' Understanding Of Force And Motion Concepts

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THE EFFECTS OF THE 5E LEARNING CYCLE MODEL ON STUDENTS’ UNDERSTANDING OF FORCE AND MOTION CONCEPTS

by

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B.S. Millersville University, 2000

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Education in the Department of Teaching and Learning Principles in the College of Education at the University of Central Florida Orlando, Florida

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ABSTRACT

As advocated by the National Research Council [NRC] (1996) and the American Association for the Advancement of Science [AAAS] (1989), a change in the manner in which science is taught must be recognized at a national level and also embraced at a level that is reflected in every science teacher’s classroom. With these ideas set forth as a guide for change, this study investigated the fifth grade students’ understanding of force and motion concepts as they engaged in inquiry-based science investigations through the use of the 5E Learning Cycle. The researcher’s journey through this process was also a focus of the study.

Initial data were provided by a pretest indicating students’ understanding of force and motion concepts. Four times weekly for a period of 14 weeks, students participated in investigations related to force and motion concepts. Their subsequent understanding of these concepts and their ability to generalize their understandings was evaluated via a posttest. Additionally, a review of lab activity sheets, other classroom-based assessments, and filmed interviews allowed for the triangulation of pertinent data necessary to draw conclusions from the study. Findings showed that student knowledge of force and motion concepts did increase although their understanding as demonstrated on paper lacked completeness versus understanding in an interview setting. Survey results also showed that after the study students believed they did not learn science best via textbook-based instruction.
ACKNOWLEDGMENTS

“The object of all science, whether natural science or psychology, is to co-ordinate our experiences and to bring them into a logical order.”
--Einstein, 1955.

This action research thesis is dedicated to the women that were a part of the Lockheed Martin/UCF Academy cohort of 2006 and to the professors associated with the program. Without your encouragement and sharing of knowledge I could not have experienced such intellectual growth. Additionally, to my husband Clint, I owe thanks for his understanding and patience throughout this two-year journey. To my parents, thank you for instilling in me the value of education and the belief that I can achieve whatever I may desire. Michelle, thank you for your superior editing skills, your honesty, and your encouragement.
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CHAPTER ONE: INTRODUCTION

Science has been a passion of mine for quite some time. It all began while growing up in the Appalachian Mountains of rural south central Pennsylvania, with the opportunity to explore the environment and view wildlife, literally, outside my front door. My parents also helped to foster my interest in science through the purchase of a chemistry set and the nurturing of my natural inquisitiveness. As an adult, my interest in the state of the global environment has been renewed and I have realized fully the power of action and inquiry via my civic engagement as a member of the Sierra Club. It is through these personal experiences that I developed a set of beliefs about what science should be in an elementary classroom. What I have realized is that, like the National Research Council [NRC] (1996, p. 1), I have a desire for my students to become independent, problem-solvers, and critical thinkers. However, my science teaching practices in the past did not necessarily complement my desires.

Through continued education at the University of Central Florida I began to understand the benefits of an inquiry approach to science teaching and learning, and discovering the means to implement them. Although I had no qualms about shelving the science book (which in my mind represented traditional science teaching) I found the next step challenging. In the transition from traditional instruction to a more inquiry-based approach, I wondered if both the students and I possessed the tools necessary to be successful in the endeavor. My worries were dissolved somewhat as I found, similar to many other approaches to teaching, there is not one specific way to integrate inquiry science. As the NRC (1996) suggests, “The importance of inquiry does not imply that all teachers should pursue a single approach to teaching science. Just as inquiry has many different facets, so teachers need to use many different strategies” (p. 2). The 5E Learning Cycle Model introduced by Bybee and Landes (1990) through the Biological Sciences
Curriculum Study (BSCS) was identified as the approach that would best fit both my needs and those of my students. In order to judge the effectiveness of this model, it was necessary that I embark on my own investigation of my teaching practices to determine if using the 5E Model was an effective method for transitioning teachers and students into the realm of inquiry science.

Rationale for the Study

Nationwide it has been found that the “movement emphasizing reading, writing, and mathematics instruction, as measured by high-stakes standardized tests, threatens to suppress the effort to make truly revolutionary progress in science education” (Jorgenson & Vanosdal, 2002, p. 602). These feelings are echoed on a local level as well by Orange County science specialist Bonnie Mizell (Postal, 2006) and I have seen this phenomenon infused in the schools at which I have taught and within the parameters of my own teaching. This nationwide perspective and the teaching practices that result from it will likely impede the quest for growth in science education. This has already been evidenced in the 2003 TIMSS (Trends in International Mathematics and Science Study) Testing. Results showed that students in countries like Japan, China, Hungary, and Korea (which spend far less on education per student than the United States) outperform American students in both mathematics and science (Gonzalez, et al., 2004). Results from the 2003 TIMSS also reveal that between 1995 and 2003, U.S. fourth-graders made no measurable gains in science or mathematics (Gonzalez, et al., 2004). Although most researchers agree that no one area of education is the exclusive source of these challenges, the matter of instructional methods is one that can be instituted individually or on a more extensive scale to help close the achievement gap among subject areas (Pennsylvania State University, 1998).

As proposed by the National Research Council [NRC] (1996) and the American Association for the Advancement of Science [AAAS] (1989), a manner in which science is
taught must be embraced not only by the leaders of this country, but also by every science teacher. In a recent issue of *Time* magazine Carl Parravano of the Merck Institute for Science Education justifies this point by stating with a traditional instructional approach, “By fourth grade we squash that curiosity with the way we teach science” (Winters Keegan, 2006, p. 26). The result is a nation with fewer students interested in or majoring in science (Winters Keegan, 2006), a deficit realized by Dewey (1910) nearly a century ago: “Students have not flocked to the study of science in the numbers predicted, nor has science modified the spirit and purport of all education in a degree commensurate with the claims made for it” (p. 121). An adjustment in instructional methods from a more traditional type of science teaching to teaching that embraces the National Science Education Standards [NSES] set forth by the NRC (1996) will be the basis of my research. These Science Teaching Standards are:

- **Standard A:** Teachers of science plan an inquiry-based science program for their students.
- **Standard B:** Teachers of science guide and facilitate learning.
- **Standard C:** Teachers of science engage in ongoing assessment of their teaching and of student learning.
- **Standard D:** Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.
- **Standard E:** Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.
Standard F: Teachers of science actively participate in the ongoing planning and development of the school science program. (pp. 30-51)

As modifications in instructional delivery are instituted, it is likely that a change in what students learn and the manner in which they do so will also be transformed, which was the ultimate goal of the NRC and this study. Once their classroom environments have been altered to support inquiry science, it is expected that students will begin to “describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others” (NRC, 1996, p. 20) as they begin to interact with and learn science differently.

The reason that force and motion concepts were chosen for the topic of this research is two-fold. These concepts were selected primarily because force and motion are the most frequently discussed physics concepts within physical science (Eryilmaz, 2002), and secondly because the concepts are required subject matter for 5th grade students per Florida’s Sunshine State Standards (Florida Department of Education, 1996). Historically the concepts of force and motion have produced misunderstandings in students of all ages, due to the content’s difficulty and ineffective teaching methods that do not adequately illuminate the concepts (Halloun, 1998; Kikas, 2004; McCloskey, 1983; Reiner, Slotta, Chi, & Resnick, 2000). This may be why some argue that force and motion are inappropriate topics of instruction for elementary-aged children (Bar, 1989).

Significance of the Study

According to international testing results over the past several years, the United States continues to fall short in comparison to other similarly industrialized countries in the area of science (National Science Foundation, 2000). Also, in a January 2006 article Leslie Postal of the
Orlando Sentinel reported that Florida students were scoring below grade average on science achievement assessments. The 5th grade students who participated in this action research study took their first state science assessment (Florida Comprehensive Assessment Test) during the academic year when this study was conducted (2005-2006). These students were chosen for this study so they could have an experience learning science content that differed from their peers in preparation for the Florida Comprehensive Assessment Test (FCAT). For information on the FCAT visit http://www.firn.edu.

Being one variable often manipulated to meet educational trends in the past, instructional methods are likely to be one area targeted in the quest for improved science scores. With the true essence of action research in mind, it was my goal that as I examined my own teaching practices, positive results in student achievement would be seen as well. Although research supports the claim that inquiry science promotes academic achievement, the majority of American teachers continue to engage in traditional teaching practices that do not allow students to compete equally with international students who are taught differently (Lee, 1998). By incorporating the 5E Learning Cycle Model it is my hope that as results are shared, other teachers will view inquiry methods as a partner in reaching their educational goals as well as their students’.

Purpose of the Study

Much of the research surrounding science inquiry reports positive gains by students and more positive attitudes and perceptions of self-efficacy by pupils and educators alike (Berg, Bergendahl, & Lundberg, 2003; Chang & Mao, 1998; Sottile, Carter, & Watson, 2001). Previous research in this area served as the basis for this study in which my current teaching practices and student achievement were examined through the implementation of inquiry-based instructional
methods in a 5th grade elementary classroom. Guiding questions for this study were slightly modified during the study. An explanation of the changes can be found in Chapter 4.

1. How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher?

2. How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion?

3. How does the implementation of an inquiry science model affect students’ perceptions of science in general, how they learn science, and how they view science outside the school setting?

4. How do science misconceptions present themselves in the study and affect the instruction of the teacher?

Definitions

5E Learning Cycle Model

One of many instructional approaches that support inquiry-based science is the 5E learning cycle model, which includes five specific components: engage, explore, explain, elaborate, and evaluate (Bybee & Landes, 1990). Similar to the motivation component of a non-science lesson plan, the engage stage of the 5E model is meant to elicit questions and prior knowledge from students and, of course, to motivate them to learn. During the explore stage students carry out the lab activity or experiment by collecting data, making observations, etc., and these explorations are given formal names in the explain stage. In the elaborate stage students have the opportunity to extend their learning to other topics or to satisfy previously held questions. Seemingly self-explanatory, the evaluate stage provides both teachers and students
with the chance to both formally and informally reflect upon what was learned (Bybee & Landes, 1990). Throughout this study the shortened terms, 5E Model and 5E Learning Cycle, were used interchangeably with the 5E Learning Cycle Model.

**Cooperative Learning**

Cooperative learning can be defined as “…the learning that takes place in an environment where students in small groups share ideas and work collaboratively to complete academic tasks” (Davidson & Kroll, 1991, p. 362). The terms *cooperative grouping* and *small group work* are used synonymously in this study with the term “cooperative learning”.

**Inquiry**

Like many terms that are used regularly within the field of education, *inquiry*, as it is related to science education, is often used incorrectly in various contexts or interchangeably with unrelated terms like “hands-on” and “real world” science (Crawford, 2000). In this study, the term “inquiry” will be used as it is defined in the National Science Education Standards [NSES] (NRC, 1996):

Scientific inquiry refers to diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (p. 23).

**Misconception**

Throughout the literature on this topic, many words and phrases are used to describe the ideas that students have about science that do not align with accepted scientific theories. For the
purposes of this study, misconception will be defined as “those beliefs students have that
contradict accepted scientific theories” (Eryilmaz, 2002, p. 1001).
Preconception

As with misconception, the term preconception also has many synonyms throughout educational literature. In this study, both “preconception” and “prior conception” will be defined as the ideas students retain before receiving formal science instruction (Eryilmaz, 2002, p. 1001).

Schema

A term often used in reference to students’ prior knowledge, schema, will be defined in this study as, “any existing generalized knowledge” (Reiner, Slotta, Chi, & Resnick, 2000, p. 2).

Self-Efficacy

Intelligence, manageability, and student motivation are just a few components of the definition of self-efficacy, which is perhaps why it is so ambiguous and difficult to define (Denzine, Cooney, & McKenzie, 2005). In this study self-efficacy was defined as teachers’ beliefs that they can positively affect students’ academic success.

Traditional Science Teaching

Traditional teaching is a method of science teaching that is still practiced in many science classrooms from elementary to college levels. Traditional teaching methods include students reading about science, watching demonstrations, listening to lectures, and memorizing scientific terms and principles (Bybee & Landes, 1990, p. 93).

Overview

Although my interest in science has been active for quite some time, I have realized that my past teaching methods have not supported the Science Teaching Standards set forth by the National Research Council (1996, pp. 30-51). In order to reach my goal for students to problem solve, think critically, and reason through decision-making, inquiry-based instructional methods must begin to replace more traditional science teaching practices. The following chapters will
outline my journey through this action research inquiry. In Chapter 2, the literature review and theoretical framework for the study will be presented as well as elaboration on why some argue that force and motion concepts are difficult for elementary aged students to understand, typical misconceptions experienced by these students, and why 5th graders can be taught mechanics in an effective manner. Chapter 3 discusses the methodological approaches used to access the data pertinent to the study. Findings from the study are presented Chapter 4, and Chapter 5 presents conclusions and suggestions for further research.
CHAPTER TWO: LITERATURE REVIEW

Introduction

Despite the fact that teachers nationwide are expected to instruct their students in the manner set forth by the NRC (1996), many educators teach science more “traditionally”, meaning they follow a prescribed set of directions, heavily rely on textbooks or lab procedures to drive their instruction, and/or they do not consider student ideas in instruction. With numerous articles and studies that support the use of inquiry, why have so many abandoned the idea of utilizing it? Put simply by Crawford (2000), “Orchestrating this kind of nontraditional, inquiry-based instruction is complex, and many teachers have not embraced the essence of this mode of learning” (p. 917). Perhaps because of this complexity and lack of instruction in scientific inquiry techniques, many educators will revert to what is familiar, but not necessarily beneficial for students. Teachers’ views and actions must be changed, however, the gap between what is necessary from the researcher’s perspective and what may be set into practice by ‘normal’ teachers has increased more and more (Duit & Treagust, 2003).

Much of the research related to inquiry science has been focused on student outcomes and behaviors, and the roles and feelings of teachers as they have encountered this “radical” method of instruction (Berg, Bergendahl, & Lundberg, 2003; Bianchini & Colburn, 2000; Dunkhase, Hand, Shymansky, & Yore, 1997). A few ways in which students benefit from “science as inquiry” are through increased scientific achievement and more positive attitudes toward science teaching and science as a general topic of interest (Berg et al., 2003; Chang & Mao, 1998; Von Secker, 2002). However, underlying variables affecting the degree to which students experience these beneficial effects: the function of the teacher within the inquiry model (Bianchini & Colburn, 2000; Dunkhase et al. 1997); the science conceptions held by the teacher...
(Kikas, 2004); the misconceptions students hold; and the ways in which science instruction is deployed to overcome these misconceptions name just a few of these variables. These topics will be discussed through the remainder of this literature overview as support for teaching inquiry science and to briefly explain how students learn science content.

Roots of Constructivism

Constructivism sets the foundation for many instructional methods in mathematics and science. As summarized by Wheatley (1991) there are two main pillars of constructivism: (1) knowledge is not passively received but is actively built by students, which can differ from person to person and (2) there is no one correct view of the world, only what is perceived as real by each person as he constructs his meaning of the world through his own experiences (p. 10). Although constructivism did not reach mainstream status until the 1980’s, Dewey (1910) was advancing these same ideas near the early part of the century. Regarding the personal connection to knowledge he states:

Knowledge of human affairs couched in personal terms seems more important and more intimately appealing than knowledge of physical things conveyed in impersonal terms. Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry, does one ever get a knowledge of the method of knowing (pp. 122, 124).

The realization of the learner as a “constructer” of knowledge and not an empty container to be filled with facts is what differentiates constructivism from other educational theories. Pre-Sputnik era approaches to teaching and learning science possessed a behaviorist flair, but afterwards, in the rush to have a nation of better prepared scientists, the focus was on a more student-centered approach for teaching science. This developed alongside Piaget’s ideas of
intellectual development (Duit & Treagust, 1998). It is not by accident that Piaget is considered one of the fathers of this philosophy.

As children proceed through the sensorimotor, preoperational, concrete, and formal operational stages, Piaget suggested that mental processes are engaged in which old and new experiences merge to form new ideas (Karplus, 2003/1977). The formal terms Piaget gives to these processes are assimilation and accommodation. As will be elaborated further in this chapter, assimilation and accommodation are what take place in equilibrating a cognitive conflict (Duit & Treagust, 1998). Familiarity with the Piagetian stages of development in relation to learning, and specifically science and mathematics learning, was not necessarily intended. Piaget classified himself as a genetic epistemologist, not a creator of learning theories (Metz, 1998) and therefore several issues present themselves as researchers and educators attempt to assimilate these developmental stages to research and classroom environments. On one hand Piaget’s theories are a useful guide for educators in judging student’ mental capabilities; on the other hand these stages do not take into consideration an instructional approach that is complementary (Metz, 1998). In spite of these draw-backs, it is generally agreed that Piaget’s work has transformed how educators approach their craft and has certainly led others to explore his seminal ideas (Duit & Treagust, 1998).

As it goes in most areas of research, one person’s work begets another, which is the case with Vygotsky and Piaget. From Vygotsky’s thoughts on learning and language to his own levels of intellectual maturation entitled the Zone of Proximal Development, Vygotsky and Piaget’s research certainly share similarities. The implications of Vygotsky’s (1978) Zone of Proximal Development in education include that it exemplifies “the development process lags behind the learning process” (p. 90) and “shows that the initial mastery of [a concept] provides the basis for
the subsequent development of a variety of highly complex internal processes in children’s thinking” (p. 90). Driver, Leach, Scott, & Wood-Robinson (1994) add that Vygotsky viewed science knowledge as constructed through relationships that also had a cultural and social connection. One only needs to read the previous statements to know that Vygotsky’s name belongs with others as an early supporter of what would become constructivism.

Many words and phrases, i.e. “contextual”, “social,” “radical,” are used to describe constructivism (Good, Wandersee, & St. Julien, 1993). Of these, the radical perspective is often associated with Ernst von Glasersfeld and his notorious commentary on this perspective. To distinguish this view from others he states, “The social constructionists tend to take society as a given, and a radical constructivist cannot accept this. … “society” must be analyzed as a conceptual construct before its role in the further construction of concepts can be explained and properly assessed” (p. 24). Like Piaget, von Glasersfeld does not explicitly address the role of social institutions in constructing knowledge, but suggests that it must be understood separately before its impact can be explored. Constructivism is also utilized within the realm of mathematics, for which von Glasersfeld is also recognized. Although it may seem that constructivism is not a fit in a subject where the result of 3 + 1 is not debatable, it is the extent of the understanding of the solution and the methods for obtaining the solution that fit the constructivist perspective. Addressed by von Glasersfeld (1993) in a question about problem solving, he replies that if the rightness of every aspect of problem solving is the focus then the “unexpected and unconventional paths to a solution” (p. 34) will be missed to the detriment of the teacher and other students. Wheatley (1991) echoes these thoughts as he discusses the importance of sharing multiple solutions during mathematics class. Furthermore, his thoughts on
constructivism in the mathematics classroom parallel those of Dewey (1910) in the science classroom insofar as they view both subjects as saturated with sets of skills and facts:

Science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking (Dewey, 1910, p. 121).

Too often school science and mathematics is studied as a disembodied set of facts and principles independent of the knower (Wheatley, 1991, p. 13).

Regardless of one’s particular feelings toward a specific constructivist perspective or classroom implementation, one thing is quite clear; a key component of constructivist thinking is that students have numerous personal experiences before they are formally educated, which shape how they perceive the world around them. With this principal in mind, know that it is not the intent of a constructivist educator to change a child’s beliefs, but to modify beliefs so they more closely follow accepted science (Colburn, 2000). This approach to constructivism can be observed through the science classroom model of conceptual change.

Addressing Constructivism Through Conceptual Change

Although based on Piagetian views, conceptual change is still considered a relatively new area of research in science (Duit & Treagust, 1998). The idea of conceptual change spawned from studies in the 1970s of students’ misconceptions in science and how misconceptions can be changed (Posner, Strike, Hewson, & Gertzog, 1982). Like many other theories in science and education at large, the theory of conceptual change has several aliases. Before the term conceptual change was widely accepted, Thomas Kuhn (1977) referred to the experience one has when encountering new phenomena or finding dissatisfaction with current ideas as a scientific revolution (p. 234). To better elucidate such a change he uses the analogy of a scientist as a
“solver of puzzles,” which parallels the conditions necessary for conceptual change set forth by Posner et al. (1982). These conditions are:

(1) There must be dissatisfaction with existing conceptions.

(2) A new conception must be intelligible.

(3) A new conception must appear initially plausible.

(4) A new concept should suggest the possibility of a fruitful research program.

(p. 241)

To return to Kuhn’s analogy, imagine the scientist, or student, holding a puzzle piece (a current conception) and no matter how it is turned it will not fit into the larger whole and so he begins searching for another piece. In the words of Posner et al. (1982), this is categorized as an anomaly. This is what must occur first for conceptual change to be successful; if discontent with the current idea is not achieved then there is no basis for change. When an anomaly occurs, the learner’s behavior is typically associated with one of the following courses of action:

(1) Rejection of the observational theory.

(2) A lack of concern with experimental findings on the grounds that they are irrelevant to one’s current conceptions.

(3) A compartmentalization of knowledge to prevent the new information from conflicting with existing belief.

(4) An attempt to assimilate the new information into existing conceptions.

(Posner et al., 1982, p. 221)

With regard to assimilation of existing conceptions, Posner et al. (1982) draw upon the work of Piaget using the terms assimilation and accommodation to explain the stages through which students proceed during the process of conceptual change. Assimilation occurs when
“students use existing concepts to deal with new phenomena” while accommodation occurs when “the students’ current concepts are inadequate to allow him to grasp some new phenomenon successfully” (Posner et al., 1982, p. 212). Accommodation requires the student to replace or restructure current concepts, but as Duit and Treagust (1998) add, one cannot exist without the other.

According to Posner et al. (1982) simply supplying information and facts falls far short of the true basis of intelligibility. For a new concept to be integrated into the student’s current thinking, he or she must exhibit a clear understanding that can be communicated to others. Initial plausibility “can be thought of as the anticipated degree of fit of a new conception into an existing conceptual ecology” (Posner et al., 1982, p. 218). It is up to the student if this stage of conceptual change is attained, as the plausibility of a concept must fit harmoniously with a student’s beliefs and prior experiences, even those that may be unrelated to science. The fruitfulness of a new concept is attained when it meets the previously stated criteria and the learner can begin extending this understanding to other concepts and create new ideas. Although Posner et al. concede that oftentimes prior conceptions are not completely replaced, Duit and Treagust (2003) claim that there are no studies that document a complete replacement of concepts. Beeth and Hennessey (1996) add that the Posner et al. (1982) model implies that students think in abstract terms, which rarely occurs as children interact with science concepts.

To address other points of departure, Duit and Treagust (2003) argue that the effectiveness of such a model is difficult to scrutinize based on inconsistencies such as the teacher’s role and the time frame in which the change may occur. Furthermore, they believe that Posner, Strike, Hewson, and Gertzog’s (1982) conceptual change model fails to look at the larger picture and instead focuses on specific science content and concepts and loosely addresses
epistemology and ontology. For one, the Posner et al. model ignores social and affective aspects of learning, namely motivation and classroom environment (Duit & Treagust, 2003). They believe multi-perspective frameworks, such as Venville and Treagust’s (1998) are superior to those holding a single point of view or instructional approach. Another alternative is to view conceptual change through a situated cognition perspective. This perspective acknowledges the difficulties of conceptual change through recognizing that all learning is “situated” or linked to a particular event (Duit & Treagust, 1998).

The framework created by Venville and Treagust (1998) acknowledges four different perspectives that must be addressed when teaching for conceptual change and specifically refers to the aspects “left out” by the Posner et al. (1982) model. These perspectives include ontological, social, and epistemological components of conceptual change, in addition to the knowledge restructuring focus of the original model. Regardless of the approach selected for teaching for conceptual change, it is the instructor that determines the success of the attempt.

The Teacher’s Role in Facilitating Conceptual Change

The role of the teacher in creating a classroom environment in which such changes could occur and facilitating these changes is vital. Even through the use of tailored and specific instruction, or the conditions outlined above, it is neither common nor easy to alter students’ prior conceptions. When presented with meaningful instruction, students oftentimes will evaluate the information inaccurately despite the good intentions of the teacher (Bliss & Morrison, 1990; Driver, Leach, Millar, & Scott, 1996; McCloskey, 1983) or they will maintain prior conceptions and continue to use them in a modified sense when contextually appropriate (Driver, Leach, Scott, & Wood-Robinson, 1994). Also, it seems that students often apply their understanding to a specific situation rather than a broader set of concepts (Beeth & Hennessey, 1996). Posner et al.
In order to address current misconceptions, it is necessary to know what will stimulate change and how the restructuring of thought occurs (Driver, Leach, Scott, & Wood-Robinson, 1994). In a study conducted by Driver (1988) several teaching strategies were used to introduce scientific topics in a manner that would likely support conceptual change:

(a) Broadening the range of application of a conception.

(b) Differentiation of a conception.

(c) Building experiential bridges to a new conception.

(d) Unpacking a conceptual problem.

(e) The importing of a different model or analogy

(f) The progressive shaping of a conception

(g) The construction of an alternative conception. (pp. 143-145)

Posner et al. (1982) include these conditions:

(a) Incorporate activities, demonstrations, etc. that cause cognitive conflict.

(b) Provide instructors with time to diagnose errors in student thinking.

(c) Provide teachers with a repertoire of intervention techniques.

(d) Present information to students in a variety of contexts.

(e) Implement evaluation techniques for tracking conceptual change. (p. 226)

These specific teaching strategies complement any conceptual change model in many ways. Perhaps the most important is the consideration given to students’ ideas. “Common to all [approaches to conceptual change] is the importance given to students’ knowledge prior to instruction” (Hewson, Beeth, & Thorley, 1998, p. 201). As the knowledge and thoughts of the
students are valued as equal to the instructor, a change in perspective of the “expert,” takes place whilst the conditions for discourse and conceptual change evolve (Hewson et al., 1998).

Metacognition, which loosely means to think about one’s own thinking, is also a condition necessary for conceptual change. In the words of Gunstone (1994 in Hewson et al., 1998) metacognition and conceptual change go hand in hand…one cannot exist without the other.

“When students give different explanations of a particular phenomenon or set of phenomena in a classroom, in effect, they are laying out the explanations themselves as objects of cognition” (Hewson et al., 1998, p. 205). Whether elicited through questioning or formal analysis, utilizing students’ ideas and metacognitive processes is an indicator of a true embrace of constructivist thinking in a science classroom.

Despite the guidelines and various methods that can be utilized for teaching for conceptual change, the process can be arduous, namely for the teacher. Put simply by Hewson, Beeth, and Thorley (1998) “teaching for conceptual change requires a great deal of teachers” (p. 215). A few roles the teacher must assume include:

(a) Setting goals for instruction

(b) Creating appropriate contexts for classroom activities.

(c) Posing problems that have relevance and meaning to students.

(d) Facilitating different levels of discourse.

(e) Establishing a classroom environment that allows students to explore without fear of ridicule.

(f) Monitoring classroom activities and deciding if, when, and how to intervene.

(Hewson, et al., 1998, p. 215)
In addition to these roles, Hewson et al. (1998) also assert that the teacher must know the content and her students at an unsurpassed level. One might concede that such an undertaking is reasonable because of the teacher’s ability to see such substantial payoffs in the end, but this is not necessarily the case. Posner, Hewson, Strike, and Gertzog found in their 1982 study of undergraduate physics students that these learners rarely recognized when an anomaly had occurred, which is the first step in addressing conceptual change. What is more, with conceptual change being difficult to pinpoint or view in a short period of time (semester, school year, etc.) Duit and Treagust (2003) suggest that when these changes occur they may not be conceptual changes at all, but simply explanations that vary in context and are not necessarily an accommodation of the information. All in all, conceptual change as a process and a gradual one at that “involves much fumbling about, many false starts and mistakes, and frequent reversals of direction” (Posner et al., 1982, p. 223), which is why it will continue to be a focus of countless inquiries in the future as researchers continue to hone the methods educators can use to implement it in their classrooms.

Student Conceptions: For Better or For Worse

Origins of Conceptions

Origins of students’ misconceptions or preconceptions can derive from various sources. Pertaining to textbooks, Dove (2002) cites ambiguous terminology and the inability of 2-dimmensional diagrams and models to adequately represent 3-dimmensional phenomena, while Owens (2003) suggests that as students read and listen to certain trade books, their ideas about science can be negatively influenced. With regard to language, Driver, Leach, Scott, & Wood-Robinson (1994) suggest that students have no point of reference for the terminology of scientists while second language learners can have difficulty comprehending and/or
communicating science terms (Clerk & Rutherford, 2000). Prior to formal science instruction and in lieu of this conventional knowledge, students rely on common sense and concrete reasoning to form their own scientific understanding (Driver et al., 1994; Karplus, 1977/2003; Ogborn & Bliss, 1990). Students’ reliance on their own schema when experiencing new phenomena can be a double-edged sword. It is often-times these prior notions that provide the basis for misconceptions, yet without these ideas it is impossible for learners to assimilate new information and establish a scaffold for additional learning (Bliss & Morrison, 1990; Hewson, Beeth, & Thorley, 1998; Posner, Strike, Hewson, & Gertzog, 1982). Reiner, Slotta, Chi, and Resnick (2000) also support this explanation in that students often attempt to apply their understanding of material objects to abstract concepts such as heat, light, electricity, and force, which are known as “substance-based” conceptions. Without concrete materials for modeling abstract concepts, Reiner et al. (2000) also concede that students may have more difficulty comprehending these ideas, and instruction devoid of models may be equally detrimental. Once students’ scientific concepts have developed over time, their reasoning can also be influenced by their own causal relationship theory (Driver et al., 1994) i.e. students believe that one phenomenon is caused by or is the result of another. Typically, accepted scientific explanations do not model these cause and effect notions, which therefore open the door to a misconception. As stated by Driver (1988), “Students’ conceptions of natural phenomena… influence the way future interactions with phenomena are construed” (p. 134) implying if a student creates an initial framework of understanding that is inaccurate, his or her future representations may also be compromised. It is often more likely than not that students’ views of science are based upon informal or inadequate science experiences. With this in mind, it is understood that two of the
most misconstrued concepts for students in the realm of science are those of force and motion (Bliss & Morrison, 1990; Kikas, 2004).

**Force and Motion Conceptions**

A study by Lebouter-Barrell in 1976 (in Driver, 1978) noted misconceptions related to force and motion, and numerous other researchers in more recent years report the difficulties of high school and post secondary students and even teachers with these fundamental ideas (Bao, Hogg, & Zollman, 2002; Bliss & Morrison, 1990; Eryilmaz, 2002; Halloun, 1998; Kikas, 2004; McCloskey, 1983). Limited research exists on how elementary-aged students view these Newtonian concepts, more than likely because it is at this age when they are developing their beliefs (Reiner, Slotta, Chi, & Resnick, 2000; Twigger et al., 1994). Again, the role of the textbook comes into play when Kuhn (1977) suggests that it may be many pupil’s first experience with the physical sciences and “their indirect influence is…larger and more pervasive” (p. 180). Bliss and Morrison (1990) note that common sense or everyday notions can be helpful pertaining to speed and acceleration, but harmful for concepts such as work and energy. An alternative notion is that students’ association with a substance-based theory is so dissimilar to the classical physics theory, that attempts to “correct” such misconceptions are often ineffective (Driver, Leach, Scott, & Wood-Robinson, 1994; Reiner, Slotta, Chi, & Resnick, 2000). One rationale for substance-based or common sense reasoning of rudimentary physics concepts is the connection of this type of thinking to Piagetian stages of development. Bliss and Morrison (1990) found that students have a better understanding of speed, acceleration, and the effects of force when they have at least reached the early formal operational stage. This can be made clearer through a brief explanation of impetus theory.
Those that hold misconceptions or naïve physics reasoning also seem to retain theories that coincide with pre-Newtonian physics or the impetus theory (McCloskey, 1983; Watts & Zylbersztajn, 1981). This theory assumes that “The act of setting an object in motion impresses in the object a force, or impetus, that serves to keep the object in motion” (McCloskey, 1983, p. 315) and that as the object slows the impetus gradually decreases. According to the impetus theory, this means that an object can exist without any net force acting on it, which is to some extent contradictory to traditional physics. In traditional physics, objects do not exist in complete and utter rest or motion…it is the frame of reference that signifies whether or not the object is in a state of motion or rest. This can be further explained by the research of Ogborn and Bliss (1990) who, using Piaget’s developmental stages as a foundation, suggest that concepts of motion are developed in the very beginning stages of life, as early as three or four months. The motion that children observe and carry out during the first few years of life is nothing like the motion scientists envision, yet it quite clearly parallels impetus-like thinking.

A thing moving alone keeps moving by some effort within it, to think of objects set in motion in these ways as taking on the effort provided when they were set moving; it [the object] can be understood as stopping because the effort has been used up (Ogborn & Bliss, 1990, p. 384).

Furthermore, it is speculated that motion according to Newtonian laws is so easily misinterpreted because so few have actually observed the movement of an object without any forces acting upon it (Reiner et al., 2000).

The role of the teacher in creating the conditions necessary for conceptual change with force and motion concepts is no less vital. Beeth and Hennessey (1996) support this by stating “The actions of the teacher help move the learner from their perceptions of motion to more
abstract thinking about what would cause an object to move” (p. 11). As noted in a study by Eryilmaz (2002) the teacher uses conceptual questions related to force and motion to facilitate discussion on specific content that is deemed problematic for students.

**Trends Within Conceptions/Reasoning**

Regardless of their prior exposures, it is suggested that students proceed through series of conceptions within certain science domains known as a “conceptual trajectory” (Driver, Leach, Scott, & Wood-Robinson, 1994). As with Piaget’s stage theory, research has shown that across biological, chemical, and physical domains same-aged students seem to construct knowledge within these areas in a rather specific sequence (Driver et al., 1994). For example, with regard to the properties of air and gases:

It appears that the conceptual trajectory starts with notions of air as insubstantial and existing only as a ‘wind’ or ‘breeze.’ The first important change is the development of the notion of air or gas as a material substance. This is followed by an appreciation that the property of weight or mass is characteristic of all material substances and hence applies to bodies of gas as well as to solids and liquids (Driver et al., 1994, p. 86).

Within the domains of force and motion, Bliss and Morrison (1990) found that certain concepts i.e. speed are easier for students than others like acceleration and potential and kinetic energy depending on their progress through Piaget’s stages of development. On the contrary, a 1994 study by Twigger et al. found that little evidence of general trends existed among force and motion concepts.

The idea of a conceptual trajectory is espoused by Gagné’s (1985) ideas concerning learning hierarchies. Gagné believed that because learning rarely takes place in isolation, what is learned initially is a prerequisite for other concepts. As these rules are retained and organized,
higher concepts can be attained. With this theory of a hierarchy in mind, one could see how misconceptions of primary rules could lead to difficulties with more advanced concepts.

The myriad ideas regarding how children first encounter science notwithstanding, the instructional methods that support such a variety of schemas are equally numerous. The instructional methods used in this study are those advocated by the National Research Council (1996) in the NSES, specifically scientific inquiry.

Science as Inquiry

What an inquiry approach to science offers to students, teachers, and the citizenry at large is something that will not lose its potency over time. This approach is what Dewey (1910) called for nearly a century ago and countless others have identified with since. Inquiry is not a fad. Inquiry is not a quick fix. What the National Research Council had in mind when they introduced inquiry in their standards in 1996 was the means to develop a scientifically literate society. A scientifically literate public is necessary for the following reasons:

First, an understanding of science offers personal fulfillment and excitement--benefits that should be shared by everyone. Second, Americans are confronted increasingly with questions in their lives that require scientific information and scientific ways of thinking for informed decision making. And the collective judgment of our people will determine how we manage shared resources--such as air, water, and national forests (p. 11).

This means that the benefits of inquiry extend past the classroom doors as a ubiquitous set of tools for those that engage in it. As students experience classroom events like real scientists, questioning, investigating, and problem solving, they will also learn to transfer these skills to other areas of life (NRC, 1996).
As indicated in the NSES, inquiry is much more than learning about science concepts; inquiry also includes communicating ideas, a standard shared by the National Council of Teachers of Mathematics (2000) and using mathematics in “all aspects of inquiry” (NRC, 1996, p. 148). The connection of mathematics and science is logical, as both subjects require critical thinking, asking questions, and presenting, collecting, and organizing data (Berlin & White, 1998; Wheatley, 1991). Considering the integration of mathematics and science, as well as problem-solving skills, the student who has engaged in science inquiry has much to gain from her exposure to such a rich environment.

The Student’s Role in Scientific Inquiry

Although the word inquiry loosely means “an investigation,” its meaning in the realm of science education is much more complex. According to the NSES, when students are engaged in scientific inquiry they will also engage in the following: “asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments” (NRC, 1996, p. 105). Quite clearly described above, the student has a very active role in inquiry science methods, which may explain the positive outcomes that result from this involvement.

Student Achievement

Much of the research on the achievement of students who experience inquiry science focuses on middle and high school students. Regardless of the level of education of the students, primary, middle, high school, or post secondary, inquiry-based learning has proved to be one cause of increased science achievement (Berg, Bergendahl, & Lundberg, 2003; Chang & Mao, 1998; Von Secker, 2002). Chang and Mao, in their 1998 study of middle school students, found
that not only were inquiry practices influential in promoting student achievement, but also that they were specifically more effective than traditional teaching methods. In a meta-analysis of research studies comparing traditional and alternative teaching strategies (including inquiry), Wise (1996) determined an average effect size of .32 for the alternative strategies. Although this particular statistic does not indicate a convincing argument (according to Gay & Airasian, 2003, p. 294) for the use of alternative strategies in science teaching, students who were instructed in these strategies performed better overall than those instructed using traditional strategies (Wise, 1996). As with most instructional methods, there are also opponents of inquiry. Klahr and Nigam (2004) argue that direct instruction is more effective for learning science than discovery learning. Not addressed in this study though are the additional positive outcomes of inquiry that encompass more than the learning of a science topic or skill.

As is set forth in the NSES, it is crucial for students not only to increase their science knowledge, but also to become adept at critical thinking and questioning as it relates to science. In a study of college students, Berg, Bergendahl, and Lundberg (2003) investigated the differences in expository and inquiry science modes of teaching and learning. They found that the advantages of learning through inquiry extended past general achievement and encompassed the types of questions students asked and their ability to evaluate the experiment.

All of the students who had carried out the open-inquiry version and the revised open-inquiry version could easily describe what they had done during the experiment. Only half of the students who had carried out the expository experiment could do that. Almost none of the students who had carried out the expository experiment could evaluate and suggest changes in the experiment (Berg et al., 2003, p. 359).
The possibilities for the growth of students exposed to inquiry science are very prevalent in the research, but not all students respond to inquiry in the same manner. Von Secker and Lissitz (1999) in their study on why gender, ethnicity, and socioeconomic status oftentimes affect achievement, determined that an inquiry approach to science might not be beneficial for all students. Unless students have the basic knowledge to engage in discussions and benefit from teaching approaches that fall under “science as inquiry,” this method could generate more negative than positive results (Von Secker & Lissitz, 1999). This notion proved to be relevant in this action research study.

**Student Attitudes**

If students experience more academic success through inquiry instruction, it only seems logical that their attitudes toward science would improve as well. Although there are many that believe in the validity of their studies on student attitudes (Berg, Bergendahl, & Lundberg, 2003; Dunkhase, Hand, Shymansky, & Yore, 1997), Baker et al. (1992) argue that “the literature on attitude toward science contains a well documented muddle of weak or inconsistent results that is linked to flaws in the construction of the measures” (p. 3). Baker et al. (1992) also claim that student attitude surveys are more likely to reflect a student’s opinion on teacher-centered versus student-centered classrooms and not necessarily his or her views on inquiry science. If indeed this is the case, it does not need to be viewed as a damaging claim against inquiry. Berg et al. (2003) found that “students were also more positive and more willing to put effort into the open versions of the experiment compared to the expository one” (p. 366), which in turn modified their feelings toward science and their scientific achievement.

In order for all of these positive effects to occur, the teacher must provide a classroom environment in which students feel free to explore and share. This and the additional
responsibilities knowing content, knowing students, and creating intriguing lessons can be overwhelming. As previously indicated by Posner, Strike, Hewson, and Gertzog (1982) the role of the teacher is pivotal in the science classroom.

The Teacher’s Role in Scientific Inquiry

Beliefs, self-efficacy, and a teacher’s knowledge and practice as they relate to inquiry science and science in general are instrumental in the facilitation of a classroom that supports such investigative practices. Each of these components gives credence to the importance of the teacher’s function in an inquiry science classroom.

Teacher Beliefs and Self-Efficacy

As stated under the assumptions the NRC (1996) holds with regard to instruction, “Teachers can be effective guides for students learning science only if they have the opportunity to examine their own beliefs, as to develop an understanding of the tenets on which the Standards are based” (p. 28). Within science these beliefs extend to general feelings about science, assessment of students, use of scientific tools, student communication, and teacher collaboration (NRC, 1996). Those with ideas that embrace inquiry science and its related habits of mind will certainly aid in the reform of science instruction, but those that hold “beliefs about students and learning, such as ability levels or the need for drill and practice, represent obstacles to inquiry-based instruction” (Keys & Bryan, 2001, p. 635).

Teacher efficacy is not easily defined. Woolfolk and Hoy (1990) indicate that it may be different for beginning teachers versus experienced teachers and cite other research that includes both a personal and professional component, an intelligence factor, control and manageability, and dependency upon student achievement, student motivation, administrative support, etc.
Fifteen years later not much as changed. Denzine, Cooney, and McKenzie (2005) likewise cite multiple factors that define teacher efficacy, but include as a general definition that teacher efficacy is teachers’ beliefs that they can positively affect students’ academic success. Because efficacy is multi-faceted, the validity of instruments used to evaluate it is in question, which has implications for past and future study results (Denzine et al., 2005). Nevertheless, these feelings are crucial and could present barriers to proper implementation of inquiry science in the classroom. Bandura (1993), who completed much of the seminal work related to self-efficacy, thus introducing the phrase explains, “Teachers who believe strongly in their instructional efficacy create mastery experiences for their students” (p. 140). Quite the opposite occurs with teachers with low feelings of instructional efficacy. Bandura (1993) also reports that, “Those beset by self-doubt construct classroom environments that are likely to undermine students’ sense of efficacy and cognitive development” (p. 140). Woolfolk and Hoy (1990) extend these ideas by suggesting that efficacy can even affect a teacher’s selection of specific instructional strategies. As stated by Crawford (2000), inquiry teaching is “complex.” If a teacher’s internal feelings are more negative than positive, one could see how feelings of inadequate self-efficacy could hinder the progress of inquiry teaching and rigorous science learning.

Teacher Practice

A teacher’s practice results from a multitude of feelings, beliefs, ideas, and past experiences that combine to create a philosophy or creed by which that teacher performs his or her work. The decisions that result from this philosophy can go far in influencing a teacher to undertake the challenge of instituting inquiry science in his or her classroom, as is stated in the National Research Council’s (1996) NSES:
The decisions about content and activities that teachers make, their interactions with students, the selection of assessments, the habits of mind that teachers demonstrate and nurture among their students, and the attitudes conveyed wittingly and unwittingly all affect the knowledge, understanding, abilities, and attitudes that students develop (p. 28).

Although many believe that the teacher’s role in promoting the proper environment to foster inquiry science is crucial (Bianchini & Colburn, 2000; Dunkhase, Hand, Shymansky, & Yore, 1997; Hewson, Beeth, & Thorley, 1998), it is difficult for the teacher to be successful without support (Sivertsen, 1993).

Research from the past few decades has indicated that the most effective way to combat negative beliefs or the use of traditional teaching practices in science is through the use of professional development (Sivertsen, 1993; Sottile, Carter, & Watson, 2001). Although including support from colleagues and experts is essential, even something as simple as a one-day hands-on science workshop can begin to shift one’s attitudes. In their study of kindergarten through eighth grade teachers’ feelings before and after encountering hands-on science activities, Sottile, Carter, and Watson (2001) found that in-service teachers felt more confident in planning inquiry lessons, performing science demonstrations, and serving as a science tutor for another teacher after the hands-on lesson. What may also give teachers more confidence in attempting inquiry science is the idea that teachers need not approach it similarly (NRC, 1996).

Inquiry Instructional Methods and Techniques

There are many instructional techniques and approaches that support inquiry-based teaching. Jeanpierre (2003) cites questioning, discrepant events, and the 5E learning cycle model and Bianchini and Colburn (2000) include the learning cycle, on which the 5E model was based. As mentioned in the above discussion on constructivism and conceptual change, a teacher must
“get to know” her students’ quite well in order to identify their current conceptions and then assist in modifying students’ beliefs that more closely follow accepted science. One method for doing so is questioning. The teacher’s questioning strategies are central to the success of the inquiry and poorly asked questions can be quite detrimental to students (Bianchini & Colburn, 2000). Although the teacher’s questions are crucial, students’ questions are equally as valuable in an environment of scientific inquiry. As stated in the NSES, inquiry requires students to ask questions and engage in critical thinking as well as carry out inquiry activities. Utilizing discrepant events is also valuable in creating a state of disequilibrium (Jeanpierre, 2003) or the anomaly required for conceptual change to take place. Insightful questioning by the teacher is also critical during a discrepant event demonstration. The next step is implementing these strategies into an inquiry-teaching model.

Questioning and discrepant events are just two techniques that support inquiry-teaching methods such as the learning cycle and the 5E Learning Cycle Model. In this study, the 5E Learning Cycle Model was selected because of its connections to constructivism and conceptual change.

5E Learning Cycle Model

One way to address constructivism, conceptual change, and inquiry learning in a classroom setting is through the 5E learning cycle model. Modified from the SCIS (Science Curriculum Improvement Study) learning cycle presented by J. Myron Atkin and Robert Karplus (1967) in the 1960’s, the 5E instructional model was developed in the late 1980’s as a component of the Science for Life and Living curriculum created through the Biological Sciences Curriculum Study (BSCS) (Bybee & Landes, 1990). According to Bybee (1997) the work of German philosopher Johann Friedrich Herbart, in addition to that of John Dewey and
Jean Piaget also influenced this model (p. 168), which has been modified over time to include 3E, 4E, and 7E variations. Given the input of such influential contributors to educational research, it should be no surprise that the 5E model is rooted in constructivism and is supported by research that addresses methods for conceptual change (Bybee & Landes, 1990).

According to Bybee and Landes (1990), “the objective in a constructivist program is often to challenge students’ current conceptions by providing data that conflict with students’ current thinking or experiences that provide an alternate way of thinking about objects and phenomena” (p. 96). Expanded from Karplus and Atkin’s (1967) learning cycle stages of exploration, invention, and discovery, the 5E model meets these conditions for conceptual change by having students “redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment…and interpret objects and phenomena” (Bybee, 1997, p. 176). What is expected of students as they proceed through these experiences is explained through the introduction of the 5E model steps.

Indications of constructivism in the 5E model are evidenced in the first phase, *engagement*. Here, students’ prior knowledge of a concept is elicited and connections to present and future topics are encouraged. Typically a discrepant event, questioning, or some other act secures the learners’ attention and interest in the topic (Bybee, 1997). The instructor’s role in this phase is key as she is expected to “raise questions and problems, create interest, generate curiosity, and elicit responses that uncover students’ current knowledge” (Bybee, 1997, p. 178). Quite possibly, this is the most critical phase of the model; if the material is not presented well, students may not make the necessary associations to fully interact with the topic and the remaining phases become meaningless.
During *exploration*, it is meant for all students to “have common, concrete experiences upon which they continue building concepts, processes, and skills” (Bybee, 1997, p. 177). With all students sharing the same activities, a point of reference is formed for later discussions and connections to past and future investigations. The teacher’s role during exploration is that of a facilitator as she encourages cooperative group discussions by asking guiding questions and serves as a resource for students. In a study conducted by Lindgren and Bleicher (2005) preservice teachers who were learning the learning cycle found this stage to be central to the process as they were able to “explore, discover, investigate, and act like a scientist” (p. 69) during this phase. Cooperative learning is also employed in this phase, which likely leads to rich discussions among students and perhaps a state of disequilibrium as they might begin to combat misconceptions and experience a conceptual change through their inquiry (Bybee, 1997).

The crux of the *explanation* phase is “to present concepts, processes, or skills briefly, simply, clearly, and directly” (Bybee, 1997, p. 180) and so one can see how the role of the teacher is so pivotal during this phase. As she assists students in understanding the connections between their own interpretations and formal science phenomena, many instructional strategies such as videos, software, and literature are utilized. At the beginning students are asked to provide their explanations from events during the explore phase and then the formal science language is introduced (Bybee, 1997). In addition to simply providing their own thoughts, students are also expected to listen to and question others’ explanations, which in turn enhances their own learning.

As the meaning of the word states, in the *elaboration* phase students are encouraged to extend their understanding of a scientific concept past what they have experienced through the previous three stages. In Bybee’s (1997) words “generalization of concepts, processes, and skills
is the primary goal of the elaboration phase” (p. 181). To achieve this goal the teacher encourages students to use formal science terms as they complete related activities and identify alternative ways to explain phenomena. Those who still hold misconceptions or have not yet achieved dissatisfaction with their current ideas may be able to clarify their perceptions through this extension of learning (Bybee, 1997).

As with all effective instructional methods, there must be a stage in which students’ understanding of concepts must be gauged and in the 5E model that is the evaluation phase. Although some type of informal evaluation has been occurring throughout the inquiry, in this phase it is specific to formal assessment (Bybee, 1997). This assessment though is not in the form of a multiple-choice test. On the contrary, evaluation in the 5E model includes open-ended questions or demonstrations and often-times probing questions that will lead to the next inquiry. Also unique to other types of assessment is the student’s opportunity to evaluate his own understanding and growth in relation to the concept in the 5E model (Bybee, 1997).

Apart from its completeness and foundations in research, a learning model cannot “make” students learn on their own. “A learning model does not prescribe a unique set of teaching sequences and strategies; and a particular teaching strategy does not determine the type of learning that will occur” (Hewson, Beeth, & Thorley, 1998, p. 199). Bianchini and Colburn (2000) found the role of the classroom teacher to be pivotal in leading discussions, answering questions, and modeling the ideas supporting the natures of science, which in turn guided the students toward a more conceptual understanding of science. Although the 5E model is conducive to providing the experiences necessary for conceptual change, it is only through the questioning techniques and awareness of the instructor that this model proves effective (Bybee, 1997; Bybee & Landes, 1990). Neither can these changes be undergone in isolation; students
need the opportunity to confer, argue, and share with others to confirm their own thoughts and explanations, which is why cooperative learning is imperative for success in science.

**Cooperative Learning**

In order for conceptual change, dissonance, disequilibrium questioning, and debating to take place there must be a forum in which to do so which the traditional classroom does not provide. “At its best implementation, cooperative learning interweaves cognitive behaviours with social skills such as active listening, responsibility, dependability, mutual respect, helping and sharing behaviours, positive-social interaction, respect for others, emphatic sensitivity to people and concerns towards the environment” (Lazarowitz & Hertz-Lazarowitz, 1998, p. 452).

Although this knowledge may seem commonplace to those who practice scientific inquiry, in this instructional setting cooperative learning is as integral as questioning and discussion. Although cooperative learning refers to more than just placing students in groups, the terms cooperative learning, cooperative grouping, and small-group work are typically used synonymously. The true type of cooperative learning, explored by Johnson, Johnson, and Scott (1978), has confirmed for educators and researchers alike that students who are taught in cooperative group settings learn more and feel better about themselves with regard to their education, than do their same-aged peers who learn individualistically. Since the early 1960’s, teachers, researchers, principals, and other educational experts have been utilizing and researching cooperative classrooms all over the world and have found that, particularly in science, that there tends to be positive trends in learning associated with cooperative learning (Lazarowitz & Hertz-Lazarowitz, 1998).

For several decades now, the United States has been aware that its students are considerably behind those from other countries in the area of science. Porter (as cited in
Mulryan, 1995) and numerous others have identified current instructional methods as part of the problem, and so part of the solution must be a change in these approaches. As stated very powerfully yet plainly by Bybee and Landes (1990) “cooperative learning is not ancillary” (p. 93) in effective science learning models. In individualistic learning settings, students have a tendency to hide their ideas and work from others, as they feel they are in competition for grades, peer recognition, and teacher praise (Johnson & Johnson, 1990). An effectively implemented cooperative approach ensures that all students in a group feel valued and learn from one another, therefore increasing learning potential.

Self-efficacy in cooperative learning situations affects more than just a student’s academic constructs; it also affects his or her social and emotional well-being. Through his research on cognitive development and functioning, Bandura (1993) found that a person’s ability to complete a task is more dependent on his or her feelings toward it than with actual intellectual capacity. For example, he states, “Ability is not a fixed attribute…it is a generative capability in which cognitive, social, motivational, and behavioral skills must be organized and effectively orchestrated to serve numerous purposes” (Bandura, 1993, p. 118). Like that which is experienced in small-group exchanges, all components of a person’s ability are tapped in cooperative situations. The opportunity for students to share their strengths, regardless of academic or social abilities, is perhaps one of the strongest points of cooperative grouping.

Researchers have found that cooperative learning can also be quite beneficial for students with mild disabilities, particularly in the area of science (Pomplun, 1996). In the NSES, Program Standard E also addresses and supports the principle that all students should be provided with access to high-level science teaching. Regarding achievement, Scruggs and Mastropieri (1994) found that students with mild disabilities learned and recalled more when taught with an inquiry-
oriented approach, compared to textbook-based instruction. One proposed reason for this success is that students who are actively engaging in learning are building upon prior knowledge through these concrete experiences. Although the concrete experiences were easily internalized, learning terminology and other factual information was difficult for students to retain (Scruggs & Mastropieri, 1994). These statements have considerable implications for this study because of the percentage of students with mild disabilities in the research setting.

Summary

The number of articles and studies that have investigated the use of inquiry science as a worthwhile teaching and learning method and reported on students’ science conceptions is expansive. This brief review provides support for the argument that as teachers become more confident in their practice and therefore in themselves, it is likely that this will have a direct impact on their students as well. Von Secker (2002) and others reiterate this, as their research supports the claim that students’ achievement and attitudes improve after exposure to science as inquiry (including cooperative learning) as opposed to other customary teaching methods. With regard to the development of students’ initial science frameworks, computer-based instruction, inservice programs, demonstration through modeling, and the use of constructivist teaching strategies have all been offered as solutions in an attempt to combat and “right” these misconceptions (Kikas, 2004; Monaghan & Clement, 1999; Reiner, Slotta, Chi, & Resnick, 2000; Tao & Gunstone, 1999). Bearing in mind the source of students’ conceptions is as extensive as the potential remedies, it seems this field of research is destined to expand. Those eager to identify additional underlying principles that surround the subject will likely begin to include political leaders as they continue to search for explanations as to why United States’ schools fail to be competitive internationally. Regardless of the thousands of research studies that
have been conducted about students’ prior conceptions of science and how these beliefs affect their future scientific encounters, there is little evidence that this issue has been implemented or discussed in current curriculum. Although these deep-rooted ideas often affect students’ understanding of science concepts, rarely are they addressed in instruction (Driver, Leach, Scott, & Wood-Robinson, 1994). With children formulating these frameworks as mere toddlers (Reiner et al., 2000) it is difficult to know if such deep-rooted schema can ever be reversed or remedied, but it is certain that traditional teacher methods are not the solution. As the country embraces the call for scientific reform supported by the NRC (1996) and AAAS (1989), it is hoped that teachers and students across the nation will willingly embrace what countless researchers, educators, and students have already discovered.

Having presented a review of previously conducted research, the following chapter details the methodology that was used to address the research questions in this study.
CHAPTER THREE: METHODOLOGY

It is quite difficult to transfer a personal love and enjoyment of science into creating an environment that fosters young minds to feel similarly. Although student-generated data were crucial components of this action research study, it is truly the premise of the previous statement that sets the foundation for this research. With an enthusiasm for science, I felt that in the past my teaching methods meant to support this interest were not effective in creating an inquiry rich classroom setting. Because data were not previously available to confirm such a conclusion, it was deemed necessary to proceed through a structured transformation of teaching methods to address the following research questions:

1. How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher?
2. How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion?
3. How does the implementation of an inquiry science model affect students’ perceptions of science in general, how they learn science, and how they view science outside the school setting?
4. How do science misconceptions present themselves in the study and affect the instruction of the teacher?

With data support to measure the effectiveness of the proposed change it would then be clear whether a modified approach produced increased student performance and interest in science. Both quantitative and qualitative data collection methods were used in this study in order to investigate the research questions previously presented. The data collection approach implemented in this study included the use of filmed individual interviews, filmed classroom
discussions, lab sheets, field notes, pre and post surveys, and pre and post knowledge assessments to ascertain best the results of this inquiry.

Model/Design

With my instructional methods at the focal point of the study, the type of research conducted falls under the realm of “action research”. Although deemed by some as an invalid form of research because of its limited scope and informality, it can in fact be far more practical for educators than other types of educational research (Gay & Airasian, 2003, p. 168). As defined by Mills (2003), action research is “any systematic inquiry conducted by teacher researchers, principals, school counselors, or other stakeholders in the teaching/learning environment to gather information about how their particular schools operate, how they teach, and how well their students learn” (p. 5). Various approaches and models of action research exist in great number but all include the following four crucial components: (1) identifying an area of focus; (2) collecting data; (3) analyzing and interpreting data; (4) developing an action plan (Mills, 2003, p. 20). Taking into consideration the sociological roots of action research, this type of personal investigation tends to be primarily qualitative in nature, but the analysis applied to this study can also be classified as quantitative data analysis (Mills, 2003, p. 4). In relation to this study, quantitative techniques were used to examine the results of pre and post surveys and assessments, while qualitative analyses applied to the review of activity sheets and filmed discussions and interviews. Once the processes of the study were completed and the data evaluated it was my charge to share the results with colleagues and to aid other teachers in the school in the implementation of these teaching practices in their classrooms. It is this call for action that differentiates action research from other forms educational inquiry.
The link between teachers and educational research has been and continues to be one plagued with strain. Kennedy (1997) sheds some insight as to why such discord exists between those who teach and those who influence the educational world beyond the classroom. She hypothesizes that in the past educational research (1) has not been perceived by teachers as convincing; (2) is not deemed by educators as applicable to their daily practice; (3) is not presented to teachers in understandable terms; and (4) the trends and findings that the research supports are not designed to transfer to United States’ classrooms (p. 4). It is this final statement that provokes frustration from this teacher researcher and supports why science and inquiry were chosen as topics for this investigation. As illustrated in Chapter 2, there is no shortage of research claims confirming the effectiveness of an inquiry approach to science and certainly little confusion in how to implement the instructional techniques associated with this method, yet the realization of its relevance has certainly not swept the nation. This is why action research is so crucial; it can serve as a bridge between the research conducted beyond the school walls and the methods practiced daily inside classrooms (Tabachnick & Zeichner, 1998). Hopefully sharing this journey with fellow educators will help them realize the relevance of teacher-led inquiries and they will see that educational research is not complicated, time-consuming, or peripheral to their professional growth, but integral and practiced informally by many of them on an almost daily basis. And therein the power lies. In a time when sweeping educational reform has many educators feeling powerless, teachers can still have control over what takes place in their classrooms and can proclaim, with evidence through inquiry, what instructional practices are productive for both teachers and students.

As Kennedy (1997) noted, the bulk of educational research remains idle in academic journals, however, Zeichner and Klehr (1999) have found that when conducting action research
teachers (1) become more confident about their ability to promote student learning, (2) become more proactive in dealing with difficult situations that arise in their teaching, (3) acquire habits and skills of inquiry used beyond the research experience to analyze their teaching, and (4) develop or rekindle an excitement about teaching (p. 17). Evidence also supports positive student outcomes (Zeichner & Klehr, 1999), which is likely the goal of all teachers—to become more effective educators and in turn create a more productive learning experience for their students and themselves. Another added benefit of teacher research is the collaboration that occurs among educators; action research is not intended to be undertaken alone (Tabachnick & Zeichner, 1998). Much of the foundation of reflective practice is established through sharing and collaborating with others, which in turn is infused with each participant’s approach to action research.

The essence of action research is continuous reflection and problem solving meant to impact student achievement and one’s instructional practice (Mills, 2003, p. 10). The choice to use action research and the 5E Learning Cycle Model illustrates that I have embraced the true essence of action research for this study.

As previously mentioned, I was initiating an inquiry learning model for the first time as part of this action research. For my benefit and the benefit of the participants a 5E Learning Model was used to facilitate instruction. There is a continuum of instructional approaches labeled as “inquiry.” Some forms of inquiry include a role for the teacher whilst others hold the students responsible for nearly all of their own learning. Choosing the latter would have been disastrous for the students participating in this study because of their inexperience with any sort of inquiry. The situation would be akin to teaching a child to ride a bike by entering her in the Tour de France. Not only would the child be destined to fail, but also she would learn nothing in the
process. The same outcome would likely be true if I had implemented an unstructured inquiry approach for this study. Although I learned the foundations of inquiry, the absence of practice was what spawned this research study. Implementing a methodology that was too demanding would have likely negated the essence of action research and in turn fostered feelings of inadequacy and frustration.

Setting/Participants

Those participating in the study were 22 fifth grade students at a suburban Central Florida elementary school with approximately 520 students in grades Prekindergarten through fifth. The students ranged in age from 10-12 years old, which may or may not be representative of other fifth grade classrooms because of factors such as retention. The school’s ethnic representation was as follows: White 45%, African American 34%, Hispanic 17%, Asian 2%, Other 3% (FileMaker Pro, Feb. 2006). Additionally, approximately 57% of the students at this school received free or reduced-priced lunches, 14% were in English Speakers of Other Languages (ESOL) programs, and 16% were in Exceptional Student Education (ESE) programs (FileMaker Pro, Feb. 2006). These students’ ethnic, ESOL, and ESE representation is as follows: White 50%, African American 32%, Hispanic 14%, Other (Guyanese) 5%, ESOL 5%, ESE 45%. Of this 45%, two had been identified as gifted, one as “other health impaired” (diagnosed with ADHD), and seven had learning disabilities. Eight out of ten of these students received ESE services for a condition that negatively impacted their ability to learn, which also impacted how groups were formed, lessons were structured, and assessment items were administered.

With regard to the nature of this research study, a purposive sampling process was required. These students were selected because I was an instructor at the school in which the participants were currently enrolled. Although this type of student sample may not be
representative of other fifth grade classrooms, it was the purpose of this study to examine the researcher’s teaching practices and not necessarily for generalizations and effect statements to be made regarding the modeled instructional methods and student outcomes.

The University of Central Florida Institutional Review Board, Orange County Public Schools (OCPS), and the principal at the previously mentioned educational setting granted permission for the research to take place (see Appendices A & B). In order to participate in the study, the students and their parent(s) signed a consent form (see Appendix C).

Instruments

Pre and Post Science Perception Survey

Although science attitude surveys abound in educational research, many of these measurement tools aim to evaluate simply that--attitudes. My interest in students’ ideas about science lay deeper than if they simply liked the subject or not. More relevant for this study was to know how the students believed they learned science and if they believed it affected their lives outside school walls. Thus, to satisfy the purpose of the research, a longitudinal survey was created and titled “Science Perception Survey” (see Appendix D). To ensure anonymity, each student chose a number from 1-30 that they would use as their identification throughout the study. I hoped that this would encourage the students to be more honest with their responses. The questionnaire included eight Likert scale items (1=Strongly Agree; 2=Agree; 3=Disagree; 4=Strongly Disagree) with a free response option following each statement. Questions 1-2 assisted in communicating students’ general view of science as a school subject. Targeting how students felt they learned science content was the focus of questions 3-4 and students’ views of science outside the parameters of a school environment were the focus of questions 5-8. As Gay and Airasian (2003, p. 288) suggest, similar-aged students not directly involved in the research
pilot tested this self-reporting instrument. To support content validity, it was also distributed to
approximately ten teachers for their input regarding clarity and completeness.

After the field-tested surveys were returned, the responses were recorded and analyzed
per question and by cluster.

Table 1. Results of Field-Tested Surveys 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Male</th>
<th>Cluster 1-2</th>
<th>Female</th>
<th>Cluster 1-2</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.6</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
<td></td>
<td>2.6</td>
<td></td>
</tr>
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<td>3</td>
<td>2.2</td>
<td>2.0</td>
<td>2.3</td>
<td>2.2</td>
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<tr>
<td>4</td>
<td>1.8</td>
<td></td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.8</td>
<td>2.4</td>
<td>2.5</td>
<td>2.7</td>
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<tr>
<td>6</td>
<td>3.1</td>
<td></td>
<td>3.4</td>
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<td>2.3</td>
<td></td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2.3</td>
<td></td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Standard Deviation 1.4
n=23; male =12; female=11

Cluster definitions: 1-2 science as a school subject; 3-4 how students learn science; 5-8 science
outside the classroom

Table 2. Results of Field-Tested Surveys 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Male</th>
<th>Cluster 1-2</th>
<th>Female</th>
<th>Cluster 1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
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<td>8</td>
<td>1.7</td>
<td></td>
<td>2.5</td>
<td></td>
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</tbody>
</table>

Standard Deviation 1.6
n=21; male =11; female=10

Cluster definitions: 1-2 science as a school subject; 3-4 how students learn science; 5-8 science
outside the classroom
Table 3. Results of Field-Tested Surveys

<table>
<thead>
<tr>
<th>Question</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Score per Question and Cluster</td>
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</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>1.5</td>
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<tr>
<td>2</td>
<td>1.7</td>
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<td>3.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

Standard Deviation 2.4

n=12; male=6; female=6

Cluster definitions: 1-2 science as a school subject; 3-4 how students learn science; 5-8 science outside the classroom

The teachers’ feedback also proved beneficial and changes were made to the survey accordingly. A few teachers expressed that the students did not understand the purpose of the lines beneath each question and as a result the sentence, “If you choose, add clarification to your answers on the lines” was added to the directions. The teachers also mentioned that the wording of question seven was confusing to some children, so the words in that statement were rearranged. Lastly, the phrase “I think” was added to the beginning of statements one, two, and five in order to emphasize the views of the student rather than those of a teacher or parent. In administering the survey to the participants in the research, the questions were read aloud to the students, with explanations added when necessary.

Pre and Post Knowledge Assessment

Traditionally, it is in the late elementary and beginning middle-school grades that students begin to learn formally about concepts related to force, motion, and physics. Consequently, that made it difficult to find a pre-made assessment that was age-appropriate for
this action research inquiry. Many of the current tests (Force Misconception Test (FMT), Force Achievement Test (FAT), Force Concept Inventory (FCI)) were designed for high school or college students, which again required me to develop an assessment tool specifically for this study (see Appendix E). Once the student activities for the study were identified, activity objectives were turned into test questions that coincided with the action research study inquiries. Developing a supply item test matched the purposes of this study as this format allowed for students to demonstrate their true understanding of a topic rather than potentially guessing a correct answer.

Again, in accordance with the recommendations of Gay and Airasian (2003, p. 151), the test was completed by groups of fifth grade students not directly involved in the study and given to teachers for their input. When reviewing the field-tested items and the recommendations from other teachers and university staff, several changes were made to the knowledge assessment. One teacher suggested adding a “word box” so that students would still have the opportunity to demonstrate their knowledge even if they could not recall the term. This suggestion was noted, but because of the low number of questions that could be answered singularly, the option of “drawing the tool” was added for items 1-3.

1. Draw/name the tool that would be used to measure the mass of a tennis ball? 

2. Draw/name the tool that would be used to measure the distance a tennis ball rolled? 

3. Draw/name the tool that would be used to measure the amount of time it took a tennis ball to roll 10 m?

Figure 1. Questions 1-3 on knowledge assessment after changes.

Regarding question four, 46% of students who completed the field-tested version answered that they would use a radar gun or speedometer to determine the speed of an object as it was rolled
down a sidewalk. When creating the question I surmised that the use of the term “sidewalk” would discourage students from thinking of the speed of cars and other vehicles, but apparently this was not the case. For the final version of the assessment “tennis ball” was traded for the word “object” in hopes that this would discourage students from thinking about the use of a radar gun to determine speed.

4. How would you determine the speed of a tennis ball that was rolled down a sidewalk?

Figure 2. Question 4 on knowledge assessment after changes.

The goal of each question was to assess a specific force and motion concept or science process skill. Questions 1-3 and 10-12 were created to gauge students’ knowledge of science process skills and to determine if the students were able to organize and graph a set of data. Speed and acceleration were the topics for questions 4-6 so that the students’ knowledge of speed and the difference between the two concepts might be evaluated. The students’ understanding of friction and force was the focus of questions 7-9. Additional instructions were to label which of Newton’s Laws would be associated with items 6-9, but none of the students were aware of these laws, so that portion of the test was not required.

Lab Sheets

Lab sheets were distributed and collected from each participant for each activity throughout the study. Following the 5E model, each lab sheet included a hypothesis statement, lab guidelines specific to the activity, a data-recording table, and questions. The lab sheets allowed students the opportunity to practice the science process skills they were so greatly
lacking, to show if the ideas and thoughts they shared during discussions were mirrored in print, and also to verify if learning was taking place.

_Filmed Whole-Class Discussions and Individual Interviews_

Class discussions typically took place at the end of a lab activity as questions were being answered and situations that occurred during lab work were revealed. As supported by Wheatley (1991) class discussions are a valuable component of a constructivist mathematics or science classroom as they “provide a forum for students to construct explanations of their reasoning” (p. 19). It was necessary to film such discussions, so that my ability to facilitate the talks would not be compromised by record keeping. It was a concern of mine that students would react to the inclusion of the video camera in the classroom environment, yet they did not notice it, on all occasions, until the filmed discussion period had ended.

After the final assessment was completed it was discovered that although it appeared in classroom discussions that students could discuss force and motion concepts, that knowledge was not transferred to paper. Data supporting this assertion is presented in Chapter 4. As suggested by Gay and Airasian (2003, p. 291) interviews were completed with the students in order to obtain more accurate responses and to include information that was beyond the scope of the assessment. While comparing the pre and post assessments, questions and opportunities for elaboration were noted for each student and then asked during a later interview session. Questions and length of interviews tended to vary per participant based on their responses, but were essentially focused on the same assessment questions for each student. Using the DVD recorder allowed for a more objective analysis of the interviews versus writing students’ responses during the questioning process.
Procedures

Several observations were made prior to the researcher’s formal introduction to the classroom. Namely, it was recognized that students would need opportunities to practice carrying out science process skills that complement the scientific method before engaging in force and motion labs directly. The order and steps of the scientific method can vary in each instructional setting. The steps used in this research situation are as follows: (a) State the problem, (b) gather information, (c) formulate hypothesis, (d) perform experiments, (e) record data, (f) reach a conclusion, and (g) repeat if necessary (Jones et al., 2000). It is not only the NSES that guide a Florida educator’s instruction, but also the Florida Sunshine State Standards as laid out by the Florida Department of Education [FL DOE](1996). Within the Sunshine State Standards for science there are several content strands, and this study focused on the following: Strand A: The Nature of Matter, Strand C: Force and Motion, and Strand H: The Nature of Science (FL DOE, 1996). Although many benchmarks were investigated throughout the course of the study, grade level expectations used most frequently were as follows:

- **SC.C.1.2.1** The student understands that the motion of an object can be described and measured.
- **SC.C.2.2.2** The student knows that an object may move in a straight line at a constant speed, speed up, slow down, or change direction dependent on net force acting on the object.
- **SC.C.2.2.3** The student knows that the more massive an object is the less effect a given force has.
- **SC.C.2.2.4** The student knows that the motion of an object is determined by the overall effect of all of the forces acting on the object.

For a complete list of benchmarks investigated in the study, please see Appendix F. These learning objectives would fall under the NSES Content Standards A and B for grades 5-8 (NRC, 1996).
As is the case for many educators, the curriculum used to support the lessons in this action research study came from many sources. *Where in the World Are My Peanuts, It’s a Bird, It’s a...,* and *Speed* were activities created for OCPS teachers by the OCPS Curriculum Services Department. These lessons, among others online, correlate to the Sunshine State Standards (FL DOE, 1996), utilize the 5E Model, and are provided for educators’ use. With the definition of action research in mind, it was also the intention of this researcher to use curriculum that would be viewed by other OCPS educators as easily accessible and uncomplicated. In hopes that other teachers would see the value of inquiry science, the more structured 5E Model lessons were used as a method of instruction that would likely replace traditional teaching methods. The *Average Joe* lab was selected from the AIMS (Activities Integrating Math and Science) book *Jaw Breakers and Heart Thumpers* (1987). Permission was granted via email to use the activity. A guide for the remainder of the activities was *Methods of Motion: An Introduction to Mechanics* (Gartrell, 1992) published by the National Science Teachers Association (NSTA). Although no lab activities were directly photocopied from the book, permission was granted for use. (see Appendices G & H for permission letters) The labs gleaned from this resource were *What’s Mass Got to Do With It?*, *How Much Force?*, and *Balloons and Cannons*. A more in-depth description of these activities is given in Chapter 4.

In addition to their knowledge of the scientific method, the students’ awareness of the relevant science process skills was also in question; therefore, time was taken to develop a student handbook of the science process skills. Although the list of skills necessary to complete science activities varies per source, the set adopted for this research is that used in the county-adopted text (Jones et al., 2000): (a) observing, (b) predicting/inferring, (c) measuring, (d) classifying, (e) communicating, (f) identifying/changing/controlling variables, (g) hypothesizing
(p. 38). After these skills were discussed, each student made a small booklet notating each scientific process. Page by page, the participants brainstormed examples of how each skill would be carried out and then sketched or described them in their individual booklets. Students were encouraged to reference and/or add to their booklets throughout the duration of the study. At this time, students were also introduced to the various roles they would undertake throughout the study. As a whole-class activity, students took turns reading the descriptions from their job tags and making suggestions as to how each job should be executed. I also created scenarios that could happen during an activity and the participants offered the job description that would be responsible for the undertaking and how the fictional issue could be resolved. The students were reassured that each would have the opportunity to carry out every job throughout the duration of the research. The jobs and responsibilities were as follows:

* **Lead Scientist**
  - ensure the safety of your team
  - make sure all procedures are followed
  - keep your team on task
  - initiate discussions/ask questions

* **Materials Manager**
  - retrieve and return lab materials
  - distribute materials to team
  - ensure science tools are used correctly
  - clean and inspect materials for damage

* **Chief Communicator**
  - communicate needs to other teams/teacher
  - add questions to KWL or question chart
  - ensure team is prepared to share findings

* **Primary Observer**
  - view activities occurring at a distance
  - communicate observations to team/recorder
  - aid team in summarizing observations

* **Data Recorder**
  - distribute recording sheets to team
  - record data from lab activities
  - ensure that team data is consistent
  - present findings to class/group

Cooperative grouping in science can oftentimes differ from cooperative grouping in other subjects. For instance, in mathematics students are often ability grouped and in elementary classrooms students are frequently arranged this way in the classroom for the duration of the day.
In this classroom students’ desks were arranged in pairs and they worked cooperatively only during science. With a rather large percentage (45%) of the class receiving exceptional education services, ability grouping was necessary for this study to ensure that someone in each group would be able to read the questions on the lab sheet, process oral information, etc. Within each group was a child designated as high, mid-high, mid-low, and low based on classroom teacher input. Groups requiring a fifth member contained either an additional high or mid-high. Students remained in the same cooperative groups for the duration of the study.

Limitations to Implementation

Several limitations presented themselves throughout the duration of the study. The participation of a relatively small number of students with backgrounds that may or may not represent other elementary classrooms affected how these results could be applied. Additionally, my role as only a “science teacher” and not the classroom teacher should also be noted. Limited interactions with the students affected the dynamics of the research setting regarding student behavior and continuity of instruction. Furthermore, the amount of time spent on science instruction also greatly differed from the time spent on other subjects. As mentioned previously, the current focus of standardized testing on math and reading (Jorgenson & Vanosdal, 2000) translates into a greater amount of time spent on these subjects (3½ hours), with a mere 45 minutes devoted to science instruction four, rather than five times weekly. These 45 minutes might seem considerable compared to the average 16 minutes per day that elementary school students receive nationwide (Winters Keegan, 2006). Compounding this shortage of science instruction was student absences. Throughout the duration of the study six students missed more than 5 days of school, equivalent to a week’s worth of science lessons. Oftentimes science time
was exchanged for an end-of-the-day movie or other non-academic activity. Not having control over how class time was spent exacerbated many of the formerly outlined limitations.

Methods of Data Collection

In order to ensure the validity necessary for a quality action research study, Mills (2003, p. 78) reports that trustworthiness must be evident in the data collection process. In short, this means the data collected should reflect the study in its entirety, the good and the bad, through triangulation methods. Triangulation is “a form of cross-validation that seeks regularities in the data” (Gay & Airasian, 2003, p. 246) by evaluating the various elements of the study. In this particular inquiry, evidence of student understanding of force and motion concepts was compared across multiple data collection method, which uncovered the themes discussed below.

Triangulation was achieved partly by the administration of pre and post knowledge assessments, pre and post science perception surveys, and conducting interviews. All of these procedures took place at the beginning and/or end of the study to evaluate the change in knowledge of force and motion concepts. Prior to the commencement of the study, field notes were considered as a method of data collection; however, once the inquiry period began it was found much too difficult to teach effectively and take accurate field notes. The field notes were ultimately replaced by the filming. For the period of study, lab sheets were collected after several days of working on an activity and after whole class discussions. Filmed class discussions and demonstrations took place weekly after the second activity. Filming did not begin immediately because of the students’ inexperience with setting up labs and conducting inquiries. Collection of all of these various types of data supported triangulation and allowed for analysis of students’ verbally demonstrated understanding of force and motion concepts, as well as the effectiveness of the researcher in implementing guided inquiry into the classroom environment.
Methods of Data Analysis

Analyzing data in qualitative research differs notably from analysis in quantitative research. It is believed by Gay and Airasian (2003) that “data managing, reading/memoing, describing the context and participants, and classifying” (p. 229) are necessary steps for properly interpreting these types of data. Although some descriptive statistical analysis was applied to the knowledge assessment and perception survey results, qualitative examination of interviews, discussions, and lab sheets were more favorable for identifying emerging patterns or themes in the study.

As the first stages of analyzing began, it was recognized that the understanding students had shown in discussions and throughout the labs was not evidenced on the post knowledge assessment. Student answers for the questions on the lab sheets were very vague, which is likely due to their inexperience with inquiry science and writing in content areas. It was because of this emerging theme that the interviews were conducted. In researching clinical interviews and how they can be used to identify conceptual change, Posner and Gertzog (1982) explain that one feature enables the researcher to “elicit and collect specific kinds of information” (p. 196), which was the purpose of these questioning sessions. During the interview process students were asked for elaboration on their answers and asked specific questions to prompt more thorough explanations than were viewed on paper. An expansion of this theme can be viewed in the data pyramid.
Patterns

Teacher adaptation to student differences in understanding of force and motion concepts.

Categories

Students’ Oral Understanding of Force and Motion Concepts

Students’ Written Understanding of Force and Motion Concepts

Topics (data pieces)

Interviews  Filmed Discussions  Filmed Labs  Pre/Post Knowledge Assessment  Pre/Post Perception Survey  Lab Sheets

Figure 3. Pyramid showing topics and categories to support emerging theme.

The lab sheets were also analyzed to uncover any misconceptions the students might hold about a topic and also to decide if the students, based on their answers to the questions, were prepared to move on to the next activity. Although additional information was gleaned from the knowledge assessments through interviews, it was beyond the capacity of this study to complete similar interviews when student understanding was unclear on the lab sheets. This vagueness made it difficult to analyze the answers to find understanding of concepts or common misconceptions. It was also a challenge to determine the amount of time needed to address how to write specific and clear answers, discuss misconceptions, and perform labs. This was perhaps one of the most demanding aspects of the inquiry.

In Chapter 4 a more in-depth analysis of data is conducted as well as specific examples of student work as they relate to the study.
CHAPTER FOUR: FINDINGS

Introduction

As mentioned previously, the students who participated in the research were not members of my own classroom, and therefore, during the first few weeks of school, I spent time observing how the classroom teacher (with primary instructional responsibilities) conducted her science lessons. Because of my role as a co-teacher during the current school year and in years past, I knew that most intermediate grade teachers taught science using a more traditional approach: they primarily used the textbook and the students “learned” science from their seats. The science instruction in this classroom initially followed this same format. Physical properties was the first topic of study for the year, and students spent the majority of their time gleaning pertinent information from the textbook and demonstrating their knowledge of it by completing multiple choice worksheets. It was then that I realized the objectives of this study would include not only deliberately designed instruction in force and motion concepts, but also components of teamwork and the utilization of science processes like “real” scientists. Before themes and data analysis are reported, it may be beneficial to attain a brief understanding of the lab activities in which students engaged during the study and on which many of the research questions were based. To review, the guiding questions of this study related to the 5E model lessons were: (1) How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher? (2) How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion? and (3) How do science misconceptions present themselves in the study and affect the instruction of the teacher?
5E Learning Cycle Model Lessons

The first lab, *Where in the World Are My Peanuts?* (see OCPS Curriculum Services, 2003), required the students to record observations related to their peanuts’ mass, coloring, texture, width, length, etc. Once these observations were noted, students put their peanuts in a bag with other group members (3), traded recording sheets, and attempted to find their partner’s peanut based solely on his or her observations. Amazingly, all the students in the class were able to find their partner’s peanut. Somewhat skeptical of this outcome, I considered repeating this activity with another observable object or honing the children’s process skills through another lab. Further review of the students’ lab sheets showed that they were riddled with measurement errors. Some of these errors included writing down non-metric units of mass when grams were specified as the appropriate units, confusion of millimeters and centimeters, and recording unrealistic measurements. A few of these errors can be viewed in the student work sample:

![Figure 4. Student work sample from *Where in the World Are My Peanuts?* showing measurement errors.](image)

After viewing these errors, I was encouraged to engage the students in another process skill activity.
Estimating, calculating, and averaging the length of various body parts was the focus of the next lab, *Average Joe* (see AIMS, 1987). As one student suggested, for the purpose of consistency, the class determined what finger, part of the leg, arm, etc. would be used throughout the activity. Once the estimating and partner measuring was complete, a partner average as well as a class average for each body part was determined. Given that the goals of the activity were measuring, graphing, and understanding average, and not necessarily the mathematical skills associated with them, averages were computed with calculators. Recalling the students’ responses on the graphing portion of the pre knowledge assessment, i.e. not having labeled axes, a title, appropriate scale, etc., it was expected that the students would also graph the results of this activity. There was some disagreement as to how the outcomes should be displayed and a brief mini-lesson ensued. Coupling arm motions with a brief description of the three main graph types (circle, bar, and line graph), I modeled and then had the students repeat these actions. For example, the students made a large circle with their arms and stated, “shows parts of a whole” for the circle graph. After this brief elaboration it was agreed that a double-bar graph would best display the partner average and class average of the body part lengths. Because there was no evidence from the pre assessment, a title, labeled axes, and an appropriate scale were modeled and included on the students’ graphs. Students were also expected to write a summary statement derived from their graph regarding the comparability of their partner average versus the class average.

Now that the students had experience practicing various science process skills, it was believed they were now better prepared to begin lab activities directly related to force and motion concepts. Uncertainty with how to calculate speed or the true meaning of it was evidenced by the majority of students in the pre assessment. It seemed logical that before
acceleration and other concepts could be discussed, students would first need to understand the concept of speed. Before engaging in an actual lab activity, *It’s a Bird, It’s a…* (see OCPS Curriculum Services, 2003) the students were assigned their teams and first job titles. Class-wide there were five teams with four to five students in each team. The lack of camaraderie in the classroom was evident and so it was decided that the students would also take some time to develop a team name based on the group’s similarities. After team names were decided and jobs explored, the students organized a deck of cards according to the speed of the item named on the card. The terms on the cards were as follows: plant, Earth, snail, time, rabbit, person, cheetah, ocean wave, radio (wave), car, jet, light. Throughout this portion of the activity, student discourse surfaced as the groups attempted to decide the criteria they would use to evaluate the item’s speed. For example, one group continually argued the rank of the cheetah and car cards. One student said that a cheetah could run as fast as a car, but another group member disagreed saying that it could not run as fast as a racecar. Although the students did debate the placement of many of the cards, it seemed most difficult for them to rank the cards for which they had no point of visual reference, i.e. light, Earth, radio (wave). Once the groups reached consensus, the ranking of each was shared. Consistency surfaced among the order the groups chose, except for the location of the light card. It was asked of the students how they might resolve this disagreement and several suggested checking an outside source. The speed of 186,282 miles per second (Patten, 1996) was shared. This received somewhat of a response of disbelief from the students, although they subsequently changed the placement of the card to the “fastest” in the group.

Once the students had activated their schema regarding speed, their first lab activity addressing force and motion, *Speed* (see OCPS Curriculum Services, 2003), was undertaken. In
this experience, students were required to roll a golf ball a distance of 5 meters and record the amount of time it took the ball to cover this distance. Consistency among groups regarding the force applied to the ball was not deemed necessary as this was the students’ first experience conducting such an activity, with the primary goal of the activity being that of having students experience calculating and observing the speed of an object. I also anticipated that the inconsistencies among the groups in the respective forces applied to the golf ball would lead to a higher quality discussion, and perhaps would lead the students to devise subsequent activities that investigated the effect of greater or smaller applied forces. The process of setting up the lab (measuring the 5 meter distance, coordinating the roll and the start of the timer, etc.) took nearly an entire class period alone and I was surprised and discouraged with the amount of time necessary to complete the activity. Although I was aware of the students’ inexperience with scientific inquiry, I did not have in mind my own inexperience in guiding and managing such labs. In an effort not to revert to traditional methods and simply tell the students what steps were necessary to calculate the speed of an object, several examples of distances and times were placed in a table on the board (i.e. 60 miles in 1 hour equals 60 miles per hour; 20 meters in 10 seconds equals 2 meters per second). The students were asked to observe and then find patterns or relationships within the data in the table, which was not as simple a task as one might assume. It took the students several minutes to determine that division was the operation being utilized to complete the equation. Once this was realized, students were permitted to use calculators to calculate the speed of the golf balls used in the lab activity. Although using decimals as a divisor is a skill that 5th grade students are expected to know (FL DOE, 1996) the purpose of the activity was for students to obtain a conceptual understanding of speed, and completing the calculations for each trial would have taken an excessive amount of time.
The basis of the next lab was discussed informally during the “explain” phase of the preceding lab. The students were asked to recall and then record if they thought the speed of their tennis ball remained the same throughout the roll, or if they remembered it traveling faster or slower at some point during the roll. The students wrote their responses on the previous lab’s data sheet. Based on the students’ answers, the next lab *Does Speed Stay the Same?* (see OCPS Curriculum Services, 2003) was introduced.

When setting up the lab the students found that the ball would not roll the expected distance of 10m and so after several trials the distance was shortened to 2m. During this lab, students calculated the speed of the tennis ball at the 0-1m interval and the 1-2m interval to determine if speed was constant or changing. In hindsight, a longer distance would have likely yielded clearer results. Although the speeds at different intervals did show a change, it was merely tenths of a second.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Distance</th>
<th>Total Time (sec)</th>
<th>m/s Speed 0-1 Interval 1</th>
<th>m/s Speed 1-2 Interval 2</th>
<th>m/s Speed 0-1 Interval 1</th>
<th>m/s Speed 1-2 Interval 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2m</td>
<td>2.16</td>
<td>0.63</td>
<td>0.57</td>
<td>1.0</td>
<td>0.71</td>
</tr>
<tr>
<td>2</td>
<td>2m</td>
<td>2.97</td>
<td>0.61</td>
<td>0.64</td>
<td>1.81</td>
<td>0.56</td>
</tr>
<tr>
<td>3</td>
<td>2m</td>
<td>3.03</td>
<td>0.66</td>
<td>0.64</td>
<td>1.98</td>
<td>0.59</td>
</tr>
<tr>
<td>4</td>
<td>2m</td>
<td>2.80</td>
<td>0.60</td>
<td>0.60</td>
<td>1.03</td>
<td>0.58</td>
</tr>
<tr>
<td>5</td>
<td>2m</td>
<td>2.84</td>
<td>0.64</td>
<td>0.64</td>
<td>1.29</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Figure 5. Student work sample from *Does Speed Stay the Same?* with examples of small interval speed differences.
This slight change in the data proved to be a common theme throughout the research period and a difficult issue to address. How much of a difference is notable? Even if it was only a few tenths of a second difference, would that be enough to signify a change in speed? Velocity, a measure of an object’s speed and direction (and a term that is often used in studies of force and motion), was not introduced in this study. The level of students’ knowledge revealed on the pretest, and the fact that most of the labs included objects moving in a straight line, supported this decision.

The lab, titled *What’s Mass Got to Do With It?*, encouraged the students to explore the inverse relationship between mass and acceleration, which coincides with Newton’s 2nd Law. The term *acceleration* was not used specifically during the course of this lesson. It was projected that the word would be brought up by a student or introduced during the “explain” or “elaboration” phase following the lab. A subsequent activity was planned in which the acceleration of each ball would be calculated. This gradual introduction of the concept was decided upon after evaluating the students’ pre assessment on which 23% of the students stated specifically that they did not know the meaning of acceleration. It was hoped that they would first observe the changes in speed over a given period of time and then the idea of acceleration would follow.

This lab took a week to complete and it seemed as if the discussion following it was equally lengthy. A setup of the lab and materials needed to complete it can be viewed below:

<table>
<thead>
<tr>
<th>Materials:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 dictionaries incline</td>
</tr>
<tr>
<td>balance meter stick</td>
</tr>
<tr>
<td>masking tape basketball</td>
</tr>
<tr>
<td>golf ball baseball</td>
</tr>
<tr>
<td>tennis ball stopwatch</td>
</tr>
</tbody>
</table>

Figure 6. Materials and setup for *What's Mass Got To Do With It?* lab.
To prepare for the lab each group chose the balls that they wanted to use and then found the mass of each. There were not enough balances and masses for each group to use, which compounded the difficulty of setting up the lab quickly. Knowing the students’ inexperience with using the balances, the masses of each ball were compared among the groups. Once displayed, the students identified that one group’s recording of the baseball’s mass seemed out of place. As I made my way among the groups during the lab execution, I noticed that there were inconsistencies regarding when one student released the ball and when the other began timing. Lining up the incline at the “0” mark for measuring distance was another issue. Additionally each group chose three balls to work with and then needed to complete at least three trials for each ball. All of these details that ensured accurate readings and consistency among the groups added to the lengthiness of the lab.

After students had worked out their calculations and answered questions related to the lab, the first question addressed in the group discussion was, “Why would it be important to compare the speeds of balls across groups?” The first response was “we need to add them” and then after referring to a previous example about comparing the balls’ masses, two students added “to compare” and “to see if it’s accurate.” When asked what speed was obtained for the golf ball, the first group gave the mass of their ball instead and then the total time. Finally the speed was given but the unit “milliseconds” was offered rather than meters per second (m/s). Through careful questioning, the two components needed for speed (distance and time) and then the units used for this lab were elicited from the students. The next group did the same i.e. gave the mass instead of the speed and then used the term milliseconds rather than meters per second. Then the third group repeated the other’s errors. When the third group actually gave the speed, the student offering the answer said “m slash s” for the unit. The next minute was spent extracting the
distance and time units—again. A process that seemed quite simple (listing and then comparing
the speeds of the various balls by group) actually turned into a long and tedious task and could be
described with one of my favorite metaphors “that was like pulling teeth from a chicken.”

When asking for the range or difference between the lowest and highest speeds recorded,
students wanted to find a visual difference rather than the mathematical difference. This proved
to be a point of confusion for some students for the remainder of the study. Once students
determined that .46 m/s separated the fastest, and lowest times, I attempted to demonstrate with a
stopwatch that particular difference and found it difficult to start and stop the device that quickly.
Regarding the difference, the students were then asked if .46 m/s would be a substantial
difference for those responsible for putting astronauts into space, to which they collectively
answered “yes”. When asked if it was a considerable difference for a classroom activity they
answered “no”.

Although the actual acceleration of each ball was not calculated during this lab, it was
hoped that the data would show the inverse relationship with just the speed calculation—it did
not. Instead what seemed to happen is that the balls with greater mass continued rolling farther
than the balls with less mass. A shorter distance should have been used which would have
yielded different speed results.

The purpose of How Much Force? was for students to use the spring scale (for the first
time) and also examine how dowels would affect the amount of force needed to move something.
A brief discussion of Newton, and how the unit of force originated, preceded the lab. Another
lesson in itself was how to read the spring scale, and more specifically, what the intervals
between the whole numbers represented, as difficulty with mathematical concepts continued to
surface. To have some consistency in the data, the students were asked to find the force of three
arrangements, the block alone, the block with 300g, and the block with 300g on dowels, but were encouraged to come up with a fourth grouping on their own.

![Figure 7. Block arrangements for How Much Force? lab.](image)

Making my way around the classroom I came upon one group that had gotten a toy car out of a bin of materials and were testing the amount of force necessary to move the car. They were pulling the car on only two wheels and we made a connection to a tow truck. The discussion then turned to why the wheels made the car easier to move. The word “circular” was used, but when asked what kind of unseen force the wheels might be helping to overcome, the students could only come up with gravity. Eventually, after consulting her notes, one student suggested friction. However, student understanding of situations when friction acts as a greater or lesser opposing force (e.g. the blocks with and without the dowels, respectively) still was not firm.

_Balloons and Cannons_ ended up being somewhat of a discrepant event in demonstrating Newton’s Third Law, that for every action there is an equal and opposite reaction. Again, this specific law was not introduced formally at this point, but would be addressed in a later lesson. The “cannon” part of the event consisted of placing a quarter tab of Alka-Seltzer® in a film canister with about 10mL, of water and was conducted outside on the basketball court. Knowing this, the students were then asked to predict in words and through a drawing what they thought would happen as the canister was released. I believed this to be a discrepant event because a
review of the students’ lab sheets showed that very few knew what would take place when the film canister was placed on the ground.

Knowing that the demonstration did not result in an *equal* (distance) and opposite reaction, the question “What would happen if they were the same mass?” was posed. A student quickly responded that if both parts had the same mass then they would go the same distance.

After the students had viewed the demonstration twice, one boy asked if the film canister could be placed on the ground upright. Knowing the misconception that could result from such an example, the following discussion commenced:

**TR:** If I placed it upright instead of lying it down, what’s going to happen?
**James:** The top would fly off and get stuck in the trees.

**TR:** Probably not get stuck in the trees, but just the top is going to go up and the bottom…there is a force there pushing down, but does the bottom have anywhere to go?

**James:** No.

**TR:** So would we be able to view the equal and opposite reaction?
**James:** No.

*Grammatical inconsistencies adjusted in dialogue. Pseudonyms used. TR=Teacher Researcher*
For the second trial, a half tab of Alka-Seltzer® was put into the canister with the water. When asked what might occur, several students yelled that it would go “higher” versus “farther”. Although the reaction happened more quickly, the ends of the canister went about the same distance as they did in the first trial.

The balloon component of the demonstration was simpler and more effective. This demonstration entailed blowing up a balloon, and then having students predict in which direction it would move when released. Contrary to the cannon demonstration, many of the students knew what would happen as the balloon was released, but what many did not realize was that the force of the air moving in the opposite direction determined the balloon’s direction. This lack of understanding about the air was evidenced in the students’ lab sheets. The students wanted more air to be placed in the balloon for the second trial and the balloon was held vertically rather than horizontally. It actually ended up mimicking the first demonstration. As the balloon began to move vertically, the wind blew it on its side and it traveled to the left similarly to the balloon in the first trial.

Figure 9. Sample of student work showing prediction and results of balloon demonstration.
The second attempt at the acceleration lab was fittingly called *What’s Mass Got To Do With It?--Revisited*. With this being their second attempt at it, the students set up the lab much more quickly than the previous time and most completed their trials in one class period. The formula for calculating the acceleration is quite intensive, and this took the students one entire class period. What was found once the final computations were started is that some of the groups ended up with a negative value for acceleration. Although this is quite permissible, I was not sure if I could communicate it to the students well or if it would cause confusion rather than clarity. I then explained to the students that negative acceleration (deceleration) could and did occur, but that it was beyond the goals of the activity to explore this through the calculations. How this deceleration occurred on an incline was unknown. It could be there were inconsistencies with the timings or the distances were too small for a notable change in speed to be recognized. What most groups did find was that it took longer for the balls with the most mass to make it down the incline to the 1m mark than it did for the balls with less mass.

Students began discussing falling objects during our data analysis. Although I wanted to include labs related to this phenomenon in the study, time did not allow. Student interest was evident when I remarked, “Well, all objects actually fall at the same rate--about 10 m/s.” To illustrate, a marker and a book were dropped from the same height and, of course, they hit the floor at the same time. As the students observed this, a flurry of questions commenced. Once students began walking around the classroom dropping objects, it was not difficult to see that the remainder of the “explanation” phase was over. If not under time constraints imposed by the study, this presented a timely opportunity to truly show students that science includes their interests and not just those of the teacher.
The final lesson of the force and motion unit included both a formal introduction of Newton’s Laws and a review of the labs. Instead of simply introducing Newton’s Laws in isolation, it was thought best to use the labs as examples. I began this lesson by reading the laws and asking the students for their own interpretations of the laws. Finally the students brainstormed labs in which Newton’s Laws were demonstrated and recorded them on a graphic organizer. Students’ versions of Newton’s Laws were recorded on posters and placed at various locations around the room. After this the students wrote the names of five labs, Speed, Does Speed Stay the Same?, What’s Mass Got To Do With It?, Balloons and Cannons, and How Much Force?, on sticky notes and then placed them on the Newton’s Law poster they thought most closely matched the lab. Following this each poster was reviewed and the labs that matched the law on the poster were verified through students’ explanation.

Data Analysis and Emerging Themes

One of the last, and perhaps most difficult, stages in action research is data collection and interpretation because of the “sense making” that must be made of the numerous data collected throughout the study (Mills, 2003, p. 102). In this action research study, data were collected from pre and post surveys, pre and post assessments, lab sheets, filmed discussions, and interviews and organized according to how each related to a guiding question. Throughout the study a few of the guiding questions were modified to more closely fit the instruments and inquiry methods utilized in the study. In question one, 5E Learning Cycle Model replaced the term guided inquiry, as the 5E Model was more structured and better suited my needs. In question three students’ perceptions replaced the phrase students’ attitudes. When developing the science perception survey, I realized that it was not information regarding students’ attitudes that was desired, but what students thought about science in general, how they learn science, and how they view
science outside the school setting. Emerging themes such as students’ ability to communicate their understanding of science concepts in writing, were organized similarly.

**Question 1 Findings**

Action research tends to be primarily qualitative in nature and the analysis of this first guiding question is categorized as qualitative. A primary purpose of action research is understanding and enhancing one’s own professional teaching practice, and the first question of this study follows suit:

Question 1: How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher?

Although a journal may have been a more structured means to track my feelings and reactions throughout the study, the filmed discussions and labs served as adequate sources of data. Relating specifically to the 5E Learning Cycle Model, I felt it served as a valuable guide and instructional tool, helping me transition from previous teaching methods to a more inquiry-based approach. I was comforted by the fact that there was some structure to it that maintained some consistency from lesson to lesson and that parts could be modified to be less structured as I discontinued my dependence on the textbook. Departing from what was determined by a text as right or wrong was evidenced in my decision to interview the students after the post assessment and modifying lessons based on their pre assessment answers and lab sheet responses. In Chapter 3, I mentioned the decision not to take field notes during the activities. I attempted it during the first few labs, but soon realized that listening to students’ conversations and asking probing questions was much more important.
Of all the stages, the “explanation” and “evaluation” stages of the cycle were the most troublesome. Even though my knowledge about science and teaching was not deficient, it did not extend deep enough to help students effectively explore their questions in an inquiry method and the science textbook was certainly not an adequate resource. Likely, I found these difficult because in the past, a paper-pencil test or worksheet would have replaced discussion in my classroom. Although I found the evaluation stage difficult, listening to the students and conversing with them was enjoyable and certainly more telling than looking at answers on a page. Truly listening to their dialogue was difficult, as I had to train myself to focus on every word and not just wait for “the answer.” As I became more skilled at doing so, I noticed that my conceptual understanding of force and motion concepts also improved through the discussions with students and preparing for labs.

All in all, I feel as if only a few aspects of my instructional self-efficacy have changed. Perhaps it is the ambiguity of the definition itself that makes such a change difficult to identify. Intelligence, manageability, and student motivation are just a few components of the definition, which was described in this study as teachers’ beliefs that they can positively affect students’ academic success (Denzine, Cooney, & McKenzie, 2005). Before the study began I believed I was an effective educator and although this experience with scientific inquiry was not perfect, I still believe that my students learned during the experience. Already possessing positive instructional self-efficacy, my self-efficacy did not dramatically change. My instructional “epiphany” actually occurred about five years ago during a school-wide staff development session with Dr. Grayson Wheatley. His ideas about a conceptual approach to mathematics and sharing of student solutions made sense to me and I have been an advocate of this philosophy ever since. My investigation of scientific inquiry was basically an extension of this way of
thinking into the subject of science. The only difference between my practice of inquiry in science and inquiry in mathematics was that I had no staff development or guidance for scientific inquiry. Although this was frustrating at times, I did not allow this lack of support to discourage me from continuing with inquiry. This and perhaps my view that teaching is a profession that constantly requires adaptation, change, and learning supports why embracing a new instructional method seemed to me like a natural fit.

Question 2 Findings

One way some teachers measure success is through the success of their students. The second question in this study addresses that particular view:

Question 2: How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion?

Results and Analysis of Knowledge Assessment

To address this question, I developed a supply item test that matched the objectives of the force and motion labs (see Appendix E). This was field-tested with other fifth grade students and reviewed by teachers. The assessments were evaluated using the FCAT Science General Scoring Rubric for Short-Response Questions (FL DOE, 2005) (see Appendix I). In short, students were given a score of 2 for correct and thorough answers, a score of 1 for partially correct answers, and a score of 0 for blank or incomplete responses. Even though the rubric is meant for scoring short response questions, those questions on the assessment that required only a single word or phrase were assessed similarly; students were given a 2 for correct responses and a 0 for incorrect responses. This applied to questions 1-3, and 10. Although the knowledge assessment
was structured to be open-response, it was expected that certain terms would be used to answer each question, which is how the rubric scores were assigned.

The knowledge assessment was administered after science process skills had been discussed and one lab related to observation was conducted, but before any labs related to force and motion had been undertaken. For the benefit of all students, the assessment was read aloud and elaboration was given when necessary. When number five was read aloud, many students volunteered that they did not know the meaning of acceleration. It was explained that this was a test designed to measure what students did or did not know of the topic and it was satisfactory to write, “I don’t know.” Several students asked for the term “cart” to be defined and so the reference of an overhead cart located within the classroom was given. Also, a student desk was lifted to demonstrate “incline” in item eight. To my surprise, many students did not have schema related to the orbit of the International Space Station. It was explained that this was an immense vessel launched by NASA (National Aeronautics and Space Administration) that is continually orbiting the Earth, far enough away from its surface not to be noticed, but close enough to take photographs of hurricanes, weather systems, etc. The students were also informed that approximately seven astronauts at a time live in the space station for months on end conducting scientific research and then are replaced by new astronauts brought up by the space shuttle. It is surprising that this disparity of understanding did not surface during field-testing. Students were also unsure what “repeating trials” meant and examples of finding an item’s mass, timing, and observing were given. Students that did not finish within the forty-five minute period were given time to complete the evaluation the following day.

The post knowledge assessment was administered at the end of the study and after a review of Newton’s Laws was completed. The graph below shows the average rubric scores per
question of the pre and post knowledge assessment. (see Appendix J for rubric scores per question).

![Averages per Question of Pre and Post Assessment](image)

Figure 10. Graph of average rubric scores per question on pre and post assessment.

Overall, the results of the pre and post assessments were what I anticipated…that students’ understanding of force and motion concepts would improve. The decrease in the accuracy of question ten was surprising and the wording “measure to the nearest millimeter or tenth of a centimeter” may have been the cause for the low scores on this question.

**Student Answers**

Moving past quantitative analysis, there were many similarities between how students responded to questions in this study and how students responded in a study conducted by Twigger et al. (1994). As found in that interview study of force and motion concepts, all participants included in their explanation that the ice was “slippery,” but 61% of these students
also mentioned friction as well. In this study 64% used the term slippery in either or both assessments, but only 18% included the term friction.

Question number nine also resembled a question in the Twigger et al. (1994) study regarding the motion of an object, a baseball and pebble respectively, in space. Students’ responses in the Twigger et al. (1994) study generally fit into four categories: (a) constant straight line motion; (b) floating around; (c) floating and stopping; and (d) other responses (p. 218). In this study, the duration of the movement was not in question, only the movement of the object once it had left the child’s hand. The responses of the students in this study could be categorized similarly except for the answers of a few students who did not believe the ball would even touch a wall inside the Space Station. I found these responses interesting and surmised, like Twigger et al. (1994) that television or movie images might have affected students’ ideas about motion. Motion that is halted or slowed down in mid-air as in the Matrix (Watchowski & Watchowski, 1999) films might have influenced these students’ ideas that an object can all of a sudden stop in the middle of movement without an opposing force being applied.

Another theme, perhaps the most pertinent, that emerged from viewing students’ responses to the assessment tests and lab sheets was their difficulty communicating their understanding of force and motion concepts in writing by adequately answering the question. Words and phrases like “it gets greater,” “it changed,” “it decreased,” “easy,” and “everywhere,” were numerous and students often forgot to explain or elaborate upon their answers which was actually the most crucial part and where true understanding could have been demonstrated.

Conducting the individual interviews resulted from the ambiguity of their answers on the force and motion assessment. Although the answers could be classified according to the rubric, it was difficult to glean what the students actually understood and what they were intending to
communicate. For example, only 18% of the students used the term friction when explaining their answers to questions 7 and 8, yet during the interview session eight more students included that term in their explanation for question 8. On average, the students’ response scores increased .4 in the interview sessions versus what they answered on paper.

Figure 11. Graph of average rubric scores on post assessment versus interview session.

Another connection to the Twigger et al. (1994) research can be made here; in summarizing their findings they stated, “they [research participants] do not correctly recognize the relevant forces acting…sometimes leaving out forces that should be included, e.g. friction” (p. 228). Asking question 9 in an interview setting was also quite telling. Student responses to that question included phrases like “go kind of slow,” “it would fall,” “it would float,” and “float around,” which were very unspecific regarding the movement of the ball. These issues are not isolated to this study. Hennessey (1996) found that “statements of intelligibility are often brief” (p. 18). In
the interview sessions, students were asked to clarify their answers as I asked questions. This is exemplified in representative excerpts from the following two interviews:

Interview 1

TR: Question #9: What would happen if an astronaut threw a baseball inside the International Space Station? So, you said, “it would keep going until it hit something.” Then you said, “or it drops.” If you threw the ball inside the space station would it drop as if you’re thinking about like if you threw a baseball here on Earth? Would it drop?

Allen: No.

TR: And you said here, “because of gravity.” What do you think would happen when it did hit something?

Allen: It would kind of just bounce off.

TR: Ok, you think it would kind of bounce off. In which direction would it move then?

Allen: In any direction.

TR: In any direction. So, if I threw it let’s say straight in this direction and it hit the wall here, you said it would go any direction once it hits the wall?

Allen: It would probably go to the side, like if it hit in a corner it would go to the side.

TR: Ok, it would probably go to the side. Do you remember the one of Newton’s Laws that we talked about when we did the exercise with the canons and the balloons? It said for every action, there is an equal and opposite reaction.

Allen: (student shakes head “yes”)

TR: So, if you threw the ball and it hit the wall inside the International Space Station, in which direction should it move back according to Newton’s Law?

Allen: Straight back.

TR: Straight back the way it came. So, would it go in all different directions?

Allen: (student shakes head “no”)

TR: No, it would come straight back. You’re right.

Interview 2

TR: Now this one #9, the one about throwing a ball inside the International Space Station. You said it would just float. So, if I threw it, it would just hover in the air or keep moving.

Natalie: It would move a little bit and then stop and just start floating around.

TR: At what point would it stop? It would just stop in the middle of an area?

Natalie: It would just kind of stop.

TR: So you would throw it and it would just go, go, go, and then it would just stop somewhere before it touched anything?

Natalie: Maybe, it depends how far you were throwing it.

TR: Ok, well let’s pretend that this room we’re in is in space and you throw the ball from here toward that door over there. What’s going to happen?
Natalie: Just like halfway it will stop and it’ll float.
TR: It’ll stop and rise up or stay the same level?
Natalie: It’ll just float around.
TR: It’ll just kind of start floating around?
Natalie: Maybe, yeah.

*Grammatical inconsistencies adjusted in dialogue. Pseudonyms used. TR=Teacher Researcher

What the students in these interviews reveal through the discussion is much more telling than what is written on their assessments.

Figure 12. Allen (1) and Natalie's (2) responses to question nine on post assessment.

To the students’ credit though, how movement differs on Earth versus in space was not addressed through any lab activity during the study. The effects of this difficulty with communicating ideas on paper will be discussed further in Chapter 5 as implications for FCAT and identifying misconceptions are addressed.

**Question 3 Findings**

At the beginning stages of planning the study this question addressed students’ attitudes, but as the student attitude surveys were reviewed I realized that they did not address what really interested me--how students thought about science as a general subject and how they felt they
learned science. As a result, the Science Perception Survey (see Appendix D) was created and the following question developed:

Question 3: How does the implementation of an inquiry science model affect students’ perceptions of science in general, how they learn science, and how they view science outside the school setting?

Results and Analysis of Perception Survey

The students were administered the Science Perception Survey before any activities related to the study were completed. Knowing that even the process skill labs would vary from what the students had experienced in science with their classroom teacher, I wanted to understand the students’ perceptions before my influence was imparted.

Students responded to the statements using a Likert scale (SA, A, D, SD) and mean values were calculated by assigning a value to each descriptor: SA=1, A=2, D=3, SD=4. Many of the students’ responses remained relatively the same between survey administrations except for statement three: “I learn/understand science from reading a textbook.” For both the boys and girls the pre survey scores equated to agreeing with this statement while the post survey results showed that both disagreed with the statement. Although comments were not required on the survey, several students added elaboration to their responses for statement three:

Student 1: Expect [sic] only when Mrs. Campbell is out.

Student 2: I can’t absorb it in my brain faster than words from a person.

Student 3: I understand better by doing it.
Table 4. Results of pre survey with research participants.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean Scores Per Question and Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>1</td>
<td>2.1  Cluster 1-2 2.0</td>
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<tr>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td>2.0  Cluster 3-4 1.8</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>5</td>
<td>2.4  Cluster 5-8 2.6</td>
</tr>
<tr>
<td>6</td>
<td>3.2</td>
</tr>
<tr>
<td>7</td>
<td>2.4</td>
</tr>
<tr>
<td>8</td>
<td>2.5</td>
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</tbody>
</table>

Standard Deviation 1.2
n=22; male n=11; female n=11

Cluster definitions: 1-2 science as a school subject; 3-4 how students learn science; 5-8 science outside the classroom

Table 5. Results of post survey with research participants.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean Scores Per Question and Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>1</td>
<td>2.1  Cluster 1-2 2.0</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>3.0  Cluster 3-4 2.5</td>
</tr>
<tr>
<td>4</td>
<td>1.9</td>
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<tr>
<td>5</td>
<td>1.9  Cluster 5-8 2.4</td>
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<tr>
<td>7</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Standard Deviation 1.2
n=22; male n=11; female n=11

Cluster definitions: 1-2 science as a school subject; 3-4 how students learn science; 5-8 science outside the classroom
Having the experience of learning science through means other than a textbook seemed to have positive results with all research participants. A review of filmed discussions and interviews and post assessments also showed that learning had taken place without the use of a textbook. Being an advocate of inquiry based instructional methods, it would be easy to say that it was the inquiry methods that supported this change, but it could be that the students did not use textbooks during the study except as a reference. It might be interesting to survey them again, now that their classroom teacher has resumed traditional, textbook-based science lessons, to see if their perceptions have changed once again. Adding the descriptor “best” to the statement might have prevented this confusion in interpretation.

Responses to statement five, “I think scientists have interesting jobs,” and statement six, “I would like to have a job as some type of scientist,” revealed more positive results in the post survey for the boys. For both statements the mean scores showed that the boys ended up agreeing more with this statement after they had engaged in inquiry labs than they had before the study started. Regarding the same questions with the girls, the mean scores showed that overall they agreed with statement five, yet the mean scores for statement six revealed they did not agree that they would like to have a job as a scientist. This was a surprise, because throughout the study it appeared as if the girls were more focused and asked more questions than the boys. This of course is only an observation and there are no tangible data to support such a conclusion.

Overall, it appears that how students felt they best learned science is the most pertinent information that resulted from the science perception survey.

Question 4 Findings

As outlined in the literature review, identifying and modifying misconceptions is not an
easy task and engaging in such an undertaking during my first attempt at scientific inquiry may have been overzealous goal. Nevertheless, question four addresses this issue:

Question 4: How do science misconceptions present themselves in the study and affect the instruction of the teacher?

Noting student misconceptions in writing, i.e. lab sheets, was easier than identifying them in conversation or during the activities. For example in the student work samples below, the students use phrases that could show impetus theory-like conceptions.

Figure 13. Evidence of impetus theory in student work.

In the How Much Force? lab, 53% of the students (n=17) said that the block with 300g on it would require the greatest amount of force to move because it had the greatest mass. No students identified that a second arrangement, the 300g on the block on dowels, would have the greater mass, but would be require less force to move because of the dowels.

Figure 14. Student work sample showing evidence of misconception relating to force and mass.
There was evidence on the post assessment (question 7) and during the interviews that students understood that “more mass” did not necessarily mean “more force”. Half of the students made the correct choice on the post assessment and during the interviews four more students answered that the books on the floor would require the most force to move.

Regarding research question four, Posner et al. (1982) concede that accomplishing this goal of identifying and modifying misconceptions is quite difficult and I must agree. Looking for these departures from accepted scientific thinking and presenting labs to modify them are quite different tasks. No specific interventions regarding these misconceptions were undertaken, except for the students’ opportunity to continue exploring these ideas through engaging in additional labs. Although identifying and modifying misconceptions is a component of inquiry-based instructional methods, the main goal of this study was to implement scientific inquiry.

Other Conclusions

*Cooperative Learning*

One emerging theme that did not seem to fit with any of the research questions identified at the beginning of the study was how students felt about working in cooperative groups. Working in cooperative groups was a new experience for most of these students and toward the end of the study I became curious about students’ feelings concerning this arrangement. The teacher then developed Self-Evaluation for Cooperative Science Groups (see Appendix K). Students were asked to evaluate themselves on three components, job performance, cooperation, and communication, using a rubric with scores from 1-4. The most telling part though was the last: *True or False. I learned to work and communicate better with others by participating in same group science labs.* Although students’ responses were either true or false, their explanations were intriguing (see Table 6).
Table 6. Student responses on cooperative grouping self-evaluation.

<table>
<thead>
<tr>
<th>True Responses</th>
<th>Explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement, True or False. I learned to work and communicate better with others by participating in small group science labs.</td>
<td>True because we didn’t have to do many things.</td>
</tr>
<tr>
<td></td>
<td>True because I learned how to listen and follow what others has to say more often.</td>
</tr>
<tr>
<td></td>
<td>Yes, because we all got along.</td>
</tr>
<tr>
<td></td>
<td>Yes, I did…I like science better.</td>
</tr>
<tr>
<td></td>
<td>True, because I cooperate better.</td>
</tr>
<tr>
<td></td>
<td>I did that by working with other people and doing it faster every time.</td>
</tr>
<tr>
<td></td>
<td>True because I’m not used to working with other people.</td>
</tr>
<tr>
<td></td>
<td>True, yes I did and how I talk and discuss so much more.</td>
</tr>
<tr>
<td></td>
<td>Yes, I did ‘cause it was easier to do it in a group.</td>
</tr>
<tr>
<td></td>
<td>I would not listen to others more now if I hadn’t participated with science groups.</td>
</tr>
<tr>
<td></td>
<td>I worked on it.</td>
</tr>
<tr>
<td></td>
<td>Yes, because I learned better in small groups.</td>
</tr>
<tr>
<td></td>
<td>True.</td>
</tr>
<tr>
<td></td>
<td>True because now I am able to work in groups and play game with people and share.</td>
</tr>
<tr>
<td></td>
<td>I learned to respect and listen to people</td>
</tr>
<tr>
<td>False Responses</td>
<td>False I always participate in groups.</td>
</tr>
<tr>
<td></td>
<td>Everyone in my group didn’t like me and I didn’t like them either.</td>
</tr>
<tr>
<td></td>
<td>False because during all the activities I did not get in an argue about something.</td>
</tr>
<tr>
<td></td>
<td>False because I didn’t work in other small groups.</td>
</tr>
</tbody>
</table>

n=19. Other responses were blank, incomplete, or off topic. Spelling errors in text corrected.
After reviewing the research related to cooperative and drawing on prior experiences, I anticipated that students would learn more as a consequence of working in cooperative groups than they would alone, but the positive responses relating to social skills were unexpected. Although the research states such outcomes often occur (Bandura, 1993; Lazarowitz & Hertz-Lazarowitz, 1998) this group of children did not necessarily represent the “model” class and their interactions during labs did not support what they wrote. They often argued about job responsibilities, failed to complete their responsibilities, and let their conversations drift to other topics. Upon review, their insightful responses were pleasantly surprising.

Summary

The focus of the study The Effects of Guided Inquiry on Students’ Understanding of Force and Motion Concepts was how I responded to implementing the 5E learning cycle model and how the use of this model affected students’ understanding of force and motion and perception of science. Over a period of fourteen weeks, I guided students through an inquiry of force and motion concepts, touching on Newton’s Laws at the end of the study. Some themes that emerged under the guiding questions were students’ perception of traditional science learning, writing explanations in science, identifying and rectifying misconceptions, and cooperative learning. The trustworthiness of the study was ensured as data were triangulated using multiple sources.

The pre and post perception surveys showed that before the study began, 77% of students either agreed or strongly agreed they learned science from textbooks. After the implementation of scientific inquiry, these percentages reversed completely with 77% of students either disagreeing or strongly disagreeing with the statement.
As suggested by Mills (2003) sometimes it is helpful to extend the data analysis by raising additional questions that surface through the process. Chapter 5 will give further elaboration on the emerging themes as well as recommendations and implications for further research. Chapter 5 will also help to synthesize the other chapters, showing connections between conclusions and implications.
CHAPTER FIVE: CONCLUSION

Introduction

When embarking on the journey that was this action research study, my main goal was to embrace a new instructional method for teaching science, which was scientific inquiry through the 5E learning cycle model and was researched through question 1: How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher? The additional research into student achievement, student perceptions, and identifying misconceptions were merely means to support and assess the effectiveness of the inquiry methods and were investigated through questions 2-4: How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion?; How does the implementation of an inquiry science model affect students’ perceptions of science in general, how they learn science, and how they view science outside the school setting?; How do science misconceptions present themselves in the study and affect the instruction of the teacher? With the newness of this instructional strategy, I found that I was in a different mindset than if I were adjusting a single component of my practice, for example the manner in which I engage students in a science activity or how I assess students. In some respect I felt like a new teacher again. As stated by Hewson, Beeth, and Thorley (1998) teaching for conceptual change and inquiry requires a great deal from the teacher:

1. Setting goals for instruction
2. Creating appropriate contexts for classroom activities.
3. Posing problems that have relevance and meaning to students.
4. Facilitating different levels of discourse.
5. Establishing a classroom environment that allows students to explore without fear of ridicule.
6. Monitoring classroom activities and deciding if, when, and how to intervene.

(p. 215)
Although the students benefited from this 14 week investigation into scientific inquiry and force and motion, it may have been more beneficial for me if I had focused on one aspect of inquiry and worked on honing it throughout the study. Attempting to ensure that all of these components were implemented properly was a challenge to say the least.

All of these variables, force and motion content, scientific inquiry, the 5E Learning Cycle Model, cooperative grouping, identifying misconceptions, etc. were documented and analyzed using pre and post surveys, pre and post knowledge assessments, self-evaluation, lab sheets, and filmed discussions and interviews. Evidence from the interviews showed that students could express their knowledge better verbally, with prompting questions, than they could in writing, which included the assessments and lab sheets. Surveys alluded to the idea that students felt they learned better using methods other than the textbook. A surprise was the impact of cooperative grouping as the students responded that they felt they were better listeners and worked better with others as a result. Although a dramatic change in my teaching did not occur, I was able to develop a more conceptual approach to teaching science. The growth of the students both socially and academically was also clear.

Limitations

Limitations that were presented in Chapter 3 are quite different than those that are presented here, at the end of the study. These limitations relate specifically to the guiding questions of this study and how they were addressed throughout the study. Time and available resources were the two primary limitations.
Time

When talking to most educators, it is not long before one may hear a phrase regarding the lack of time available to complete a particular task, and time constraints presented in this action research study are no different. The time allocated for science instruction was, of course, an issue, but more importantly the time available to address question 4 was also detrimental to the overall success of the study. Not only was there a lack of school time for probing into students’ ideas of force and motion concepts, but also time to evaluate their lab sheets was deficient. Furthermore, in the rush to “complete the study” some labs could have been more thoroughly explored and students deserved more time to investigate. In a typical classroom, this unit of study may be allocated a few weeks’ focus, but certainly not fourteen weeks, as was the case with this inquiry. The need to “cover more material” was evidenced by the classroom teacher’s action of assigning science homework on other science topics, i.e. reading chapters and answering questions about ecosystems, during the research period. It seems that identifying time as a limiting factor of the study is as common as identifying student misbehavior as a contributing factor to a learning environment, yet it must be addressed and its impact on this study is evident.

Resources

Perhaps one of the most difficult components to implementing scientific inquiry is finding the resources, for both the teacher and the students, to support it. Finding what I identified as quality investigations for this study was quite an endeavor, and the final collection of labs was pieced together from many different sources. Also relating to the lessons, all the materials necessary to carry out the labs were not available at the school, and I ended up cutting my own inclines, dowels, and wooden blocks from leftover wood in my garage. Even finding
enough stopwatches for each group proved difficult. Science kits are part of the textbook science series, but what is included in a classroom science kit is typically enough for one group or a demonstration, not whole-class investigation. More time might have been available for more analysis of student work, if obtaining materials was not as difficult.

Additional support that was required during this investigation was instructional support. Research discussed in Chapter 2 identifies that without support it is difficult for a teacher to be successful in implementing inquiry based instructional methods (Sivertsen, 1993; Sottile, Carter, & Watson, 2001). This is why models that pair a university professor and a classroom teacher(s), such as those explored by Roth, Tobin, and Ritchie in *Re/Constructing Elementary Science* (2001), are so effective. I knew that I could commit to and carry out the research study, but was unsure about the quality the implementation. Carr, Herman, and Harris (2005) note that teachers who engage in a mentoring or coaching relationship are more likely to attempt and implement new instructional strategies more so than those do not partake in such relationships (p. 95). I really needed this relationship and a seasoned science teacher adept in inquiry methods to serve as a mentor; unfortunately no one at the school matched that description.

Conclusions and Implications

*Research Question 1*

With my instructional methods at the focal point of this study, it is fitting that the first research question relates to that.

**Question 1:** How does the implementation of the 5E Learning Cycle Model affect the instructional self-efficacy of the teacher?

As I mentioned in Chapter 4, what occurred in this study with regard to my instructional self-efficacy was a continuation of a philosophy of teaching content with a conceptual understanding
in mind. In an effort to continue this growth, a few changes that took place in my science teaching methods and their effects are noted in the following paragraphs.

Regarding the use of the textbook, I have been teaching mathematics without one for years and so adopting the same approach for science did not seem like a dramatic change. What resulted from it though was a transformation in my approach to assessing students. No longer was I focused on a worksheet or a test to tell me what students had learned. Evaluation started to become an on-going, interactive process, rather than a monthly one-sided opportunity. This movement away from what was a “correct” or “incorrect” response as determined by a textbook manufacturer allowed me to truly understand what students comprehended through the inquiry labs. Not using the textbook is certainly not the easy choice. I spent weeks searching for resources and piecing together the labs that supported this unit of study, and once I found them, spent hours preparing the related materials. Finding resources, trade books, etc., that served as references for students and creating lab sheets “from scratch” was additionally time consuming. It would have been much easier to open the science teacher’s guide, read some pages, and assign a worksheet, but for whom would that have been convenient? It would have been convenient for me. It is my students’ learning that I want to thrive, not my leisure time. Knowing this, I will continue to change and tweak and modify and learn with regard to my practice. That has always been part of what I consider teaching though and I do not believe it is such a departure from what is part of being an effective educator.

Research Question 2

How science knowledge is evaluated and assessed was very relevant to this question and the findings resulting from it illuminate a very pertinent issue in education.
Question 2: How does the implementation of an inquiry science model affect the science achievement of students, particularly in the content strand force and motion?

Overall, the students showed improvements on all questions on the knowledge assessment, except for the measurement question. The mean score for the remaining questions increased from the pre to the post assessment, which of course was the desired effect. More telling though were the interviews that resulted from incomplete or ambiguous responses on the instrument. When asked to elaborate upon their answers, students often came up with words or phrases that would have secured them a higher rubric score, but their written work did not demonstrate this understanding. This trend has implications in many areas in education, specifically standardized testing. Using the same rubric that is utilized in evaluating student responses on the FCAT (Florida Comprehensive Achievement Test), I found the scores increased an average of .4 per question (for questions 4-9) in the interview setting. This change is meaningful for all students, but particularly those with disabilities who have documented difficulties with written expression, processing, etc. Although outside the scope of this study, one question that could be further researched with the current data, was how students with disabilities fared in the study in relation to their non-disabled peers. For this question, it was not what the students learned that became the focal point, but how they effectively communicated what they learned. Another advantage to having access to this grade level during the study was the opportunity to view their standardized test results when FCAT scores were returned in May 2006, in which students must demonstrate their knowledge by answering multiple-choice and essay questions.

Research Question 3

How students perceive science and ultimately what can influence a change in these perceptions was the focus of question 3.
Question 3: How does the implementation of an inquiry science model affect students’ perceptions of science in general, how they learn science, and how they view science outside the school setting?

The results of the perception survey remained fairly stable from one administration to the next with the exception of statement 3. At the beginning of the study, 77% of the participants believed that they learned science through a textbook, yet that same percentage disagreed with that statement after the conclusion of the study. What was equally as interesting were the results of the following statement. When reviewing the pre and post data I was so focused on the numbers and what changes were evident, that I failed to look at the statements unless the data showed a notable change. Statement four was: I learn/understand science from doing science activities. Before the study began, 95% of the students agreed or strongly agreed with that statement, but after the study that percent dropped to 86%. Although this was not a considerable change (only 2 students) it negates some of the excitement over the change in the previous statement. If investigated again in the future, the focus of the survey would likely include how students believe they learn science, rather than the other statements which were neither telling nor indicators of a change in perception.

Research Question 4

The limitations touched upon earlier in this chapter are perhaps of greatest consequence for this question.

Question 4: How do science misconceptions present themselves in the study and affect the instruction of the teacher?

As discussed in Chapter 4, with insufficient time to identify misconceptions and the absence of
support to modify them, I feel as if this question was hardly addressed in the study. It might have been more beneficial to identify two or three common misconceptions related to force and motion (i.e. impetus theory) and specifically work to identify and modify those. Once decided upon, the misconceptions could be recognized through pre assessments and pre interviews and then inquiry activities could be chosen to help modify them. Selecting the activities for this lab first did not allow for such planning. From what I have read in the research, identifying misconceptions in students tends to be an individual study on its own and was perhaps beyond the scope of this action research study.

Discussion

When it comes to implementing scientific inquiry in an elementary classroom, I found that in this study, it is not the idea of inquiry that is so difficult to embrace, but the imposition of school bureaucracy. For example, the need for the classroom teacher to have grades forced me to evaluate the students’ work differently. One reason the classroom teacher may have assigned science homework during the study was in the quest for grades. When she asked me for grades for the students I did not feel that assessing their work in a formal fashion was supportive of inquiry, nor fair to these students who, like I, were embarking on this voyage of scientific inquiry for the first time. I felt that I had to find things “wrong” in order to assign a grade, which could have distracted my focus from identifying misconceptions. The transformation in assessing students more informally does not coincide with current educational practices in many schools, where papers, grades, and state-wide assessments determine what students know. Unfortunately, it does not seem like this practice will be modified anytime in the near future. To address these issues more formally in future inquiry lessons, creating a rubric or checklist with key points for both content and group work might be a more fair and effective method for evaluating students.
Beyond question, one of the most influential variables a teacher deals with daily is time. The focus on mathematics, reading, and writing on standardized tests has not left much time for science in the elementary classroom. Although a tested subject on the state assessment in Florida, the subject is still not given the time it deserves. In the words of my principal, testing seems to be used as a vehicle for making something important or valued. In my opinion, all subjects are equal, necessary, and depend upon one another. One way to incorporate science into the curriculum more often is to integrate it with mathematics. As mentioned in Chapter 2, science and math fit together “logically.” Both subjects require critical thinking skills, questioning, explaining, and analyzing data (Berlin & White, 1998; Wheatley, 1991). Also, students would learn both subjects more meaningfully if they were not isolated.

The idea that knowledge is constructed differently from person to person and can vary from situation to situation can be an overwhelming notion for teachers (Duit & Treagust, 1998). If viewed through a constructivist perspective though, it is not the charge of the teacher to instruct all these individuals, but to use this diversity in knowledge and thinking to create a more enriching learning environment for all students (von Glasersfeld, 1993; Wheatley, 1991). For these students, having the opportunity to construct knowledge differently, through discussion, debate, and action rather than reading and writing, was invaluable. If in no other way, this was evidenced simply by engaging the students in labs and providing them with the opportunity to explore through labs and explaining their work. Although I had greater expectations for myself as a facilitator of these experiences, giving the students the opportunity to explore and create in their own minds a different definition of “science” was worthwhile.
Recommendations

With regard to this specific study, further inquiry into students’ verbal versus written knowledge of science concepts must be pursued if indeed their understanding will be continually tested in this manner. This has implications not only in states where standardized science testing is conducted yearly, but nationwide as American students continue to be compared to international students. Generally speaking though, the body of research that exists to support cooperative learning, scientific inquiry, and reflective practice in education is massive. What will one more study achieve? Will that be the one that will incite educational change? What is necessary now is action. Educational research that does not incorporate the teacher or that takes place in unnatural school environments is not truly beneficial in the search for educational reform. Kennedy (1997) supports this claim in that the educational system in the United States is not designed to support the conclusions of educational research. Teachers and researchers must form a partnership in which one supports the other; teachers help researchers hone their methodologies as they are implemented in real classrooms, and researchers offer teachers the knowledge base and instructional support they need to make the transition from one instructional method to another. Dewey (1910) made his point nearly 100 years ago:

I mean that science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are formed. Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry does one ever get a knowledge of the method of knowing (pp. 121, 124).
What has happened since then? Have the changes he suggested been embraced? It seems as if the wish for a sweeping decision for science to be taught differently will not come to fruition anytime soon. In the meantime then, it is up to this teacher researcher to pass this passion for science teaching to those around her in an effort to invoke the changes so desired.
APPENDIX A: UCF IRB APPROVAL
August 1, 2005

Meghann A. Campbell
University of Central Florida
Teaching and Learning Principles
College of Education
Orlando, Fl 32826

Dear Mrs. Campbell:

With reference to your protocol #05-2703 entitled, "The Effects of Guided Inquiry on Student Understanding of Force and Motion Concepts" I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. **This study was approved on 7/20/05 and the expiration date will be 7/19/06.** Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman or full IRB at least one month prior to the expiration date. This is the responsibility of the investigator. Please notify the IRB office when you have completed this research study.

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

Barbara Ward
Barbara Ward, CIM
IRB Coordinator

Copies: IRB File

BW:cc
APPENDIX B: OCPS APPROVAL
Submit this form and a copy of your proposal to:
Accountability, Research, and Assessment
P.O. Box 271
Orlando, FL 32802-0271

Orange County Public Schools

RESEARCH REQUEST FORM

Your research proposal should include: Project Title; Purpose and Research Problem; Instruments; Procedures and Proposed Data Analysis

Requestor's Name: Meghann A. Campbell
Date: 20 July 2005

Address: Home 5155 Lighthouse Rd, Orlando
7800 Edgewater Dr 32808
Phone: 407-288-4455
407-276-6440

State Business: Lockhart Elementary, Orlando FL 32808

Project Director or Advisor: Dr. Aldrin Sweeney - UCF
Phone: 407-823-2536

Address: Univ. Central FL, College of Edu, Dept. Teaching & Learning
4000 Central FL Blvd. Orlando, FL 32816

Degree Sought: (check one)
- Associate
- Doctorate
- Bachelor's
- Master's
- Specialist
- None

Project Title: The Effects of Guided Inquiry on Student Understanding of Science Concepts

ESTIMATED INVOLVEMENT

PERSONNEL/CENTERS

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>AMOUNT OF TIME (DAYS, HOURS, ETC.)</th>
<th>SPECIFY/DESCRIBE GRADES, SCHOOLS, SPECIAL NEEDS, ETC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>25</td>
<td>2-3 days/wk, intermediates, grade students, including ESL, special education</td>
</tr>
<tr>
<td>Teachers</td>
<td>1</td>
<td>for about 10 weeks</td>
</tr>
<tr>
<td>Administrators</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Schools/Centers</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Others (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Specify possible benefits to students/school system: Benefits incurred by students could include an increase in scientific knowledge & a more positive attitude toward science.

ASSURANCE

Using the proposed procedures and instrument, I hereby agree to conduct research in accordance with the policies of the Orange County Public Schools. Deviations from the approved procedures shall be cleared through the Senior Director of Accountability, Research, and Assessment. Reports and materials shall be supplied as specified.

Requestor's Signature: Meghann A. Campbell

Approval Granted: Yes □ No □ Date: 8-3-05

Signature of the Senior Director for Accountability, Research, and Assessment: Lee Baker

NOTE TO REQUESTER: When seeking approval at the school level, a copy of this form, signed by the Senior Director, Accountability, Research, and Assessment, should be shown to the school principal.

Reference School Board Policy GCS, p. 249

FORM ID #GB0103/23-1/FY REV 1/04
APPENDIX C: PARENTAL CONSENT AND STUDENT ASSENT FORMS
Dear Parent/Guardian,

For the past year I have been completing coursework at the University of Central Florida for completion of a master’s degree program in mathematics and science education. In order to fulfill the requirements for this program, I must complete an action research study in which I will examine an aspect of my teaching and will be under the supervision of UCF faculty member, Dr. Aldrin E. Sweeney.

My research will examine how using a “science as inquiry” instructional method will affect the students understanding of science content including force, motion, and related concepts. Engaging students in learning science through guided inquiry will allow them to explore topics as scientists would, posing questions and answering them on their own as they participate in lab activities. By modifying, developing, and critiquing their own experiences, the students will hopefully attain a deeper understanding of these concepts.

Your child’s participation in this action research is purely voluntary. Students who choose not to participate in the study will complete similar activities on an individual or small group basis with other nonparticipating members. If your child chooses to be involved in the study he or she would take a pre and post survey that would include questions related to his or her current perceptions about science and prior scientific experiences. A pre-assessment of your child’s current understanding of force, motion, and other linked topics will follow. As students complete lab activities, their lab sheets will be reviewed and during select labs their dialogue and interactions will be videotaped. Videotaping will serve as a valuable tool in evaluating the extent of the students’ understanding of the aforementioned science topics. Videotapes will not be made public or copied without parental permission nor will they be shown to individuals outside of the UCF faculty who will be supervising my study. At the conclusion of the study, the students will complete a post-survey that will attempt to see if their perceptions about science have changed since their involvement with an inquiry science approach. A post-assessment of force, motion, and related topics will be given in order to measure the knowledge growth of the students with regard to these specific concepts.

Results will only be reported in the form of group data and will be available upon request. Participation or nonparticipation in this study will not affect the children's grades or placement in any programs. You and your child have the right to withdraw consent for your child’s participation at any time without consequence. With regard to the surveys and assessment tools, your child does not have to reply to questions he/she wishes not to answer. At the conclusion of the study all videotapes, transcripts, surveys, and related data will be destroyed.

If you have any questions about this research project, please contact me at (407) 296-6440 or my faculty supervisor, Dr. Sweeney at (407) 823-2561 or via email at asweeney@ucf.edu. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 302, Orlando, FL 32826 or by phone (407) 823-2901.

Sincerely,

Meghann A. Campbell
UCF Graduate Student
Varying Exceptionalities Teacher
I have read the procedure described above and have received a copy of the description.

I voluntarily give my consent for my child, ______________________, to participate in Mrs. Campbell's study of inquiry science.

I give permission for my child to be videotaped.

_________________________________/________
Parent/Guardian Name         Parent/Guardian Signature   Date

_________________________________/________
Parent/Guardian Name         Parent/Guardian Signature   Date

Dear Student,

As I have explained to you recently that I am a graduate student at the University of Central Florida and will be doing some research about teaching science. I would like to ask you to complete a survey, a pre and posttest, and to participate in science lab activities. I also would like to videotape you in your group while you are working. You may stop participation in this research activity at any time and you will not have to answer any questions related to the study you do not want to answer. Would you like to do this?

_______ Yes, I would like to participate.

_______ No, I would not like to participate.

______________________________
Signature
Science Perception Survey

Please take a few minutes to complete this survey about science. Your responses will be very helpful to your teacher, but you do not have to respond to any questions you don’t want to answer.

Read each statement and using the scale provided, circle the answer that best states your view of the statement. If you choose, add clarification to your answers on the lines.

<table>
<thead>
<tr>
<th>Statement</th>
<th>(SA) strongly agree</th>
<th>(A) agree</th>
<th>(D) disagree</th>
<th>(SD) strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think science is an important subject.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I think science is an exciting subject.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I learn/understand science from reading a textbook.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I learn/understand science from doing science activities.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I think scientists have interesting jobs.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I would like to have a job as some type of scientist.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I only think about science related topics at school.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Science has a lot to do with my everyday life.</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E: KNOWLEDGE ASSESSMENT
Assessment of Science Knowledge

1. Draw/name the tool that would be used to measure the mass of a tennis ball? ________________

2. Draw/name the tool that would be used to measure the distance a tennis ball rolled? ________

3. Draw/name the tool that would be used to measure the amount of time it took a tennis ball to roll 10 m? ______________________________________________________________

4. How would you determine the speed of a tennis ball that was rolled down a sidewalk?
   ____________________________________________________________________
   ____________________________________________________________________
   ____________________________________________________________________

5. Sketch and then describe an activity/experiment that you could set up that would demonstrate the difference between speed and acceleration.
   ____________________________________________________________________
   ____________________________________________________________________
   ____________________________________________________________________

6. As the mass of an object increases, describe what would happen to its acceleration. Why would this occur?
   ____________________________________________________________________
   ____________________________________________________________________
   ____________________________________________________________________
7. Which object would require the greatest force to move on a smooth surface, a stack of 10 science books, a stack of 10 science books on a cart, or a cart? Explain your answer.


8. Imagine an ice cube, a wooden block, and a dry sponge perched on the end of your desk. If you lifted your desk to make an incline, which item would fall off the end first? Explain your answer.


9. What would happen if an astronaut threw a baseball inside the International Space Station? Explain why you think this would occur.


10. Measure the line below to the nearest millimeter or tenth of a centimeter. __________________


11. Why is it a good idea to repeat trials when completing an experiment/activity?


12. Elvira has been measuring the amount of rainfall during the past few weeks. On the back of this page, organize her data and then create a graph that would best display what she observed.

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 7th</td>
<td>5 cm</td>
</tr>
<tr>
<td>August 1st</td>
<td>0 cm</td>
</tr>
<tr>
<td>August 14th</td>
<td>6 cm</td>
</tr>
<tr>
<td>August 21st</td>
<td>2 cm</td>
</tr>
<tr>
<td>August 28th</td>
<td>1 cm</td>
</tr>
</tbody>
</table>
APPENDIX F: LIST OF FLORIDA BENCHMARKS COVERED IN STUDY
SC.A.1.2.1 The student determines that the properties of materials (e.g., density and volume) can be compared and measured (e.g., using rulers, balances, and thermometers).

SC.C.1.2.1 The student understands that the motion of an object can be described and measured.

SC.C.2.2.2 The student knows that an object may move in a straight line at a constant speed, speed up, slow down, or change direction dependent on net force acting on the object.

SC.C.2.2.3 The student knows that the more massive an object is the less effect a given force has.

SC.C.2.2.4 The student knows that the motion of an object is determined by the overall effect of all of the forces acting on the object.

SC.H.1.2.1 The student knows that it is important to keep accurate records and descriptions to provide information and clues on causes of discrepancies in repeated experiments.

SC.H.1.2.2 The student knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.

SC.H.1.2.3 The student knows that to work collaboratively, all team members should be free to reach, explain, and justify their own individual conclusions.

SC.H.1.2.4 The student knows that to compare and contrast observations and results is an essential skill in science.

SC.H.2.2.1 The student knows that natural events are often predictable and logical.

SC.H.3.2.2 The student knows that data are collected and interpreted in order to explain an event or concept.

SC.H.3.2.4 The student knows that, through the use of science processes and knowledge, people can solve problems, make decisions, and form new ideas.

MA.A.2.2.1 The student uses place-value concepts of grouping based upon powers of ten (thousandths, hundredths, tenths, ones, tens, hundreds, thousands) within the decimal number system.

MA.A.3.2.3 The student adds, subtracts, and multiplies whole numbers, decimals, and fractions, including mixed numbers, and divides whole numbers to solve real-world problems, using appropriate methods of computing, such as mental mathematics, paper and pencil, and calculator.

MA.E.1.2.1 The student solves problems by generating, collecting, organizing, displaying, and analyzing data using histograms, bar graphs, circle graphs, line graphs, pictographs, and charts.

MA.E.1.2.2 The student determines range, mean, median, & mode from sets of data.

MA.E.1.2.3 The student analyzes real-world data to recognize patterns and relationships of the measures of central tendency using tables, charts, histograms, bar graphs, line graphs, pictographs, and circle graphs generated by appropriate technology, including calculators and computers.
APPENDIX G: AIMS PERMISSION FOR REPRODUCTION RIGHTS
From: Terry Walther [mailto:twalther@aimsedu.org]
Sent: Thu 9/15/2005 11:56 AM
To: Campbell, Meghann A.
Subject: Duplication Rights

Dear Ms. Campbell

Thank you for your request to duplicate AIMS materials. Attached is our standard Duplication Rights policy. I believe your request falls in this category. If not, there is also information about how to purchase additional rights.

Sincerely,
Terry Walther
Business Manager
AIMS Education Foundation
"Engaging Students--Meeting Standards."
888.733.2467 or 255.4094 x137
www.aimsedu.org

Duplication Rights

Standard Duplication Rights
Purchasers of AIMS activities (individually or in books and magazines) may make up to 200 copies of any portion of the purchased activities, provided these copies will be used for educational purposes and only at one school site. Workshop or conference presenters may make one copy of a purchased activity for each participant, with a limit of five activities per workshop or conference session. Standard duplication rights apply to activities received at workshops, free sample activities provided by AIMS, and activities received by conference participants. All copies must bear the AIMS Education Foundation copyright information.

Unlimited Duplication Rights
To ensure compliance with copyright regulations, AIMS users may upgrade from standard to unlimited duplication rights. Such rights permit unlimited duplication of purchased activities (including revisions) for use at a given school site. Activities received at workshops are eligible for upgrade from standard to unlimited duplication rights. Free sample activities and activities received as a conference participant are not eligible for upgrade from standard to unlimited duplication rights.
Upgrade Fees
The fees for upgrading from standard to unlimited duplication rights are:
  1. $5 per activity per site; and
  2. $25 per book per site;
  3. $10 per magazine issue per site.
The cost of upgrading is shown in the following examples:
  1. activity: 5 activities x 5 sites x $5 = $125
  2. book: 10 books x 5 sites x $25 = $1250
  3. magazine issue: 1 issue x 5 sites x $10 = $50

Purchasing Unlimited Duplication Rights
To purchase unlimited duplication rights, please provide us the following:
1. The name of the individual responsible for coordinating the purchase of duplication rights.
2. The title of each book, activity, and magazine issue to be covered.
3. The number of school sites and name of each site for which rights are being purchased.
4. Payment (check, purchase order, credit card)

Requested duplication rights are automatically authorized with payment. The individual responsible for coordinating the purchase of duplication rights will be sent a certificate verifying the purchase.

Internet Use
Permission to make AIMS activities available on the Internet is determined on a case-by-case basis.

AIMS Education Foundation
P. O. Box 8120, Fresno, CA 93747-8120. aimsed@aimsedu.org. 888.733.2467 (toll free). 559.255.6396 (fax). www.aimsedu.org.

Note: This policy must be consistent on the book copyright page, book duplication rights page, catalog duplication rights page, and online activities cover sheet.
Hi Meghann --
I received your fax requesting permission to use NSTA material.
We now have a contract with the Copyright Clearance Center to handle all permission requests. Here are the steps you need to follow:
1. Go to www.copyright.com
2. Click on the "For Business Use" link under the "Content User" heading
3. Click on "Find Title" under "Get Permission"
4. Describe how you will use the material
5. Type "Science & Children" into the "Search for" box, and leave "Publication Title" in the "Search by" box
This will bring up the title of the journals and you should find "Science & Children." If you should have problems navigating through CCC's online system, please give them a call @ 978-750-8400. A customer rep should be able to walk you through the process.

Let me know if you have questions, or if I can help further.
Thanks
Sue Addington
NSTA
1840 Wilson Blvd
Arlington VA 22201

Permission is granted in advance for photocopying brief excerpts for one-time use in a classroom or workshop. Requests involving electronic reproduction should be directed to Permissions/NSTA Press, 1840 Wilson Blvd., Arlington, VA 22201-3000; fax 703-526-9754. Permissions requests for coursepacks, textbooks, and other commercial uses should be directed to Copyright Clearance Center, 222 Rosewood Dr., Danvers, MA 01923; fax 978-646-8600; www.copyright.com.
General Scoring Rubric for Short-Response (SR) Questions
Grades 5, 8, and 11

2 points  A score of two indicates that the student has demonstrated a thorough understanding of the scientific concepts and/or procedures embodied in the task. The student has completed the task correctly, in a scientifically sound manner. When required, student explanations and/or interpretations are clear and complete. The response may contain minor flaws that do not detract from the demonstration of a thorough understanding.

1 point  A score of one indicates that the student has provided a response that is only partially correct. For example, the student may arrive at an acceptable conclusion or provide an adequate interpretation, but may demonstrate some misunderstanding of the underlying scientific concepts and/or procedures. Conversely, a student may arrive at an unacceptable conclusion or provide a faulty interpretation, but could have applied appropriate and scientifically sound concepts and/or procedures.

0 points  A score of zero indicates that the student has not provided a response or has provided a response that does not demonstrate an understanding of the scientific concepts and/or procedures embodied in the task. The student’s explanation may be uninterpretable, lack sufficient information to determine the student’s understanding, contain clear misunderstandings of the underlying scientific concepts and/or procedures, or may be incorrect.
APPENDIX J: PRE AND POST ASSESSMENT RESULTS BY QUESTION
Table 7. Rubric scores per question with percents for pre assessment.

<table>
<thead>
<tr>
<th>Question</th>
<th>Acceptable Response</th>
<th>Rubric Score Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>balance, scale or drawing of either.</td>
<td>50% 50%</td>
</tr>
<tr>
<td>2</td>
<td>ruler, yardstick, meter stick, tape measure or drawing of any tools listed above</td>
<td>82% 18%</td>
</tr>
<tr>
<td>3</td>
<td>stopwatch, watch, clock or drawing of any tools listed above</td>
<td>73% 27%</td>
</tr>
<tr>
<td>4</td>
<td>mention of time and distance</td>
<td>- 9% 91%</td>
</tr>
<tr>
<td>5</td>
<td>mention change in speed; constant speed or average speed</td>
<td>- 5% 95%</td>
</tr>
<tr>
<td>6</td>
<td>acceleration would decrease as mass increased; heaviness</td>
<td>9% 9% 82%</td>
</tr>
<tr>
<td>7</td>
<td>10 books; friction; greater/weaker force</td>
<td>- 23% 77%</td>
</tr>
<tr>
<td>8</td>
<td>ice cube; mention of friction</td>
<td>- 86% 14%</td>
</tr>
<tr>
<td>9</td>
<td>straight line/same direction/less gravity</td>
<td>- 45% 55%</td>
</tr>
<tr>
<td>10</td>
<td>Acceptable: 13 cm, 130 mm Actual: 13.1 cm or 131 mm</td>
<td>36% - 64%</td>
</tr>
<tr>
<td>11</td>
<td>mention of accuracy, error, check/re-check average; compare</td>
<td>14% 14% 72%</td>
</tr>
<tr>
<td>12</td>
<td>data in order by date; must be a line graph must have x and y-axis labels; must have a title scale must extend past 6 and begin at 0.</td>
<td>- 5% 95%</td>
</tr>
</tbody>
</table>

**Don’t know/blank responses were given a rubric score of 0. n=22**
Table 8. Rubric scores per question with percents for post assessment.

<table>
<thead>
<tr>
<th>Question</th>
<th>Acceptable Response</th>
<th>Rubric Score Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>balance, scale or drawing of either.</td>
<td>82%</td>
</tr>
<tr>
<td>2</td>
<td>ruler, yardstick, meter stick, tape measure or drawing of any tools listed above</td>
<td>91%</td>
</tr>
<tr>
<td>3</td>
<td>stopwatch, watch, clock or drawing of any tools listed above</td>
<td>95%</td>
</tr>
<tr>
<td>4</td>
<td>mention of time and distance</td>
<td>32%</td>
</tr>
<tr>
<td>5</td>
<td>mention change in speed; constant speed or average speed</td>
<td>9%</td>
</tr>
<tr>
<td>6</td>
<td>acceleration would decrease as mass increased; heaviness</td>
<td>32%</td>
</tr>
<tr>
<td>7</td>
<td>10 books; friction; greater/weaker force</td>
<td>5%</td>
</tr>
<tr>
<td>8</td>
<td>ice cube; mention of friction</td>
<td>9%</td>
</tr>
<tr>
<td>9</td>
<td>straight line/same direction/less gravity</td>
<td>5%</td>
</tr>
<tr>
<td>10</td>
<td>Acceptable: 13 cm, 130 mm Actual: 13.1 cm or 131 mm</td>
<td>23%</td>
</tr>
<tr>
<td>11</td>
<td>mention of accuracy, error, check/re-check; average; compare</td>
<td>23%</td>
</tr>
<tr>
<td>12</td>
<td>data in order by date; must be a line graph must have x and y-axis labels; must have a title scale must extend past 6 and begin at 0.</td>
<td>-</td>
</tr>
</tbody>
</table>

**Don’t know/blank responses were given a rubric score of 0. n=22**
APPENDIX K: SELF-EVALUATION FOR COOPERATIVE SCIENCE GROUPS
Self-Evaluation for Cooperative Science Groups

Performance Rubric

<table>
<thead>
<tr>
<th>Job Performance</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not follow my job description.</td>
<td>I did not fully complete the tasks for my job.</td>
<td>I did exactly what was required when doing my job.</td>
<td>I went beyond what was required when completing my job.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooperation (lab &amp; questions)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not work with my teammates to complete the labs.</td>
<td>I worked mostly by myself to complete the labs.</td>
<td>I worked with only a few teammates to complete the labs.</td>
<td>I worked with all of my teammates to complete the labs.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not communicate with my teammates about the labs.</td>
<td>I did not listen to others and rarely discussed the labs with my teammates.</td>
<td>I sometimes listened to others &amp; discussed the labs with my teammates.</td>
<td>I listened to others opinions &amp; discussed the labs with my teammates.</td>
<td></td>
</tr>
</tbody>
</table>

Using the rubric above, rate yourself on your experiences completing the labs on force and motion. After giving yourself a rating, give one example that supports your selection.

1. Job Performance:__________
Example:_____________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

2. Cooperation: _________
Example:_____________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

3. Communication: _________
Example:_____________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

4. True or false.
I learned to work and communicate better with others by participating in small group science labs. Explain.
REFERENCES


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