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Analysis of Attitude and Achievement Using the 5E Instructional Model in an Interactive Television Environment

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ANALYSIS OF ATTITUDE AND ACHIEVEMENT USING THE 5E INSTRUCTIONAL MODEL IN AN INTERACTIVE TELEVISION ENVIRONMENT

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ABSTRACT

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The purpose of this quasi-experimental study was to examine attitude and achievement among fifth grade students participating in inquiry and lecture-based forms of instruction through interactive television. Participants (N = 260) were drawn from registered users of NASA's Digital Learning Network™. The first three levels of Bloom's Revised Taxonomy were used to measure levels of achievement while the Science Attitude Inventory II was used to measure science attitudes.

Results indicated a significant interaction between inquiry and topic area, as well as achievement for remember, understand, and apply levels of Bloom's Revised Taxonomy. Differences between mean scores were in favor of the treatment group on both topic and achievement levels. Findings echo research that encourages the use of inquiry-based instruction to improve achievement. This study also serves as a reference for supplemental content providers searching for an effective instructional strategy when delivering instruction through interactive television.

Recommendations for future research include the examination of: development time between inquiry-based and lecture-based strategies, a longitudinal study of attitude and achievement from elementary through middle school, differences between interactive television sessions and asynchronous sessions, and types of inquiry-based instruction related to student achievement and retention through interactive television.

This is dissertation is dedicated to my parents, Cater and Louise Cherry who have always encouraged me to excel at whatever I do, while maintaining balance. You are responsible for a great deal of my accomplishments as well as my continued pursuit for personal excellence. I appreciate all that you have done for me, along with the sacrifices you have made and the life lessons that I will continue to use for the rest of my life. I hope to be half of the parents that you have been to me! Thanks Mom and Dad!

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Chapter I

Introduction

"Education is not about filling a pail but about lighting a fire."

—W.B. Yeats

This research study examines the effects of inquiry-based instruction delivered through interactive television (ITV) on learner attitudes about and achievement in science. The first chapter includes the background, problem statement, definition of terms, and professional significance of the study. The second chapter is a literature review focused on inquiry-based instruction. Chapter three explains the methodology used in the research study. Chapter four presents the results from the research study and chapter five will discuss the results and provide input for further research.

Science education has transitioned through a period of constant reform in the 20th century with reports such as *A Nation at Risk* (National Commission on Excellence in Education, 1983) highlighting the National Commission on Excellence in Education's dissatisfaction with science education, and *Science for All Americans* (1995). These reports suggested instructional designs should include inquiry-based practices that engage students on a deeper level, proposing that how science is taught is just as important as student learning. The National Science Foundation (1996) developed national standards and referred to inquiry as a strategy by which student learning should be emphasized (p. 212). A renewed sense of attention has been focused on teacher professional development as one of the three major goals highlighted in the Glen Commission's, *Before It's Too Late* report (Glen et. al, 2000). Beginning in 2007, science has been added to the list of subjects for which the United States federal government is holding states accountable under the No Child Left Behind Act of 2001 (NCLB, 2002).

Background of the Study

In the first decade of the 20th century, John Dewey supported the idea that instruction beginning with concrete examples of a learner's world manifested the teaching of science through inquiry (Dewey, 1910). Predictions by the National Commission on Excellence in Education asserted that without major reform of the entire education system, a setback in the success of U.S. international competitiveness was imminent (Gardner et al., 1983). After several years of refining and reforming science education due to reports such as *A Nation at Risk*, the National Research Council (NRC) published the National Science Education Standards (1996). The NRC standards outlined student content, professional development, and evaluation benchmarks as drivers to promote science inquiry in classroom settings. These critical changes remain relevant for creating a more scientifically literate population.

The National Academy of Sciences firmly suggested a shift in the way science instruction should be conducted in elementary grades, indicating that students should have a more active role in learning science in order to boost science literacy at an earlier age (Duschl, Schweingruber, & Shouse, 2007). The development of the America Competes Act (2007) was to increase professional development for in-service and pre-service teachers. Additionally, the U.S. government has recently redirected its focus on science assessment with a renewed sense of urgency, expressed through the passage of the Science Accountability Act (2009). Inquiry-based methods have been successful in increasing learner attitudes and achievement through both formal and supplemental and classroom experiences (Gibson & Chase, 2002; Harris & Marx, 2006; Pine et al., 2005).

Despite the constant attempts at science reform, some schools have removed or repositioned science instruction due to more pressing educational mandates. Researchers at the University of California at Berkeley found that 80% of kindergarten through fifth-grade teachers in nine Bay-area counties spent approximately 60 minutes a week on science instruction compared with the previously reported 125 minutes in 2000 (Dorph et al., 2007). The Center for Education Policy (2007) found that 44% of 349 responding school districts across the county decreased time in other subjects in addition to science to accommodate mandated testing.

Constructivism

Constructivist epistemology emphasizes a learner-centered approach in which students learn from processing their experiences while adding to their prior knowledge based on new experiences. Dating back to Socrates and Plato, constructivist-based strategies have evolved throughout years of use and refinement (Haywood, 1983). Dewey, Piaget, Bruner and Vygotsky, all endorsed constructivist teaching as a way to build knowledge through experiential learning (Brainerd, 2003; Bruner, 1960; Mintzes, Wandersee, & Novak, 1998; Piaget, 1970).

Further research shows that constructivist-based teaching strategies, particularly inquiry-based instruction, can lead to higher levels of science learning when compared to more traditional methods of instruction (Montgomery, 1969; Stover & Bay, 1987; Wolf & Fraser, 2007).

Inquiry-based instruction. Inquiry-based instruction is often described as a reflection of the natural progression by which scientists execute the scientific process. According to the Center for Science, Mathematics, and Engineering Education (2000), inquiry-based teaching techniques are vital for primary-grade science education teachers to teach science in primary grades. Research focusing on teachers' beliefs about inquiry-based practices used in science instruction is consistent with improved attitude and achievement more than other forms of instructional design for classroom instruction (Johnson, 2004; Luera & Otto, 2005; Wallace & Kang, 2004). Fostering excitement in science at an early stage is also important. Palmer (2009) found that science interest increased as evidenced by the survey responses from 224 students regarding their interest during sections of instruction that used guided-inquiry practices.

Instructional Foundations

Blooms revised taxonomy. The original Bloom's Taxonomy was developed in 1956 to serve as a framework for categorizing educational objectives. Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001) continues to serve as a framework that provides a structure according to the cognitive and knowledge dimensions when creating learning objectives. The taxonomy's six cognitive levels provide a framework for developing instruction that stretches from low to high-level cognitive activities. The assessment developed for the instructional modules used in this study are aligned with the revised taxonomy.

Learning cycle. The learning-cycle approach is an inquiry-based strategy for science instruction that provides specific structure (Marek, 2008). Continuous exposure to instructional concepts has been found to be a vital factor in learning at intermediate grade levels (Nuthall, 1999). The learning cycle uses an inquiry-based approach to help learners with science concepts through an iterative process. This process assists learners in building knowledge as they reinforce prior knowledge through instruction. The learning cycle continues to show positive results when used in both formal and informal education settings (Cavallo, 2005; Gerber, Cavello, & Marek, 2001).

Five E instructional model. The Five E (5E) Instructional Model is a learning-cycle approach focused on five phases: (a) engagement, (b) exploration, (c) explanation, (d) elaboration and (e) evaluation. In each phase, educators may serve solely as a facilitator or they may choose to lecture students on specific concepts, depending on the level of their students' prior knowledge. The 5E model is noted as being effective in terms of learning and attitude. Researchers have determined that the 5E is an effective strategy for exciting students about learning science (e.g., Akar, 2005; Bybee, 2006). Maidon and Wheatly (2001) found that programs using the 5E instructional model yielded positive significant results when compared with traditional approaches to science instruction. Coulson (2002) examined the level at which the model was used, as it related to student learning. He found that learning increased according to the level of understanding and effective use of the 5E model.

Attitude and Achievement

Engaging learners in instruction that enhances their attitudes toward science requires innovative techniques. Gibson and Chase (2002) noted a significant improvement in attitudes toward science over a 2-year period resulting from inquiry-based strategies. Young and Lee (2005) found that instructional time spent on inquiry-based classroom activities compared to traditional approaches has yielded higher student achievement. Additionally, Amaral, Garrison, and Klentschy (2002) found that achievement in science, writing, reading, and mathematics were positively correlated to the use of inquiry-based instructional methods. Shymansky, Hedges, and Woodworth (1990) found significantly higher science achievement among those who used inquiry-based, hands-on programs compared with a more traditional approach. The research cited here took place in traditional face-to-face settings, comparing inquiry-based strategies with traditional lecture. However, empirical studies have not been conducted involving the implementation of inquiry-based practices through ITV.

Interactive Television

Interactive television (ITV) is a delivery technology through which students can engage in supplemental instruction offered by private and government agencies. ITV can offer more than a person talking on a screen in front of learners. Authentic learning environments are possible through ITV formats that improve the perception of science concepts and are a popular way of supplementing classroom instruction (Sullivan & Smith, 2001). Empirical research is limited on viable instructional methods for providing a more robust instruction through an ITV medium. A number of supplemental content provided via ITV consists of static lecture instruction also known as a "talking head". The intent of this study is to provide empirical evidence that the 5E model is an effective strategy that can be successfully implemented through ITV.

ITV provides educators with an additional resource offering the potential to enhance an inquiry-based approach to teaching science (Cavanaugh, Gillan, Kromrey, Hess, & Blomeyer, 2004; Newman, 2008). Such a distinction leads researchers to believe that supplemental instructional activities delivered through a flexible environment may improve learner interest if introduced with the proper techniques (Allen et al., 2004). Heath, Holznagle, deFord, and Dimock (2002) found that ITV is a tool that provides instructors with the ability to promote a higher level of activity in the classroom. Through an extensive review of the literature, they discovered that students are able to develop and ask questions of subject-matter experts, gain understanding from their peers, and compare information with their peers through ITV settings. Empirical research examining ITV has been relatively nonexistent in the elementary education arena for a number of years due to access, expertise, and technical flexibility constraints (Barfurth, 2002; Geelan & Fiege, 2004). However, using ITV for supplemental means of instruction remains an area that still needs further exploration.

A number of ITV providers offer supplemental services that do not market themselves as being grounded in educational, standards-based practices and effective strategies. Several government agencies offer experiences that are aimed at supplementing existing classroom instruction while corresponding to national and state standards. The National Aeronautics and Space Administration (NASA) developed the Digital Learning Network™ (DLN) to service schools with a science standards-based approach while leveraging effective strategies through ITV.

In the fourth quarter of 2003, NASA education specialists created the DLN to supplement instruction through ITV. Each of NASA's 10 field centers has its own ITV studio delivering NASA-related, standards-based science, technology, engineering, and mathematics supplemental content. The audience has grown to over 2,000 teachers across the country, with a sustained annual growth rate for the past 3 years, at a cost of less than $10 per child for programming (C. Smith-Long, personal communication, December 14, 2009). Furthermore, the DLN offers national standards-based content to its customers with a science, technology, engineering, and mathematics approach combined with inquiry-based practices utilizing the 5E instructional model. DLN sessions normally consist of a preliminary activity accompanied with a videoconference and then a closing activity providing the teacher with a chance to follow-up with additional activities. Certified teachers are recruited from all over the country to work for NASA as DLN presenters alongside NASA engineers and scientists. This research study addresses the relationship between the 5E instructional model and learners' attitudes and achievements via ITV.

Statement of the Problem

The theoretical underpinnings of learner-centered models reflect a constructivist tradition, focusing on individual activity and exploration of physical phenomena as a starting point for personal construction of meaning (Piaget, 1970). Inquiry-based research advocates a more student-oriented instructional design that yields more satisfaction, efficacy, and achievement in science classrooms (Barron, 1987; Greenwood, 1998; Wynia, 2000). ITV provides an avenue to broaden the reach of supplemental materials for a more authentic learning experience in the classroom.

Significance of the Study

The continuous push for innovative classroom science methods at early grade levels creates for opportunities to conduct research on effective methods in alternative delivery technologies such as interactive television (Plevyak, 2007). Thus far, professional development has been the main driver for using ITV in intermediate education settings. Current research examining inquiry-based science instruction that focuses primarily on collegiate and high school learners, lead the researcher to believe that there is an unexplored relationship between learner attitudes and achievement through ITV delivery at intermediate grade levels.

This study provides an empirical contribution to the body of literature examining the best practices for delivering instruction through an ITV delivery method for elementary grade levels.

Research Questions

1. What are the differential effects of the 5E vs. a traditional instructional model on 5^{th} graders' attitudes towards science taking into account prior attitude and prior knowledge?
2. What are the differential effects of the 5E vs. a traditional instructional model on 5^{th} graders' achievement, taking into account prior knowledge and attitudes?
3. What is the relationship between attitude and achievement in science delivered using the 5E instructional model?

Assumptions

1. ITV sessions will be a maximum of 50 minutes in length.
2. Participating teachers are computer literate.
3. Participants answered each question to the best of their knowledge.
4. Participants were familiar with the use of SurveyGizmo for online submission.
5. Participants were comfortable with participating in a videoconferencing setting.

Barriers/Delimitations

The following are barriers and delimitations for this study:

1. Intact classes of students will be used.

2. There is one ITV coordinator assigned to each participating school.
3. The sample size will be limited due to challenging accessibility to homogeneous groups that have direct access to ITV.
4. Students will only be exposed to treatment for a six-week period.
5. Schools will have to meet seven criteria in order to participate in the study.
6. Instruction will occur during the resource time at each one of the schools.
7. Instruction will be used as a supplement to regular classroom instruction.

Definition of Terms

The following terms are defined according to their use for this study:

1. *Attitudes toward science.* A measure of student's attitude determined by the Science Attitude Index II scale.
2. *Far end.* An entity that is being communicated with from the entities' vantage point through videoconferencing.
3. *Inquiry-based instruction.* An instructional method that is child-centered in which examples, observations, or experiments are provided prior to generalizations.
4. *Interactive television.* A type of communication that employs a two-way audio–videoconferencing medium as the sole source of communication between pupil and teacher.
5. *Internet protocol.* An Internet-based protocol of data communications.
6. *Near end.* An entity that is delivering or originating information for another entity through videoconferencing.
7. *Supplemental instruction.* Instructional experiences that uses prior knowledge, to build new knowledge.

8. *Traditional instruction.* An instructional method that is teacher-centered and employs a lecture-based approach to learning.

Summary

Teachers who use inquiry-based instructional methods for science instruction may be able to enhance their effectiveness by supplementing their classroom activities with ITV. Research focused on the use of inquiry-based methods has shown evidence of increased learning and comprehension in science. This study examines the effect of inquiry-based instruction on student attitudes and achievement. Chapter one included an introduction to the problem, its professional significance, and research questions. Chapter two is a review of the literature providing a focused empirical approach to the study. Chapter three discusses the research design and methods. Chapter four presents the results from the research study, and chapter five discusses the results and recommendations for future research.

Chapter II

Literature Review

This study explores the difference between attitudes and achievement in science learning for students who are taught via Interactive Television (ITV). This chapter provides an overview of relevant learning epistemology and empirical studies that analyze the impact of attitudes and achievement resulting from the use of inquiry-based instruction. The theoretical rationale of constructivism and inquiry-based learning are presented at the beginning of the review. The body of the review is divided into four sections based on literature examined in (a) instructional foundations, (b) the Five E (5E) instructional model, (c) ITV for science instruction, and (d) inquiry-based instruction implementation. In each section of the review, a brief summary of the work is presented followed by an analysis of relevant research or literature. Last, the summary will present a brief synopsis of the literature covered to help identify the gap in empirical literature examining inquiry-based practices through ITV.

Constructivism

The theoretical underpinnings of learner-centered approaches are rooted in constructivist epistemology, with a focus on individual activity and an exploration of physical phenomena, as a starting point for the personal construction of meaning (Piaget, 1970). Inquiry-based learning strategies direct learners to process their surroundings and develop meaningful experiences that focus on critical thinking. Thus, the inquiry approach calls for a more student-oriented instructional design that fosters satisfaction, efficacy, and achievement (Barron, 1987; Colburn, 2004; Greenwood, 1998; Wynia, 2000).

The epistemology of constructivism is rooted in the questioning techniques used by Socrates and Plato. Socrates used techniques to help Plato explore his own existing knowledge to construct new knowledge (Hawkins, 1994). In the 1800s, Kant presented an organization of categories, a basic system of questions that inquiry must ask of nature and guide an ongoing process of constructing, testing, and reconstructing hypotheses (Haywood, 1983).

While the works of Socrates and Kant centered on knowledge construction, James and Dewey posited that children's prior knowledge is a critical factor for their construction of new knowledge (Dewey, 1902; James, 1902). James therefore proposed a four-step blueprint for effective teaching: (a) recognize the child's interest, (b) determine prior knowledge of material to be presented, (c) present material clearly, and (d) connect new knowledge to old knowledge in a logical way (James, 1902). Dewey built on James's thinking as he concentrated on the holistic education of each child.

Similarly, in Dewey's (1902) writing, the child is the focal point of instruction. The child is the starting point, the center, and the end. Formal education efforts are subservient to the growth of the child and serve as instruments valued for the needs of growth. Dewey and James put forth similar tenets on assessing prior knowledge, constructing new knowledge, and experiential learning; positing that experiences are extrapolated by more contemporary practitioners of constructivism such as Piaget, Bruner, and Vygotsky.

Piaget believed that students create their knowledge as they interact with the world around them (Brainerd, 2003; Piaget, 1970). Piaget asserted that for students to grow cognitively, they must experience a discrepancy and come to grips with current knowledge, wrestle with that knowledge, and ultimately assimilate the new knowledge to their understanding (Brainerd, Marlowe, & Page, 1988). Piaget's work later influenced the work of Bruner, who introduced Piaget to American educators (Mintzes, Wandersee, & Novak, 1998). Bruner's philosophy centered on the structure and cognition of learning throughout a learner's multiple stages of development. At each stage of development, children have a characteristic way of viewing the world and explaining it to themselves. The task of teaching a subject to a child at any particular age is one of representing the structure of that subject using the child's perspective (Bruner, 1960).

To Bruner (1960), Piaget's levels of cognitive development were an internal structure and his own philosophy focused on the external structures of knowledge (Lutkehaus & Greenfield, 2003). Bruner identified the three stages of cognitive learning as enactive, iconic, and symbolic. The three stages depended on one another but were not developmental stages. Bruner's work also supported constructivist learning theory in several ways: Bruner concluded that the structure of content knowledge provides students with a scaffold to construct their own knowledge; children can learn more advanced concepts when they are presented in a developmentally appropriate manner; and students should be allowed to emulate the work of scientists by actively inquiring during instruction. Piaget's and Bruner's theories of knowledge construction focused on stages of learning and knowledge construction, while Vygotsky focused on the actions of the child.

Vygotsky's (1978) emphasis was on the student as an active participant in learning. Vygotsky stressed Bandura's Zone of Proximal Development, comprising the gap between an adolescents' level of actual development, determined by independent problem solving, and their level of potential development, determined by problem solving supported by an adult or through collaboration with more capable peers. The zone of proximal development compares the level of problem solving of a child who has been working individually and one working with more capable peers (Vygotsky, 1978). Ultimately, active engagement and facilitation are key factors in developing knowledge.

The work of Socrates, Plato, James, Dewey, Piaget, Bruner, and Vygotsky provides a scaffold upon which constructivism is built. Central to this belief is identifying the prior knowledge of the children, providing opportunities for children to discover, presenting a discrepant event so that they can wrestle with constructing their own knowledge, and allowing the time to do so are all critical components of constructivist learning.

Applications of strategies that adhere to constructivist epistemology have informed teachers about the learning ability of students and how they have influenced instructional practices (Appelton & Asoko, 1996; Novodvorsky, 1997; Plourde & Alawiye, 2003). Constructivist-based methods stress that teachers create environments in which their students are encouraged to think and explore. According to Appleton's (1997) cognitive research, focusing on different models of instruction reaffirms constructivist thinking as a viable guideline for models of science instruction. Appleton's research led to the development of an identified model that described students' cognitive progress throughout lessons. Such a discovery provides teachers with valuable information when determining best practices for instructional purposes. Other researchers also support inquiry-based instruction following constructivist epistemology as a main component of science instruction in contrast to traditionally based instruction (Montgomery, 1969; Stover & Bay, 1987; Wolf & Fraser, 2007).

Inquiry-Based Instruction

Educators frequently have various interpretations of what inquiry learning is and how they should implement inquiry-based instructional practices (Camins, 2001). The U.S. Department of Education has given attention to inquiry-based science curricula since the late 1950s. Evaluators from the NRC (1996) expressed a common distinction between science and education when referring to inquiry-based instruction because "scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (p. 23).

Additionally, the National Science Teachers Association provided a more focused definition for teachers of scientific inquiry as,

> the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (National Science Teachers Association, 2002, p.2).

The NRC's science-education standards (1996) provided suggestions for shifting focus to a conceptual understanding rather than fact recall. Inquiry should be used as the strategy for teaching conceptual understanding of science-content knowledge, attaining a deeper conceptual understanding of fewer concepts rather than the convergence of many. The NRC's recommendations are: (a) activities should include student investigation and analysis of concepts, rather than only verification of previously known knowledge or demonstration lessons; (b) investigations and experiments may take more than one class period to complete and should be encouraged; and (c) process skills should be used in investigating science concepts and solving problems. Rather than quickly moving through the textbook, students should complete more investigations to develop "understanding, ability, values of inquiry, and knowledge of science content" (NRC, 1996, p. 113). Students should not simply explore, but be able to explain science concepts and defend arguments.

Inquiry also refers to the actions of students in the classroom. Students should view themselves as scientists by recognizing science as a process, engaging in activities that reflect the work of scientists, designing investigations, revising knowledge, and understanding how scientists examine and make explanations about natural phenomena (NRC, 1996, 2000). In science as a discipline, students should: (a) use prior knowledge to raise questions about the world around them, (b) predict or formulate hypotheses about explanations and solutions to their questions, (c) design and complete simple investigations, (d) use observations to collect data, (e) develop explanations based on collected data, (f) consider alternative explanations, and (g) communicate findings to other classmates. Students in classrooms should experience science as a process and should be actively engaged in science (Biological Sciences Curriculum Study [BSCS], 1994; Layman, 1996; NRC, 1996). Educators, researchers, and publishers have historically referred to several teaching methods as inquiry-based instruction that include but are not limited to problem-based learning, discovery learning, and learning cycle. Educators commonly break down inquiry into three different categories: (a) structured, (b) guided, and (c) open.

Structured inquiry, provides students with a given a problem to solve, a method for solving the problem, and necessary materials, but not the expected outcomes. Students are to discover a relationship and generalize from the data collected. Guided inquiry requires that students must also figure out a method for solving the problem but the instructor does not prescribe the process or the outcome. Learners are in charge of those explorations. Open-inquiry instructional methods encourage students to formulate the problem they will investigate along with their own procedures and outcomes (Staver & Bay, 1987). Studies examined for this literature review are consistent with the guided-inquiry approach. Research-focused inquiry-based practices compared to more traditional methods of instruction offer much richer information, featuring the benefits of using inquiry-based instruction in educational settings

Science classroom teachers that implement inquiry-based practices tend to gravitate toward a structured approach due to the complexity and amount of prior planning required for both teachers and students (Blumenfeld et al., 1994; Hodson, 1988; Tobin, Tippins & Gallard, 1994; Welch, Klopfer, Aikenhead, & Robinson, 1981). Perkins (1991) and Roblyer (1996) advocated stronger guidance for science instruction noting that learners benefit more from a more formal type of inquiry that falls between guided and structured types. Roblyer, Edwards, and Havriluk (1997) also found that open inquiry-based approaches work best when students have prerequisite knowledge of the subject matter, allowing them to further develop prior knowledge. Such knowledge is not commonly found in elementary grade levels. Thus, Kirschner, Sweller, and Clark (2006) cautioned that novice students without appropriate prior knowledge may become frustrated and lost in purely open inquiry-based instructional approaches. The literature examined for this review focuses on guided-inquiry practices.

Why Inquiry-Based Instruction?

More recent instructional design theories strive to advocate for a combination of learner-and instructor-centered approaches (Riegiluth, 1999). However, intermediate-grade science educators often do not have sufficient content knowledge to readily facilitate science discussions and tend to revert to more traditional methods of instruction (Appleton, 2006; Davis, Petish, & Smithey, 2006; Magnusson, Krajcik, & Borko, 2001; Smolkin, McTigue, 2001). The following examination of traditional and inquiry-based approaches provides more basis and support for using inquiry-based instructional practices for science.

Traditional lectures are commonly divided into the categories of interactive, mastery, and traditional. Interactive lectures promote critical thinking by helping learners actively process new information. For example, mastery lecturing links new knowledge to familiar concepts and ideas familiar to the learner(s). Those using traditional lecturing, which is the most common strategy used, present information solely dependent on the teachers' understanding, organization, and instructional delivery (Kubicek, 2005).

Although lecture is beneficial for specific instructional situations, several meta-analyses denote inquiry-based methods as a better approach for science instruction. Bredderman (1983) examined 57 studies focusing on the effectiveness of three activity-based curricula to find significant results between control and treatment groups. Shamansky, Hedges, and Woodworth (1990) conducted an analysis of 81 studies comparing hands-on science programs with traditional textbooks; these classrooms showed more statistical results in favor of guided inquiry-based practices. Wise (1996) examined 140 comparisons of inquiry-based science education and traditional teaching in middle and high schools, finding a 13% increase in achievement scores favoring inquiry-based instruction. Each of these reviews found that achievement increased with the use of inquiry-based practices when compared with traditional approaches.

Research specifically exploring the impact of traditional lecture instruction compared to inquiry-based instruction has shown that students using inquiry-based techniques have progressed further than their counterparts in attitude and achievement in science (Montgomery, 1969; Wolf & Fraser, 2007). Empirical studies focused on K–12 education further substantiate the concept that the efficacy of inquiry-based instruction results in a more science-literate elementary through middle-school population (Marx et al., 2004; Ruby, 2006; Stohr-Hunt, 1996).

Montgomery (1969) examined how inquiry-based techniques compared to traditional approaches across 30 different classrooms using the BSCS curriculum of instruction. Two groups of students were chosen for comparison, examining achievement and retention of biology concepts after going through the BSCS curriculum. Findings revealed that students taught with inquiry-based instruction scored higher on their assessments and retained more information than their peers when using inquiry teaching methods along with BSCS curriculum. However, the study emphasized that inconsistency in using inquiry-based methods and teacher training can be a barrier to effectiveness.

Wolf and Fraser (2007) investigated how students' perceptions of classroom environments, attitudes, and achievement related to science were changed due to inquiry and non-inquiry laboratory instruction. Seventh-grade students were exposed to two types of science laboratory experiences for a period of six consecutive weeks. Quantitative results, indicated by both attitude and achievement, increased in the inquiry-based group but not in the traditional group. Qualitative results revealed that students receiving less guidance in the inquiry-based group were not as structured in their approach as the traditional group and exhibited significant differences in classroom cohesiveness when examining student understanding.

Marx et al. (2004) conducted a district-wide research study examining the impact of inquiry-based curriculum in urban school districts. The project was a part of a Detroit school reform project that occurred between 1998 and 2001. Participants consisted of sixth-, seventh-, and eighth-grade classes. Each grade level participated for an 8- to 10-week time span. The curriculum content consisted of simple machines for the sixth grade, air quality and water ecology for seventh, and physics for the eighth grade. A pre–posttest design was used to assess learning resulting from curriculum use. Results showed that a significant increase in scores resulted in each population sample indicating that the inquiry-based strategy was a success.

Ruby (2006) followed learner matriculation from fourth to seventh grade to examine students' science-achievement progression. Participants were paired with other students across school districts and compared during a three year period. The talent-development model was used with the treatment group's teachers while the control group teachers did not receive a model of instruction. Results indicated that the inquiry-based group scored better on standardized tests than their counterparts.

Stohr-Hunt (1996) explored the frequency of hands-on experience and science achievement looking for a correlation between frequency and achievement. Participants consisted of 24,599 eighth-grade students from 815 public and 237 private schools. Results indicated that participants who received science instruction one or more times per week performed better on a cognitive test battery developed by the Educational Testing Service.

Inquiry-based learning continues to show benefits for both learner attitudes and achievement in science over more lecture-based approaches. Not only has inquiry proven to be beneficial for teaching science, it has proven to be worthwhile in other subject fields as well. More recently, the use of inquiry-based instruction has been expanded to literacy practices that intertwine literature with science classrooms (Howes, Lim, & Campos, 2008) and teacher preparation when attempting to improve content knowledge (Davis & Smithey, 2008). Inquiry-based methods of teaching involve substantial work and environmental considerations to be successful.

Teachers often experience challenges when trying to implement inquiry-based practices in their science classrooms. Increased content knowledge has been shown to improve educator's ability to use inquiry-based methods (Kim, Hannafin, & Bryan, 2007). The multiple definitions and instructional choices of inquiry-based instruction have caused a noticeable level of dissonance for unseasoned educators (Newman et al., 2004). Using tried models of instructional development while teaching science through inquiry can help structure course content so that instruction is learner centered and teachers are facilitating conceptual understanding.

Instructional Foundations

Goals and objectives are the foundation of instructional designs. Bloom's revised taxonomy helps designers identify the placement of objectives based on knowledge and cognitive-processing dimensions (Anderson & Krathwhol, 2001). Using the proper instructional design and objectives can help educators meet goals and identify measurable outcomes of the instruction, guide content development, and establish how instructional effectiveness is evaluated (Gagné, Briggs, & Wagner, 1992).

Bloom's revised taxonomy. Bloom's revised taxonomy (Anderson & Krathwohl, 2001) serves as a framework that educators can use to provide structure according to two dimensions when creating learning objectives. The revised taxonomy consists of the knowledge and cognitive-process dimensions. The knowledge dimension consists of preexisting factual, conceptual, and procedural knowledge and adds metacognitive knowledge (See Table 1). According to Krathwhal (2002), factual knowledge focuses on concepts, details, and terminology that learners must know in order to understand subjects. Conceptual knowledge focuses on classifications and categories, principles and generalizations, theories, and models and structures. Procedural knowledge focuses on methods, techniques, and skills. Lastly, metacognitive knowledge focuses on cognition, awareness, and knowledge of personal thinking.

Table 1

Knowledge Dimension of Bloom's Revised Taxonomy

A. Factual Knowledge—The basic elements that students must know to be acquainted with a discipline or solve problems.	Aa. Knowledge of terminology Ab. Knowledge of specific details and elements
B. Conceptual Knowledge—The interrelationships among the basic elements within a larger structure that enable them to function together.	Ba. Knowledge of classifications and categories Bb. Knowledge of principles and generalizations Bc. Knowledge of theorists, models, and structures
C. Procedural Knowledge—How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.	Ca. Knowledge of subject-specific skills and algorithms Cb. Knowledge of subject-specific techniques and methods Cc. Knowledge of criteria for determining when to use appropriate procedures
D. Metacognitive Knowledge—Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.	Da. Strategic knowledge Db. Knowledge about cognitive tasks, including appropriate contextual, and conditional Knowledge Dc. Self knowledge

Note. Adapted from A Revision of Bloom's Taxonomy: An Overview" by D. R. Krathhwal, 2002, *Theory Into Practice*, *41*(4), p. 214.

The cognitive-process dimension hierarchy consists of the following categories: *remember*, *understand*, *apply*, *analyze*, *evaluate*, and *create*. Krathwal (2002) described the cognitive-process dimension as moving from simple to complex as instructional rigor increases and "the 19 specific cognitive processes within the six cognitive process categories receive the major emphasis" (p. 214; see Table 2).

Table 2

Cognitive Process Dimension of Bloom's Revised Taxonomy

1.0 Remember—Retrieving relevant knowledge from long-term memory.	1.1 Recognizing
	1.2 Recalling
2.0 Understand—Determining the meaning of instructional messages,	2.1 Interpreting
including oral, written, and graphic communication.	2.2 Exemplifying
	2.3 Classifying
	2.4 Summarizing
	2.5 Inferring
	2.6 Comparing
	2.7 Explaining
3.0 Apply—Carrying out or using a procedure in a given situation.	3.1 Executing
	3.2 Implementing
4.0 Analyze - Breaking material into its constituent parts and detecting how	4.1 Differentiating
the parts relate to one another and to an overall structure or purpose.	4.2 Organizing
	4.3 Attributing
5.0 Evaluate—Making judgments based on criteria and standards.	5.1 Checking
	5.2 Critiquing
6.0 Create—Putting elements together to form a novel, coherent whole or	6.1 Generating
make an original product.	6.2 Planning
	6.3 Producing

Note. Adapted from A Revision of Bloom's Taxonomy: An Overview" by D. R. Krathhwal, 2002, *Theory Into Practice*, *41*(4), p. 215.

When combined, the knowledge and cognitive-process dimension structures create the Taxonomy Table (see Table 3). The horizontal axis is formed by the cognitive-processes dimension and the knowledge dimension forms the vertical axis. Intersections between the two dimensions form the cells of the table. Krathhwal further explained the placement of objectives in the cells: "Any objective could be classified in the Taxonomy Table in one or more cells that correspond with the intersection of the column(s) appropriate for categorizing the verb(s) and the row(s) appropriate for categorizing the noun(s) or noun phrase(s)" (p. 215).

Table three presents an example of a higher-level learning objective along with sub-objectives categorized using Bloom's Revised Taxonomy. This example is from the Planet Hopping Module used in this study. Main Objective 1: Given a presentation on Gravity, students will use their prior knowledge to select the correct statement that explains how satellites orbit the Earth. Sub-objective 1: Given the definition of weight, the learner will recognize the correct term from the list of answers with 100% accuracy.

Table 3

Bloom's Revised Taxonomy Table for Planet Hopping

	The cognitive dimension					
	Nouns: Newton's First Law, the correct term; Verbs: choose, recognize.					
The knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual knowledge	X(Sub-objective)					
Conceptual knowledge			X(Main Objective)			
Procedural knowledge						
Metacognitive knowledge						

The "X" indicates the cognitive level of the objective, Remember, and the knowledge dimension, Factual. The verb, recognize, indicates the cognitive level of the objective is at remember level. Each level of Bloom's revised taxonomy provides proponents with a visual tool that links educational standards, goals, objectives, and activities, when developing instruction (Anderson, 2005; Raths, 2002).

The learning cycle approach. The learning-cycle approach is a strategy for structured inquiry-based science instruction (Marek, 2008). Nuthall (1999) recommended elementary students have three or four experiences with a topic before they commit the information to long-term memory. Nuthall's findings, from examining an integrated science and social studies unit, indicated that students should be presented with opportunities to expand their schema through guided-inquiry approaches. This method of inquiry-based instruction engages K–12 learners in hands-on activities throughout the instruction, providing several opportunities to explore new concepts, thus improving understanding and achievement (Beeth & Hewson, 1999; Cavallo, 2005; Cavallo, & Marek, 2001; Gerber, 1996).

Beeth and Hewson (1999) presented a case study that examined student understanding and engagement resulting from use of the learning cycle. A case study was conducted to examine a teachers' instructional practice in action as the teacher progressed through natural classroom activities. As the teacher witnessed a practical application of the learning cycle, the instruction alternated from hands-on to goal-directed discussion. Results of the study showed an increase in students' assimilation of information, understanding of the topics of instruction, and engagement resulting from the instructional strategies used with the learning cycle.

Gerber et al. (2001) examined the impact of the learning cycle in informal settings. They used an inquiry vs. non inquiry approach through informal supplemental experiences with 505 students ranging from 7th to 10th grade in rural, suburban, and urban settings. Both groups of students were administered the Informal Learning Opportunities Assay (Gerber, 1996), and the Classroom Test of Scientific Reasoning (Lawson, 1995) instruments to gauge the difference between students who received inquiry-based and non inquiry-based instruction. Results indicated that students who participated in the learning-cycle instruction demonstrated better scientific reasoning abilities than those in the non inquiry-based groups.

Primary-grade informal qualitative observations also identify the learning-cycle approach as an effective means of science instruction. Cavallo (2005), a classroom teacher, used plant seeds with the learning cycle, walking students through the process of seed germination through plant growth with inquiry-based activities. The assessment of informal student learning is achieved by reviewing notes, teamwork, and group contributions. Student understanding was perceived to be at a higher level by the participating teacher, indicating a more in-depth experience.

The learning-cycle approach to instruction promotes the development of reasoning abilities through experiences and interactions across multiple age groups. The learning-cycle approach offers teachers a more structured format for inquiry-based instruction that can easily be followed and provides students with a more involved process, encouraging active engagement (Blank, 1999; Hanuscin & Lee, 2008; Lindgren & Bleicher, 2005). One specific example of the learning cycle is the 5E instructional model. Derived from the Atkin-Karplus Science Curriculum Improvement Study (SCIS), the 5E instructional model uses concepts from prior research in student learning on the previous cycle to provide students with a more rounded approach to learning and teachers with a more learner-centered intent.

The 5E instructional model. A precursor to the 5E instructional model, the SCIS learning cycle, is described as being comprised of three phases of instruction that alternate between hands-on and cognitive engagement. These phases are (a) exploration, which provides students with authentic investigation of science phenomena through unstructured experiences; (b) invention, which allows interpretation and encourages students to build science ideas through interactions with resources such as peers, texts, and teachers; and (c) discovery, which involves the application of ideas to solve new problems (Karplus & Their, 1967). More natural discovery-learning approaches allowing students to explore variations of the learning cycle have been developed since Karplus and Their's original concept. The 5E model of instruction is one such model that builds on the initial success of the Karplus and Their model.

The 5E instructional model is a more empirically tested version of the learning cycle (Bybee, 1997; Cakiroglu, 2006; Ergin, Kanli, & Unsal, 2008; Evans, 2005; Maidon & Wheatly, 2001; Wilder & Shuttleworth, 2004), developed in the mid-1980s in part from the previous success of the SCIS model by the Biological Science Curriculum Study BSCS and International Business Machines (1989). The three core learning-cycle phases of the SCIS model function at the base, but BSCS added Engagement and Evaluation components to facilitate change in student learning (Table 4). Champaign (1988) influenced the addition of the engagement phase by stressing the need for learners to be cognizant of their prior knowledge before exploring a new topic. Further requirements for assessment data and accountability served as the impetus for including the evaluation phase to strengthen the model (Klum & Malcom, 1991).

Table 4

Phases of the SCIS and the BSCS 5E Models

SCIS	BSCS
	Engagement
Exploration	Exploration
Invention (term introduction)	Explanation
Discovery (concept application)	Elaboration
	Evaluation

Note. SCIS = Science Curriculum Improvement Study; BSCS = Biological Sciences Curriculum Study; 5E = Five E Instructional Model.

Research initiatives and standards-based content have been adopted to ensure that science is taught using an inquiry-based approach and the 5E instructional model rather than through traditional didactic methods (Bybee, 2006). This form of instruction places students in a more active environment by asking open-ended questions and thus enabling students to make discoveries in collaboration with others, rather than just listening. Teachers are encouraged to step out of their traditional roles to facilitate learning through the five phases of the cycle (Table 5).

Engagement. Problem solving and connections to prior experiences are important for successful implementation of the cycle at the beginning. The engagement phase of the 5E instructional model is designed to uncover current knowledge while presenting new information, placing the learner in a state of disequilibrium. Techniques can include asking questions, showing an event, or role-playing. Teachers are encouraged to set ground rules and procedures for establishing the task (Bybee et al., 1989).

Table 5

BSCS 5E Summary and Teacher Roles

Phase	Summary
Engagement	Prior learning is assessed to encourage problem solving, engagement, or the exploration of a new concept. Teacher role: Facilitator, Lecturer
Exploration	Activities in current topics are provided to encourage and facilitate conceptual change. Teacher role: Facilitator
Explanation	Students' attention is focused on explaining their conceptual understanding of the new concept, process, or skill. Teacher role: Facilitator, Lecturer
Elaboration	Teachers challenge opinions and explanations to encourage a deeper understanding and cognitive engagement of the students. Teacher role: Facilitator
Evaluation	Students evaluate their own understanding of their new abilities. Teacher role: Facilitator

Note. Adapted from *The BSCS 5E Instructional Model: Origins, Effectiveness, and Application*, by R. W. Bybee et al., 2006, Colorado Springs, CO: Biological Sciences Curriculum Study and National Institutes of Health; BSCS = Biological Sciences Curriculum Study.

Exploration. After successful engagement, students should be ready for the exploration phase of the learning cycle. Here, teachers are encouraged to engage students in hands-on, concrete experiences allowing them to explore concepts in an authentic environment. Bybee et al. (1989) suggested that teachers remove themselves from the traditional role of instructor and shift their efforts to becoming facilitators or coaches. The teacher will initiate activities and allow sufficient time and resources for students to explore phenomena.

Explanation. So far, the engagement of the students have allowed them to form an opinion of what they have observed through exploration. The next phase, explanation, occurs in two parts: (a) teachers provide students with the opportunity to explain their positions with regard to the problem, furthermore, (b) teachers provide students with a more formal scientific explanation of the concept or topic of discussion. Teachers should express any common terms that are related to the learning task. Additionally, teachers should clarify any misconceptions or confusion by stating concepts, processes, or skills necessary to move on to the next step in the cycle (Bybee et al., 1989).

Elaboration. Subsequently, teachers should involve students in opportunities to elaborate on the new concepts, skills, or processes previously explained. Misconceptions and dissonance regarding the new topic can be addressed here by engaging students in an authentic experience. Group discussions and elaborative feedback are encouraged throughout this phase before moving to the next phase of the cycle (Bybee, 1997).

Evaluation. Last, students should have the opportunity to use their newfound skills to evaluate their own mastery of the concepts. Teachers should provide feedback as appropriate, based on the environment and situational constraints.

The 5E instructional model serves as a more structured approach to the learning cycle when implementing an inquiry-based method of instruction. Each component of the model is geared toward learner autonomy while instructors facilitate learning and development. Next, research examining the effectiveness of the 5E instructional model is presented.

Five E Instructional Model Research

A meta-analysis, comprised of 25 years of data conducted by Shymansky, Kyle, and Alport (2003), revealed that students in effective inquiry-based classrooms excelled more than peers in traditional classrooms. Inquiry-based teaching has been effective in fostering scientific literacy and understanding science processes (Lindberg, 1990), positive attitudes toward science (Kyle, Bonnstetter, McCloskey, & Fults, 1985; Rakow, 1986), and higher achievement on tests (Winnie & Kong, 2007). The 5E instructional model builds on these practices to offer a more guided inquiry-based approach to science. Few empirical studies have specifically compared instruction using the 5E instructional model in K–12 education. Some have found significant differences in attitude and achievement between experimental and control groups (Akar, 2005; Cakiroglu, 2006; Colson, 2002; Ergin, Kanli, & Unsal, 2008; Maidon & Wheatly, 2001). Bybee et al. (2006) encouraged additional empirical research comparing and contrasting the 5E instructional model with other methods of instruction to prove its reliability. Next, the research examining attitude and achievement as they relate to the 5E instructional model will be discussed.

Impact on attitude and achievement. The 5E model has been shown to increase student attitude and achievement across several science subjects in K–12 education. Maidon and Wheatly (2001) explored the use of the 5E model throughout an entire curriculum to examine process skills, conceptual knowledge, and thinking skills of fifth-grade students. Researchers compared the National Center for Improving Science

Education *Science for Life and Living* curriculum, developed by BSCS (1992), with an activity-centered traditional science program. A total of 443 participants matriculated through the two methods of instruction throughout the school year. Results indicated that students who were exposed to the 5E instructional model scored significantly higher on the standardized *end of grade* test, understanding of process skills, conceptual knowledge, nature of science, and manipulative skills than those in the traditional activity-centered science program.

Cakiroglu (2006) examined the effectiveness of the 5E instructional model on photosynthesis and respiration in plants. Eighth-grade students participated in a 3-week-long study that compared instruction using the 5E instructional model and a control group that received traditional instruction. The treatment group performed significantly better on posttest analysis for both concept and overall achievement. This result is consistent with other studies that examined the differences in conceptual understanding when the 5E model was compared to more traditional forms of instruction.

Ergin et al. (2008) found the 5E model to be more effective than a traditional approach when teaching physics. The effectiveness of the 5E model was examined using a pretest–posttest design with 84 first-grade students. Students were divided into control and experimental groups and administered the *Inclined Projectile Motion Multiple Choice Success Test*, the *Test for Reasonable Thinking Ability,* and the *Attitude Determining Scale* for the *Subject of Projectile Motion* indices. Post treatment results revealed a significant change in attitude and achievement between the control and treatment groups in favor of the treatment group.

Akar (2005) conducted research addressing the impact of the 5E instructional model on attitudes and achievement related to chemistry instruction. Posttest results revealed an overall significant difference between control and treatment groups for achievement but not attitude. Further analysis of achievement scores found that participants in the experimental group also had a significant increase in conceptual understanding.

Increased attitudes and achievement across multiple disciplines exemplify the utility of the 5E instructional model in face-to-face instructional settings. Although limited in number, empirical studies have found achievement scores, encompassing standardized and classroom examinations for students using the 5E model, were higher than those of traditional instruction. Likewise, attitudes across science disciplines favor the 5E approach when compared to other instructional techniques. Next, the addition and impact of an ITV medium for inquiry-based instruction is discussed.

Interactive Television

ITV advocates assert that videoconferencing or ITV can reduce time, broaden the scope of instruction, reduce travel costs, increase training productivity, and improve access to learning across both industry and education markets (Martin, 2005; Rose et al., 2000; Townes-Young & Ewing, 2005; West, 1999). This section of the review will focus on ITV in K–12 education. Typically, this delivery mode of instruction falls under the broader category of distance education in most K–12 institutions.

Researchers, educators, and other audiences generally use the term distance education or distance learning interchangeably. The influence of technology has altered the definition of distance education. Rumble (1989) asserted that the separation of teacher and student is the key determinant in distance education. Keegan (1990) identified five elements of modern distance education categories that include ITV:

1. the quasi permanent separation of teacher and learner throughout the length of the learning process, distinguishing it from conventional onsite education;
2. the influence of an educational organization, both in the planning and preparation of learning materials and in the provision of student support services, distinguishing it from private study and self-directed programs;
3. the use of technical media print, audio, video, or computer to unite teacher and learner and carry the content of the course;
4. the provision of two-way communication that allows students to benefit from or even initiate dialogue, distinguishing instruction from other uses of technology in education; and
5. the quasi permanent absence of the learning group throughout the length of the learning process so learners can be taught as individuals and not in groups, with the possibility of occasional meetings for both didactic and socialization purposes (Keegan, 1990, p. 44).

Simonson's (1995) Equivalency Theory suggests that distance education experiences should be equivalent for both distant and local learners. Concepts central to his theory are equivalency, learning experience, appropriate application, students, and outcomes. Each concept supports the notion that distance learning should be just as effective as face-to-face instruction.

Research examining the effectiveness of overall K–12 distance education is expanding. Cavanaugh's (2001) meta-analysis examined (a) the achievement of K–12 learners who participated in online courses through videoconferencing or online telecommunications, and (b) characteristics such as instructional design, grade level, frequency, and subject area, identifying those that were most effective. A sample of 19 studies ranging from 1980 to 1998 was included in the study for analysis. Of those, 13 used videoconferencing, 5 used e-mail, and 1 used the Internet. Overall, a small positive effect size (0.147) supporting distance education was shown overall. No statistically significant differences were found across independent variables related to student achievement. Cavanaugh concluded the analysis by cautioning generalization of the results because of the relative novelty of technology during that time.

Cavanaugh et al. (2004), conducted another meta-analysis of 14 different Internet-delivered K–12 education programs conducted between 1999 and 2004. The analysis focused on subject area, grade level, and outcomes. The weighted mean effect size was -0.028 (SD = .045) at the 95% confidence interval from -.116 to 0.060. Given the results, the analysis indicated that distance education can be as effective as classroom instruction for K–12 learners.

Anderson and Rourke's (2005) literature-review results determined that ITV was being used for supplemental-instructional interventions, focused on achievement and attitude. They found mostly anecdotal writing and divided results into six categories that do not point to a clear empirical conclusion about ITV for K–12 settings. Rather, they suggest that the prevalence of anecdotal information is endemic of the beginning stages of technology integration and persists until the trend increases.

The previously discussed meta-analyses spanning from 1980 to 2004, support the use of distance education for Grades 3 through 12, with the comprehensive argument that distance education is at least as effective as traditional face-to-face classroom instruction. Given the early adoption of the technology by most school districts, delivery technologies such as ITV should be further explored with additional empirical research in K–12 education.

Supplementary experiences through an ITV format present educators with an additional way to potentially excite learners about science with the intention of continuing the enthusiasm throughout the school year (Leonard & Minogue, 2004). Greenwood (1998) asserted that ITV improves elementary science satisfaction through a team-teaching approach with the educator at the "far" end of the session. Newman (2008) further substantiated increased satisfaction with nine quasi-experimental studies that showed improvement in student attitude resulting from ITV sessions with supplemental organizations. Rural and remote areas that have trouble accessing supplemental information can use a format such as ITV to engage learners in meaningful instruction, increasing overall course satisfaction (Petracchi & Patchner, 2001; Rees & Downs, 1995; Ward Melville Heritage Organization, 2002). Despite the benefits of inquiry-based learning, this teaching technique is not without its challenges.

Factors that Influence Implementation

Inquiry-based instruction such as the 5E instructional model presents challenges in three areas: student learning, teacher practices, and classroom environment (Kim, Hannafin, & Bryan, 2007). Interaction, levels of comprehension, and the learning environment can impact instruction while teachers use inquiry-based learning strategies for classroom instruction. Similarly, an ITV format can present parallel challenges to those of a traditional classroom. Next interaction, levels of comprehension, and the learning as they relate to ITV instructional delivery will be discussed.

Interaction. Interaction has remained a focal point when examining ITV uses. Amirian (2003) argued that, “interaction is the key component of this use of technology (videoconferencing) to support a more social learning, negotiating meaning through interaction with peers over a distance, and forming a sense of community using the technology” (p. 4).

Interaction in distance education has been recognized as being just as important as in traditional instruction (Anderson, 2003; Laurillard, 1997; Lou et al., 2006; Moore, 1989; Muirhead, 2001a, 2001b; Sutton, 2001; Wagner, 1994). Wagner (1994) defines interaction as: “reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another. An instructional interaction is an event that takes place between a learner and the learner’s environment.” (p. 8).

Four main types of interaction have been identified to date: (a) learner-to-content, (b) learner-to-instructor, (c) learner-to-learner, and (d) learner-to-interface (Hillman, Willis, & Gunawardena, 1994; Moore, 1989). Moore (1989) identified the first three types, which are ubiquitous for traditional and distance-education settings. Hillman et al. (1994) argued that learner-to-interface interaction is solely related to distance education and focuses on the interaction between the learner and the technology being used in the specific distance-education interaction while the other three forms of interaction are taking place. This position was later supported by Ross (1996) and Tsui and Ki (1996) when examining necessary skills for computer conferencing in relation to successful interactions through online environments. Further examination of the facets of interaction provides a frame of reference when developing ITV instruction.

Learner-to-content. Moore (1989) contended that the first type of interaction is that of the learner with the content matter. Content developed with the 5E instructional model have a high rate of learner-to-content interaction, with interaction at the forefront (Bybee, 2006). This type of interaction further supports an inquiry-based approach in which students have to use their knowledge to construct meaning from content experiences. Hung and Tan (2004) and Shaklee (1998) found that a situated environment with activities connecting students to scientists, experts, and professionals enhanced learning. Students learned how to manipulate tools to solve complex problems through interactions and trial and error. Pachnowski (2002) used ITV as a replacement for student field trips. This author argued that the use of ITV broadened the scope of content that the teacher was able to provide students, in authentic environments through the technology.

Learner-to-instructor. Instructor presence and interaction play a large role in making learners feel comfortable in distance-learning settings (Moore & Kearsley, 2005). In an ITV setting, learner-to-instructor interaction can occur in a synchronous manner, allowing teachers to provide immediate feedback and learners to see and hear a "real" person. Moore (1989) noted this feature of distance education as highly desirable, arguing that this type of interaction has more advantage than learner-to-content. Furthermore, this type of interaction is particularly important in K–12 educational settings, because teacher presence and attitude can have an impact on student learning (Duschl, Schweingruber, & Shouse, 2007). McCombs, Ufnar, and Sheperd (2007) found that when presented with virtual science instructors via ITV, students had improved access to scientists who were not previously available, and teacher satisfaction with the content matter rose.

Learner-to-learner. Student collaboration through ITV provides students with opportunities to not only build on their current knowledge but also see and hear authentic accounts of individuals who are very different from themselves (Anderson & Rourke, 2005). This phenomenon consistently occurs in the case of language learning and multicultural education where ITV has been used to enhance learner-to-learner interaction (Gerstein, 2000; Kinginger, 1999).

Gage, Nickson, and Beardon, (2002) found that students enjoyed dialogue through ITV when discussing mathematics problems. Learners were able to compare and contrast their ideas with those of their peers in the context of mathematics. Geelan and Fiege (2004) used electronic whiteboards in conjunction with ITV, allowing 16 students, spread across four remote high schools, to collaborate with one another as a part of the Rural Advanced Community of Learners project.

Learner-to-interface. Several research studies examined learner-to-interface interaction through the use of tablet PCs and asynchronous environments (Clark & Abbott, 2004; Fisher, Cornwell, & Williams, 2007; Simon, Anderson, Hoyer, & Su, 2004) Educators who use ITV for instructional purposes have to adjust to technical barriers more frequently than learners citing technical issues as the main barrier to effective use (Barfurth, 2002; Geelan & Fiege, 2004). As ITV technology advances, the technology will become more and more transparent to learners.

As the four forms of interaction increase, a more robust level of interactivity will be achieved. Anderson (2003) argued that videoconferencing or ITV inherently support lower levels of learner-to-content interaction and only moderate levels of learner-to-instructor interaction. Subsequently, Anderson advocated for this form of technology, resulting in greater leaner-to-learner interaction. This stance contrasts with research that implies that ITV can encourage all three types of interaction. To ensure optimal levels of interactivity, Cyrs (2001) provided a list of 123 best practices of ITV that can help guide content development and delivery. Ultimately, the use of ITV requires instructors who have strong communication, organization, and management skills, similar traits to effective face-to-face classroom teachers.

Levels of comprehension. Inquiry-based learning implies, according to the underlying tenets of constructivism, that a more comprehensive level of learning will take place. This type of learning falls in the higher-order-thinking-skills area of Bloom's Revised Taxonomy, in which learners are asked to use information they have gained in the first three levels. Consequently, learning may be enhanced with the assumption that instructor practices and classroom environments are conducive for such learning. For example, Karplus and Their (1967) found significant results revealing higher-order thinking when employing their learning cycle. A meta-analysis, comprised of 25 years of data gathered by Shymansky et al. (2003), revealed that students in inquiry-based classrooms demonstrate a more comprehensive understanding of concepts than their peers in traditional classroom settings.

Instructional environment. Educators who do not understand their role in inquiry-based instructional environments may have trouble implementing the desired format (Edelson, Gordan, & Pea, 1999; Shymansky, Yore, & Anderson, 2004). Results from their research using the *Student Perceptions of Classroom Climate* (Yore et al., 1998) indicated that students exposed to more prepared teachers had more positive attitudes toward science. Empirical research examining the impact of ITV environments targeted at inquiry-based science instruction is scarce. However, numerous researchers acknowledge anecdotal literature, suggesting that inquiry-based ITV is a viable resource, but they do not uphold claims with relevant studies of empirical data (Rogers & Irwin, 1997). Based on Kubasko, Jones, Tretter, and Andre, (2007) sessions involving inquiry-based activities with scientists discussing nanotechnology showed an increase in the level of questions that were asked. Interactions with scientists were compared in both ITV and e-mail settings. Students who participated in the ITV session asked significantly more inquiry-level questions of scientists than those who corresponded through e-mail.

Inadequate teacher support and content knowledge can leave both teachers and learners feeling frustrated, making the educational experience more tedious than enjoyable when employing technology-rich solutions (Kam, Lee, and Songer 2002). Similarly, Kim, Hannafin, and Bryan (2007) pointed out that lack of resources or improper planning in the case of technology-enhanced classrooms can present significant challenges to the implementation of inquiry-based instruction. Educators who plan to use ITV in inquiry-based settings should be cognizant of interaction, levels of learning, gender, and instructional environment when developing content for instructional purposes.

Summary of the Review

According to the empirical literature examined for this study, guided inquiry-based instruction can potentially increase attitude and achievement over traditional lecture methods when examining impact on teaching science topics. As science reform continues to be the focal point of discussion, inquiry-based teaching practices have continued to be an appropriate form of science instruction. However, structured inquiry-based teaching methods can help teachers cope with the ambiguous nature of inquiry-based teaching itself, thus providing students with a richer experience.

The learning-cycle approach provides instructors with a more structured way to provide a learner-centered environment while improving the instructional experience. Traditional instructional methods have not proven to be as consistently successful when providing students with higher levels of understanding and improving attitudes when compared with inquiry-based methods such as the 5E instructional model. The Biological Science Curriculum Study's (BSCS) 5E instructional model continues to frame the learning cycle, giving instructional designers a more formal model to follow when developing science content (Ergin et al., 2008).

Delivering content through ITV creates circumstances that can intensify the challenges of using inquiry-based methods of instruction. System functionality, familiarity, and willingness to become a remote team teacher are changes with which instructors must become comfortable when receiving content from service providers. Although sometimes challenging, the benefits from meaningful supplemental content can make a difference for both teachers and learners in science instruction (Cavanaugh, 2001, 2004; Dennison & Haydock, 2004; Newman, 2008).

Interaction, levels of comprehension, gender, and instructional environment are four factors of which designers should be aware when designing inquiry-based instruction via ITV. All forms of interaction, learner-to-content, learner-to-learner, learner-to-instructor, and learner-to-interface should be considered when developing instruction through ITV for maximum results (Hillman et al., 1994; Moore, 1989). Developing learning objectives and instruction coinciding with target cognitive levels aid instructional designers in charting instruction along with related activities. Gender research supports the notion that boys and girls have similar attitudes toward science during intermediate grade levels but divide into different categories of interest while exhibiting less interest in the opposite gender's preference during adolescence (George, 2006; Hoffman, 2002). Last, constant awareness of the environmental considerations for inquiry-based instruction have helped learners gain the most from their experience (Bryan et al., 2007). Therefore, teachers who use ITV for supplemental instructional purposes should frame interactions in collaboration with their respective content providers.

Structured inquiry-based learning does not leave students who lack sufficient prior knowledge lost in the middle of an instructional experience, as some suggest regarding open instructional experiences (Kirschner, Sweller, & Clark, 2006; Klahr & Nigam, 2004; Mayer, 2004). Supplemental inquiry-based science instruction providers must clearly identify successful methods, due to the limited time and span of instruction. If a model of science instruction is acknowledged as being effective, designers can identify an approach that produces significant results compared to traditional instruction through ITV. The next section of the proposal discusses the proposed methodology of the study.

Chapter III

Methodology

The purpose of this research study is to determine the effectiveness of supplemental inquiry-based science education delivered through interactive television (ITV) specifically focusing on attitudes and achievement. This chapter discusses the method used in the study beginning with a description of the design and participants, followed by the procedure, instrumentation, data collection, and data analysis. Three research questions examined the impact of the 5E instructional model on achievement, attitude, and the relationship between attitude and achievement in science instruction.

The 5E instructional model was developed by the Biological Sciences Curriculum Study (BSCS) in accordance with International Business Machines to improve science instruction in the domain of biology. The model employs an inquiry-based approach within the learning cycle of science instruction by dividing instruction into the categories of (a) engagement, (b) exploration, (c) explanation, (d) elaboration, and (e) evaluation (see Appendix A). The 5E instructional model has been used across several science education domains (e.g. Chemistry, Biology, Physics) resulting in parallel positive results in achievement and attitude when compared with other methods of instruction.

One week prior to the study, measures of prior knowledge and attitude were gathered in the form of a pre-test to serve as covariates for analysis. Thereafter, participants experienced one of two treatments (Lecture or 5E Instructional Model) for a period of six weeks. At the conclusion of the instruction, participants retook the content and attitude instruments.

Rationale

Scientific challenges of historic proportions such as cloning, environmental change, alternative-fuel research, and stem-cell research are just a few of the complex issues that 21st century leaders will have to address. Students today will need to be well prepared and scientifically literate to make intelligent decisions that will positively impact our way of life in the near future. Historical trends of science-education reform have aimed to improve one generation over the next for a more scientifically literate community (Duschl, Schweingruber, & Shouse, 2007; Gardner et al., 1983). President elect Barack Obama and Vice President elect Joe Biden (2008) laid out their plan for science and innovation targeting education as a fundamental building block to success asserting,

> High quality STEM education is essential for not only for those who would become scientists; all students must have equal opportunities to learn 21st century content and skills. Only this can maintain our country's leadership in innovation and create a nation of engaged citizens who can participate in a vibrant democracy and know how to learn for a lifetime in a knowledge economy (p.3).

Recently, the Office of Science and Technology Policy Executive Office of the President (2009) outlined a plan supporting science, technology, engineering and mathematics (STEM) fields with a $98 million dollar increase raising the amount of funding for STEM initiatives to 3.7 billion dollars. This plan sets the stage for a cross-cutting approach to STEM education that encompasses elementary school through graduate level research opportunities.

Empirical research points to inquiry-based instructional methods as a meaningful instructional practice for science instruction (Gibson & Chase, 2002; Harris & Marx, 2006; Pine et al., 2005; Shamansky, Hedges, & Woodworth, 1990). Additionally, significant differences in attitude and achievement have been observed when comparing inquiry-based approaches with traditional approaches in face-to-face environments (Montgomery, 1969; Wolf & Fraser, 2007). The continuous push for innovative classroom science methods at early grade levels begs for opportunities to conduct research on effective methods in alternative mediums such as interactive television (ITV) or two-way audio/videoconferencing. Thus far, professional development has been the main driver for using ITV in elementary education settings. Current research examining inquiry-based science instruction that focuses primarily on collegiate and high school learners exposes an unexplored relationship between learner attitudes and achievement through ITV delivery at early grade levels. The intent of this study was to provide an empirical contribution to the body of literature, supplementing best practices for delivering instruction through an ITV medium for elementary grade levels.

Research Questions

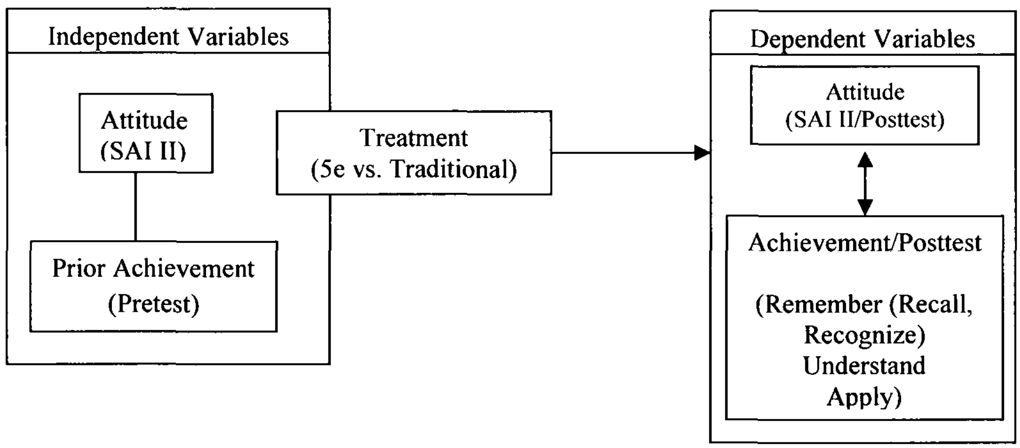
This quasi-experimental study examines three research questions examining the effect of the 5E instructional model on attitude and achievement along with the relationship between the two in science instruction after controlling for demographic characteristics. The research questions are:

1. What are the differential effects of the 5E vs. a traditional instructional model on 5th graders' science achievement, taking into account prior knowledge and prior attitude?

2. What are the differential effects of the 5E vs. a traditional instructional model on 5th grade students' attitudes toward science taking into account prior attitude and prior knowledge?
3. What is the relationship between attitude and achievement in science delivered using the 5E instructional model?

The following conceptual framework shows the essential variables of the study (Figure 1).

Figure 1. Conceptual model of the research study.



Sampling Strategy

A purposeful sampling strategy was used to select classrooms. To determine an adequate sample size, the researcher used G*Power software to conduct a priori power analysis. Statistical power is the probability that a specific statistical test will reject the null hypothesis when alternate hypotheses are true. A medium effect size of .3 (medium) was selected due to the lack of research indicating a commonly achieved effect size for this type of research. The G*Power v3.1 priori analysis, based on power = 0.90 (90% chance of detecting and effect), alpha = .05, and effect size = 0.3 for an analysis of variance (ANOVA) with two groups and two dependant variables indicated a sample of no less than 238 participants were required. A total of 317 elementary grade teachers using the NASA's DLN were solicited through e-mail invitation to participate in the research study (Appendix H). Respondents were required to meet the following seven criteria for eligibility:

1. Participating teachers had to gain approval from their principals before procedures can begin.
2. Each school had a technology coordinator facilitating ITV sessions.
3. Each school had similar science standards required by their respective state authority.
4. Participating classes had 40 to 60 minutes of uninterrupted time per school week for a six-week period devoted to ITV sessions.
5. Participants had conducted at least three ITV sessions with a content provider prior to volunteering to participate in the study.
6. Participating classes had access to a computer laboratory for all assessments.
7. Students' primary instructional method for science instruction could not be the 5E instructional model.

After the preliminary email, a cadre of eleven schools were interested in participating in the study. The researcher spoke to the interested teacher at each school through e-mail and telephone confirming interest. A formal letter was sent to each school specifying the requirements of the study (Appendix H). The researcher then secured dates with the technology coordinators to schedule test calls for a short discussion to confirm eligibility before narrowing the population size. Only three of the eleven schools met the criteria for participating in the study. Two schools, one rural, and one suburban, were located on the East Coast of the United States and the third school was from a suburb in Alberta, Canada. To control for confounding variables with each school, the researcher cross-referenced all three schools' science curriculum in addition to their access to supplemental activities.

All three schools were similar regarding their curriculum and access to supplemental instruction indicating no critical threat to the research study. Classes within each school were randomly assigned to control or treatment groups within the intact groups. Since removing students from intact classrooms would disturb time devoted to other subjects, the instruction occurred during resource times at each participating school. Six classes were assigned to the treatment group and five classes were assigned to the control group using a Microsoft Excel random number generator.

Sample

A total of 271 fifth grade students from two suburban and one rural school districts participated in the study. However, only 260 participants completed the pre and post-assessments (n = 260) (Table 6). The excluded 11 students were omitted due absenteeism or unwillingness to participate. Table 7 shows the distribution of classes based on instructional strategy, number of students, and percent per strategy. All participants spoke English as their primary language and covered the topics of Force and Motion as a part of their curriculum after participating in the study. Ethnicity demographics are presented in Table 8.

Table 6

Participants by School

School	N	%
School1	70	26.92
School 2	92	35.38
School 3	98	37.60
Total	260	100

Table 7

Distribution of Classes per Strategy

Strategy	*n*	School 1			School 2			School 3		
		Classes	*n*	%	Classes	*n*	%	Classes	*n*	%
Lecture	118	1	23	19.49	2	43	36.44	2	52	44.06
Inquiry	142	2	47	33.09	2	49	34.50	2	46	32.39

Table 8

Ethnicity and Numbers of All Students

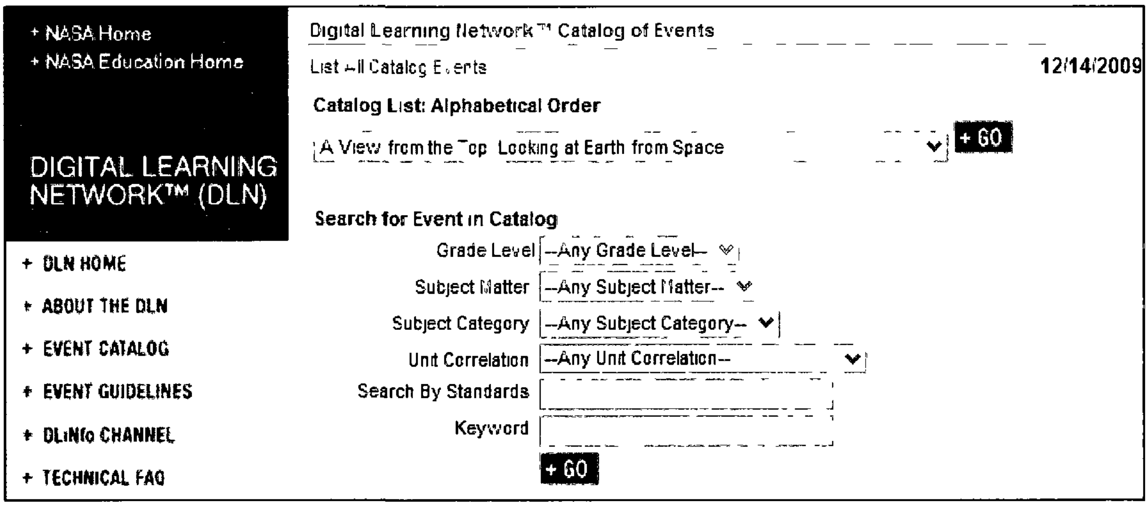
Subgroup	School 1	School 2	School 3
African American	-	18	-
Asian	-	3	2
Hispanic	1	15	-
Native American	-	-	2
White	69	48	93
Other	-	8	2
Females	26	47	51
Males	44	45	47

NASA's Digital Learning Network

The National Aeronautics and Space Administration (NASA) developed the Digital Learning Network (DLN) in 2004 to deliver NASA-specific content through interactive instruction via ITV across the country. The program leverages the talents of NASA scientists, researchers, engineers, and technicians in an attempt to bridge the gap between theory and practice of science, technology, engineering, and mathematics concepts. The 5E instructional model is used extensively in each content module structure, while national standards are used as a guide to frame subject-matter content.

DLN sessions are interactive in nature and provide a forum for learners to talk with NASA employees or educators about specific topics. Special programs are frequently offered that take students on exploratory trips into a scientist's laboratory or even out to view a space-shuttle launch (Talley, & Cherry, 2009). Hung & Tan 2004 advocate that other virtual field trips in simulated environments help students understand concepts. Instruction consists of 50-minute modules registered for through an online system (http://www.nasadln.gov) (Figure 2). After completing registration, confirmation was sent via email and a test connection occurs to ensure connectivity. On the day of the event, customers "dial" the Internet Protocol address to begin the event. After the connection is established, the respective DLN Coordinator presents the module.

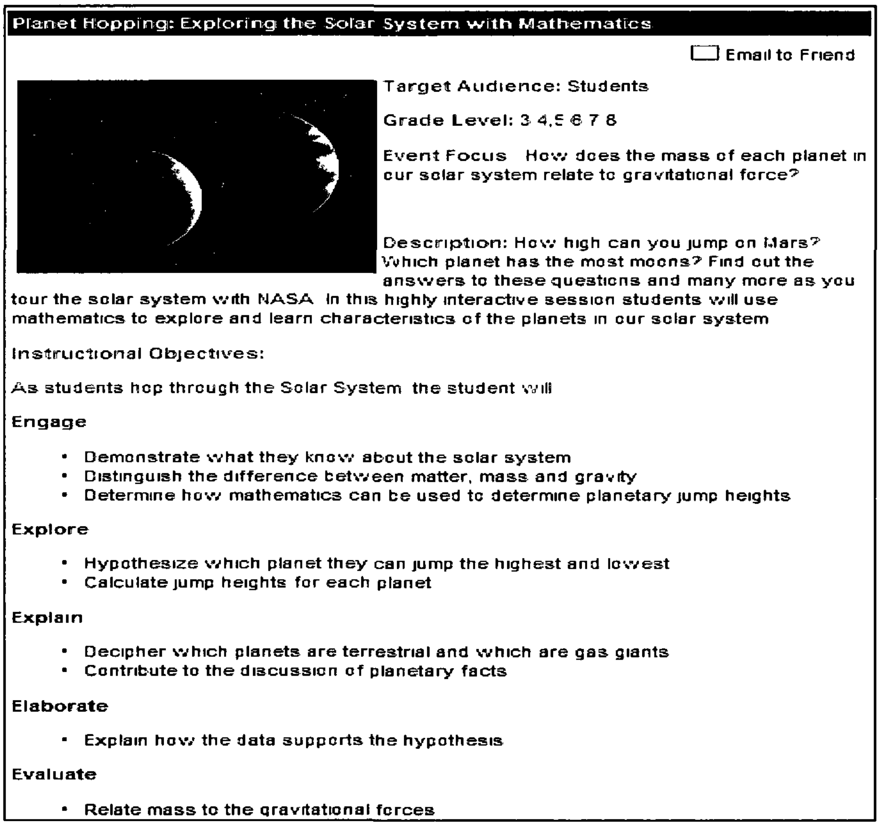
Figure 2. Screenshot of Catalog of Events Search Criteria



Treatment

Module content. Because the DLN's customer base spans the United States, a national-standards approach was adopted for instruction. The module content used in this study is comprised of six modules focusing on Force and Motion (Appendix B). The modules were developed using the 5E instructional model by education content developers employed by NASA. Content developers are former classroom educators. To ensure content validity modules were subjected to a review process that includes inter-agency education colleagues and outside educators. Each page provides information on the target audience, focus, description, and instructional objectives in context of the 5E instructional model (Figure 3).

Figure 3. DLN Module Example



Planet Hopping: Exploring the Solar System with Mathematics

Email to Friend

Target Audience: Students

Grade Level: 3 4,5 6 7 8

Event Focus How does the mass of each planet in our solar system relate to gravitational force?

Description: How high can you jump on Mars? Which planet has the most moons? Find out the answers to these questions and many more as you tour the solar system with NASA In this highly interactive session students will use mathematics to explore and learn characteristics of the planets in our solar system

Instructional Objectives:

As students hop through the Solar System the student will

Engage

- Demonstrate what they know about the solar system
- Distinguish the difference between matter, mass and gravity
- Determine how mathematics can be used to determine planetary jump heights

Explore

- Hypothesize which planet they can jump the highest and lowest
- Calculate jump heights for each planet

Explain

- Decipher which planets are terrestrial and which are gas giants
- Contribute to the discussion of planetary facts

Elaborate

- Explain how the data supports the hypothesis

Evaluate

- Relate mass to the gravitational forces

Instructional strategy. Modules used for this study adhered to DLN development guidelines. Content modules were developed by a NASA Aerospace Education Specialist Project teacher, a NASA DLN representative, and the researcher. The researcher's role in development included establishing objectives, locating graphics, and identifying activities. The five topics (a) Friction, (b) Gravity, (c) Newton's First Law (d) Newton's Second Law and (e) Newton's Third Law span six weeks of instruction under the broader theme of Force and Motion (see Table 6). The control-group modules were developed using a standard lecture-based method augmented with graphics and limited topic discussion until the point at which instructors determine that students should contribute (Table 9). Treatment-group modules were developed using the 5E instructional model.

Table 9

Module Matrix

Title	Friction	Gravity	Newton 1	Newton 2	Newton 3
Force and motion	⊗	⊗	⊗	⊗	⊗
Push or pull?	⊗				
Planet hopping		⊗			
How fast can you go?			⊗		
Four forces of flight				⊗	
May the force be with you					⊗

Instructional modules consisted of an overview of the concept then a further explanation of the topic using either inquiry-based or traditional lecture strategies. For example, *The Four Forces of Flight* module focuses on how airplanes use the forces of flight against one another to achieve and maintain aeronautical stability (Appendix C). Both groups (5E and control) had the same learning objectives: (a) Recognize how lift, weight, thrust, and drag relate to airplane flight, (b) Identify how Bernoulli's Principle affects an airplane wing, and (c) Determine how Newton's 2nd Law affects airplane flight.

Lecture-based. The lecture-based strategy used for the control-group presentations consisted of primarily didactic instruction. Graphics were incorporated to illustrate the key concepts and points that participants were expected to remember during the module. Each session began with a review of the previous concepts. The instructor toggled back and forth from the camera to the graphics while delivering the content in a direct manner. Participants built a paper airplane and the presenter explained how the four forces act on one another in flight. Questions were permitted during and at the end of the ITV session at the discretion of the instructor.

Five E inquiry-based. The treatment group received the 5E instructional model strategy (Appendix D). The session began with a review of the previous concepts. Then, the instructor asked the students a guiding question about flight: "How do airplanes fly?" (Engagement). A discussion ensued giving students an opportunity to express their explanation of the forces of flight and Newton's Second Law. Next, participants were asked to build an airplane that maximizes the use of the previously discussed concepts (Exploration). Guidance was not provided to the participants as they built the airplanes. The instructor then asked participants to volunteer to articulate their engineering decisions (Explanation). The instructor then elaborated on what was built and tied in specific concepts that participants may or may not have addressed to ensure the airplane could fly highlighting Newton's 2^{nd} Law (Elaboration). Last, the instructor queried participants regarding the concepts and how different designs can be used on different airplanes. Graphics of different examples of aircraft were shown and participants evaluated the application of the four forces of flight and explain how they relate to the example (Evaluation). Each module in the *Force and Motion* series was modified similarly to the previous example with various activities.

Dependent Variables

Attitude: Science attitude inventory II. The revised Scientific Attitude Inventory II (SAI II; Foy & Moore, 1997) was used to collect attitudinal data from participants (Appendix, E). The SAI II's Spearman Brown is .805 and the Cronbach's alpha reliability coefficient of .781 indicated the reliability of the instrument was strong. This 40-item scale is the second iteration of SAI, used extensively for science-attitude research (Baker, 1985; Finson & Enochs, 1987). Critical analysis and improvement led to the revision of the original inventory for improved reliability and the removal of gender-biased language, while keeping the assessment of learner attitudes toward science intact.

The SAI II is composed of 12 position statements, six of which are positive and labeled 1-A through 6-A and six of which are negative and labeled 1-B through 6-B, representing intellectual and emotional attitudes. Statements one through five have three questions associated with both positive and negative position statements. Statement six has five positive and negative statements. The questions are broken up into the six different categories of (a) laws and theories of science, (b) observation of natural phenomena being the basis of scientific explanation, (c) traits that are needed to operate in a scientific manner, (d) science as an idea-generating activity, (e) progress in science requires public support, and (f) being a scientist or working in a job requiring scientific knowledge. Scoring is done on a five-point Likert scale including strongly agree, mildly agree, undecided, mildly disagree, and strongly disagree. Point values range from five to one for items corresponding to positive position statements and one to five for questions corresponding to negative position statements (Table 10).

Table 10

Point Values for Positive and Negative Items

	Positive Items	Negative Items
Strongly Agree	5	1
Mildly Agree	4	2
Neutral/Undecided	3	3
Mildly Disagree	2	4
Strongly Disagree	1	5

See Appendix A for the position statements and attitude statements of the SAI II (Foy & Moore, 1997). The researcher examined all six domains based on the position statements of the SAI II to determine attitudes toward science.

Achievement: Content assessment. The content assessment included multiple choice and matching questions evaluating student knowledge at the remember, understand, and apply levels of Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001). Both control and treatment groups were given the assessment one week prior to the six-weeks of instruction. The content assessment was made up of 35 questions. Both tests consisted of 20 questions at the remember level (ten recall, ten recognize), ten at the understand level, and five at the apply level (Table 11). The questions were then broken down into their respective Bloom's level according to objectives (Appendix F).

Table 11

Assessment Matrix

Bloom level	Remember–recall	Remember–recognize	Understand	Apply
Friction	1, 2	3, 4	5, 6	7
Gravity	8, 9	10, 11	12, 13	14
Newton's 1st law	15, 16	17, 18	19, 20	21
Newton's 2nd law	22, 23	24, 25	26, 27	28
Newton's 3rd Law	29, 30	31, 32	33, 34	35

To ensure content validity, the assessment questions were developed in collaboration with a science-content expert from NASA Langley Research Center and a science teacher at NASA Langley Research Center. University professors and a science official at each of the participating schools later approved the assessment. All three parties verified the assessment was aligned with instructional objectives, levels of learning, and standards. One NASA education specialist and one science educator determined inter-rater reliability. The officials rated each question with a one, two or three rating based on the clarity of the question and answer choices. A rating of one indicated neither question nor answer choices were clear. A rating of two indicated the question was clear but the answer choices were not. A rating of three indicated both the question and answer choices were clear to the rater. Wording adjustments were made to questions 2, 15, 19, 26 and 35 to the content assessment were made reach a Cohen's Kappa of 1.0 for inter-rater reliability.

An assessment pilot was conducted with a sample of 71 participants from a suburban school in Charlotte, NC to determine the reliability of the revised content assessment. An internal consistency above .70 was sought after according to Kuder-Richardson 20 calculations (Kuder & Richardson, 1937). The Kuder-Richardson 20 is a measure of internal consistency reliability for measures with dichotomous choices. This method was chosen as opposed to the Kuder-Richardson 21 because the KR-20 does not assume that all of the test items are equally difficult. Participants took the assessment the summer before the final research study was scheduled. Eight respondent's answers were omitted due to not the completing the assessment. The pilot assessment yielded a Cronbach's alpha of .756.

Covariates

Prior knowledge. Participant prior knowledge was assessed by administering the pre-test before the instruction. Prior-knowledge levels have shown to be an indicator of the effectiveness of inquiry-based instruction. By isolating prior knowledge, a more robust analysis of results from the instructional strategy can be obtained. The same instrument was used for both prior knowledge and the posttest for achievement.

Attitude. Attitude was assessed by administering the SAI II instrument one week before and after all six instructional modules were complete.

Procedure

Permission to conduct research with human subjects was obtained at the university, school, and classroom levels. Old Dominion University's Institutional Review Board reviewed the research study. Upon confirmation, documentation was forwarded to participating schools as part of the request to participate. Participating school officials were contacted in the form of a letter, email, and a phone conversation and the pertinent documentation explaining the details of the research study. (Appendix H).

Prior to module delivery, participants completed the SAI II instrument and the content pre-test. Participants (n = 2) that did not take the assessments before instruction started were not counted in the data analysis. Both instruments were administered via the Internet in a controlled environment overseen by participating coordinators approximately one week prior to the first module session according to the pre-defined schedule. A total commitment of eight weeks (1 pre-test, 6 module delivery, 1 post-test) was required of participating schools. The *Force and Motion* module series was presented sequentially to each of the participating classrooms once per week during the six-week period. To avoid researcher bias a certified science-education NASA specialist (not the researcher) with more than ten years teaching experience delivered the instructional modules to all groups. A roster for each class resided with the technology coordinator to address any absenteeism issues that may skew data. The researcher did not have access to the roster. Participants missing more than one session (n = 7) were permitted to attend all sessions but were omitted from the post-test and subsequently omitted from the pre-test data. Last, two students declined to participate in the study. Group A (treatment group) received inquiry-based instruction according to the 5E instructional model and Group B (control group) received a traditional direct form of instruction using lecture and basic graphics. Identical content was covered through each ITV session with instructional strategy as the only differentiating factor.

After module sessions were complete, participants retook the SAI II and the content post-test for subsequent analysis. Each student received a NASA gift bag for their participation in the study and the teachers received an educator pack from NASA as a token of appreciation from the researcher.

Data Collection

The Scientific Attitude Index II (SAI II) and the Forces in Motion content assessment were administered through SurveyGizmo web software before and after the Force and Motion treatment. Teachers used a predetermined universal resource link (url) when directing participants to the assessments in the designated computer laboratory at each school. Participants were required to respond to each of the SAI II items as well as the multiple-choice content-assessment questions. Names were collected on the online surveys for tracking purposes and deleted immediately after the data was cleaned for absent participants. The SAI II took participants between 15 and 20 minutes to complete. The content pre and post-test took approximately 20 minutes to complete.

Upon data collection, pre-analysis data screening was conducted for accuracy, missing data, outliers, and to assess the degree of fit between statistical procedures and collected data (Mertler & Vannatta, 2005). Additionally the three general assumptions of normality, linearity, and homoscedasticity were addressed. Missing data values for content and attitude assessments were dropped from the study. No threat of a drastically reduced sample size occurred so a regression approach was not used to estimate missing values. Outliers were detected through standardizing the data by transforming the raw data into *z*-scores in addition to an analysis of the online data. A box plot was run using the Statistical Package for the Social Sciences to indicate outliers in the data. Normality was explored using a normal probability plot or Q-Q plot testing for the sample distribution (Mertler & Vannatta, 2005). A Leven's Test with a *t*-test of independent samples did not indicate a significant difference (Mertler & Vannatta, 2005).

Data Analysis

SAI II and achievement data were analyzed using the Statistical Package for the Social Sciences (SPSS) computer software. Descriptive statistics for treatment and control demographics and dependent variables were computed and provided via visual format.

Inquiry and attitudes. To answer the first research question, What are the differential effects of the 5E vs. traditional instructional model on 5th graders' attitudes toward science taking into account prior attitude and prior knowledge?, independent t-tests and ANCOVAs were used to examine positive and negative attitudes of the participants. The SAI II is broken into six different categories, (a) laws and theories of science, (b) observation of natural phenomena being the basis of scientific explanation, (c) traits that are needed to operate in a scientific manner, (d) science as an idea-generating activity, (e) progress in science requires public support, and (f) being a scientist or working in a job requiring scientific knowledge from the SAI II before and after treatment, each having a positive and negative statement to make up the total score. Pre-test SAI II scores and prior knowledge scores were used as covariates to reduce error variance and symbiotic bias. An analysis of variance was used to further examine the pre/post-data to determine any interactions between classroom attitudes.

Inquiry and achievement. To answer the second research question, What are the differential effects of the 5E vs. a traditional instructional model on 5th grader's achievement, taking into account prior knowledge and attitudes?, independent t-tests and one way ANCOVAs were run on each group's achievement mean score for each topic and each of the three levels using prior knowledge and prior attitudes as covariates (remember (recognize/recall), understand, apply).

Attitude and achievement. To answer the third research question, What is the relationship between attitude and achievement in science delivered using the 5E instructional model?, a correlation coefficient and factorial MANCOVA were used to examine the effects of strategy type (5E and traditional instruction), prior knowledge, and prior attitude on attitude and achievement.

Validity Threats

Internal validity refers to factors that may compromise the integrity of the proposed study that will serve as a plausible alternative explanation for research findings (Shadish, Cook, & Campbell, 2002). The phenomena described below have been identified as major internal threats to the research study.

ITV Coordinator bias. Coordinators at each participating school may have a bias toward instructional content or methodology used in the ITV sessions due to internal or external motivations such as test scores, personal preference, or threats to alter their current teaching style. This threat was addressed with the requirement that each coordinator feel comfortable with remaining agnostic toward the instruction at each participating school. The researcher informed each principal and ITV coordinator of their roles and responsibilities in addition to the importance of maintaining the integrity of the study.

Researcher bias. The researcher was removed from the study after initial contact and acceptance by the participating schools. The researcher did not have any contact with the participants what so ever and limited formal contact with the school coordinators during the time of the research study. Informal conversation to check on progress of the study was the only type of communication from the researcher. The teacher delivering the ITV sessions served as the primary point of contact for the six-week period.

Presenter consistency. Inconsistency of content delivery could potentially skew data. This threat was addressed with the selection of one presenter for the instruction and a back up presenter with similar qualifications. Additionally, the presenter agreed on the content developed and the schedule and flow of events for each ITV session with the researcher to address any concerns one month before the official start (i.e. the amount of time devoted to review and closure for each session).

Student absenteeism. Absenteeism could potentially skew the data if a record of participants is not kept. A student roster was filled out for every class by the participating school coordinator to account for any absences in the instruction according to the agreed schedule. If a student was absent from more than one ITV session, their pre-test scores will be removed from data analysis. However, the student was allowed to participate in the remainder of the study but was not counted in the statistical analysis. Students were asked to provide their names on the pre and post-test instruments for tracking purposes. Names were deleted from the data prior to statistical analysis after the module series was concluded to ensure anonymity.

Instrument validity/reliability. The SAI II instrument, examining attitude, has been previously validated with a Cronbach's alpha of .781 (Foy & Moore, 1997). The content assessment reliability was addressed through inter-rater reliability and a pilot assessment resulting in a Cronbach's alpha of .756.

Repeated testing. Bias toward previously selected answers on the pre-test may cause participants to maintain their current stance on items that were previously selected during the pre-test administration. Based on prior studies, the researcher believes that there was sufficient time in between administrations of the test that would further mitigate this threat.

Diffusion of treatment. To limit the amount of diffusion associated with this research study, participants were exposed to all activities in some form. The control group relied on the instructor to deliver examples and the experimental group conducted small experiments. The two groups have common language associated with their experiences therefore mitigating the impact of diffusion.

Equipment failure. When delivering instruction via ITV, equipment failure is often a challenge. The researcher addressed this threat by sampling a population that frequently uses ITV as a means of instruction with reliable equipment and ample connectivity. Coordinators at respective schools were required to be knowledgeable about the technology in order to deal with potential challenges. One session experienced technical difficulties and was promptly rescheduled by the primary instructor.

External Threats

External validity refers to the extent to which the results of the experiment can be generalized from the research study (Bracht, 1969). The following phenomena were identified as significant external validity threats to the study.

Population validity. Due to limited access to intact classrooms that met the required criteria, the researcher pulled from a unique population. The researcher addressed this threat by only making generalizations that are homogenous with the population. Further research is recommended to broaden the study for wider generalizability.

Other external ecological validity threats such as explicit description of experimental treatment, novelty, disruption effect, and multiple-treatment interface were addressed through the research design and procedures. For example, sample lesson plans, sample presentation slides and activities were included to maximize replicability of the study. The research design limited the novelty and disruption effect of interactive television by requiring that participants have had prior experiences with ITV. Last, the research design allowed the researcher to clearly link participants with their assessments and exposure to treatment without potentially harming the confidentiality of the data.

Assumptions

1. ITV sessions will be a maximum of 50 minutes in length.
2. Participating teachers are computer literate.
3. Participants answered each question to the best of their knowledge.
4. Participants were familiar with the use of SurveyGizmo for online submission.
5. Participants were comfortable with participating in a videoconferencing setting.

CHAPTER IV

RESULTS

The purpose of this research study was to examine 5^{th} grade students' attitudes and levels of achievement when exposed to lecture and inquiry-based instruction through interactive television. All statistical analyses were conducted using SPSS version 16 software. This chapter presents the major findings from the electronic survey and content assessments as they correspond to the following research questions:

1. What are the differential effects of the 5E vs. a traditional instructional model on 5^{th} graders' attitudes toward science, taking into account prior attitude and prior knowledge?
2. What are the differential effects of the 5E vs. a traditional instructional model on 5^{th} graders' achievement, taking into account prior knowledge and attitudes?
3. What is the relationship between attitude and achievement in science delivered using the 5E instructional model?

Inquiry and Attitudes

The Scientific Attitude Inventory (SAI II) was used to answer the first research question, "What are the differential effects of the 5E vs. traditional instructional model on 5^{th} graders' attitudes toward science, taking into account prior attitude and prior knowledge?". *T*-test and one-way analysis of covariance (ANCOVA) were conducted for the research question. The independent variable, strategy, included two levels: lecture and inquiry. The dependent variables consisted of six positive and six negative attitude statements about science. The covariates were prior knowledge and positive and negative attitude.

Mean scores for positive attitudes were mixed in favor of the lecture and inquiry groups. Lecture group mean scores were: 1A (M = 11.10), 2A (M = 11.83), 3A (M = 11.05), 4A (M = 11.94), 5A (M = 10.53), and 6A (M = 16.98). Inquiry group mean scores were: 1A (*M* =11.11), 2A (*M* =11.86), 3A (*M* = 11.05), 4A (*M* = 11.94) 5A (M = 10.53) and 6A (M = 16.98) (Table 12).

Table 12

Mean Scores for Positive Attitude Statements

Variable	M	*SD*	*n*
1A Lecture	11.10	2.254	118
1A Inquiry	11.11	2.202	142
2A Lecture	11.83	2.120	118
2A Inquiry	11.86	2.196	142
3A Lecture	11.05	1.839	118
3A Inquiry	10.95	1.917	142
4A Lecture	11.94	2.177	118
4A Inquiry	11.78	2.542	142
5A Lecture	10.53	2.162	118
5A Inquiry	10.27	2.403	142
6A Lecture	16.98	3.483	118
6A Inquiry	18.01	3.983	142

Similarly, mean scores for negative attitudes were mixed in favor of both lecture and inquiry groups. Lecture group mean scores were: 1A (M = 8.17), 2A (M = 8.32), 3A (M = 9.49), 4A (M = 8.20), 5A (M = 10.00), and 6A (M = 15.28). Inquiry group mean scores were: 1A (*M* =8.15), 2A (*M* = 8.07), 3A (*M* = 9.67), 4A (*M* = 8.80) 5A (M = 10.21 and 6A (M = 16.66) (Table 13).

Table 13

Mean Scores for Negative Attitude Statements

Variable	M	SD	*n*
1B Lecture	8.17	2.576	118
1B Inquiry	8.15	3.253	142
2B Lecture	8.32	3.495	118
2B Inquiry	8.07	2.894	142
3B Lecture	9.49	2.483	118
3B Inquiry	9.67	1.741	142
4B Lecture	8.20	2.209	118
4B Inquiry	8.80	2.276	142
5B Lecture	10.0	3.219	118
5B Inquiry	10.21	3.281	142
6B Lecture	15.28	4.620	118
6B Inquiry	16.66	4.708	142

A paired samples *t*-test analysis was conducted to determine differences in overall positive and negative attitude changes between pre and post-treatment. Group means are presented in Table 14. Results indicated that the mean change for both positive attitude (M = -.380, SD = 12.42), t(-.494) p > .05 and negative attitude (M = -1.411, SD = 13.104), t(-1.737) p >.05 statements were not significant (Table 15).

Table 14

Descriptive Statistics for Paired Sample Statistics

	Group	*M*	*n*	*SD*
Control	Pre-Positive	73.31	260	9.19
Treatment	Post-Positive	73.69	260	8.14
Control	Pre-Negative	60.25	260	9.56
Treatment	Post-Negative	61.65	260	9.50

Table 15

Paired Sample Attitude Statistics

Group	*M*	*n*	*SD*	*t*	*p*
Positive	-.380	260	12.42	-.49	.622
Negative	-1.41	260	13.10	-1.73	.084

ANCOVAs (between-subjects factor: strategy [control, inquiry]; covariate: prior knowledge, prior attitude) revealed no main effects for strategy and positive or negative attitude statements. The ANCOVA tests of Between-Subject Effects for positive attitude revealed that the *F* test for the main effect did not reach significance $F(1) = .950$, $p > .05$. Similarly, the ANCOVA for negative attitudes also revealed that the *F* test for the main effect did not reach significance $F(1) = 1.133$, $p > .05$. Due to the absence of statistical significance, it was concluded there is no significant main effect for inquiry associated with the dependent variables of positive and negative attitude.

Inquiry and Achievement

Question two, "What are the differential effects of the 5E versus a traditional instructional model on 5th grader's achievement, taking into account prior knowledge and attitudes?", was addressed with a series of *t*-tests and ANCOVA statistics conducted on group achievement scores for each of the four levels using prior knowledge, positive and negative attitude as covariates. Each ANCOVA was used to compare the mean differences among the groups by multiple dependent variables (remember [recognize/recall], understand, apply) while controlling for prior knowledge and prior attitude (positive, negative).

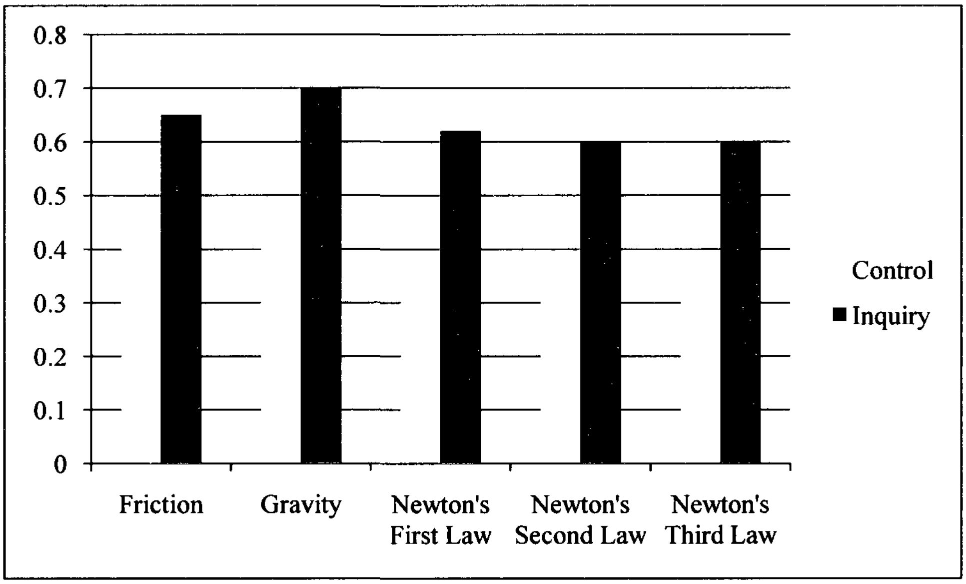
First, each topic (Friction, Gravity, Newton's First Law, Newton's Second Law, Newton's Third Law) was analyzed using independent samples *t*-tests to determine significant differences between strategy and the dependent variables. Descriptive statistics indicate a significant difference between subject means (Table 16). Figure 4 displays the scores in a graphical format.

Table 16

Descriptive Statistics for Topics

	Strategy	*n*	*M*	*SD*
Friction	Control	118	.42	.199
	Inquiry	142	.65	.217
Gravity	Control	118	.49	.175
	Inquiry	142	.70	.187
Newton1	Control	118	.39	.190
	Inquiry	142	.62	.219
Newton2	Control	118	.38	.208
	Inquiry	142	.60	.232
Newton3	Control	118	.33	.197
	Inquiry	142	.60	.261

Figure 4. Mean Scores for Topics



Differences in topic area. The *t*-tests compared each subject area on the independent variables. There was a significant difference in the scores for control (M =.42, SD = .19) and inquiry (M = .62, SD = .21); $t(258) = -8.82$, $p < .05$ for Friction showing a 54.08 percent difference in favor of inquiry. Scores related to Gravity revealed a significant difference for control (M = .49, SD = .19) and inquiry (M = .70, SD = .18); $t(258) = -9.52$, $p < .05$ showing a 43.84 percent difference in favor of inquiry. Results from Newton's First Law revealed a significant difference in the scores for control (M = .39, SD = .19) and inquiry (M = .626, SD = .21); $t(258) = -8.98$, $p < .05$ showing a 58.67 percent difference in favor of inquiry. Results from Newton's Second Law revealed a significant difference in the scores for control (M = .38, SD = .20) and inquiry (M = .60, SD = .23); $t(258) = -8.20$, $p < .05$ showing a 59.59 percent difference in favor of inquiry. Results from Newton's Third Law revealed a significant difference in the scores for control (M = .33, SD = .19) and inquiry (M = .60, SD = .26); $t(258) = -9.30$, $p < .05$ showing an 82.24 percent difference in favor of inquiry. Overall t-test results suggest that the treatment group scored better on each subject area resulting from the treatment in the study (Table 17).

Table 17

Independent T-test for Topic Area

		Levene's Test for Equal Variances		t-test for Equality of Means			
Subject		*F*	*p*	*t*	*df*	*p	*MD*
Friction	Equal variances assumed	2.314	.129	-8.823	258	.000	-.23052
Gravity	Equal variances assumed	.408	.523	-9.520	258	.000	-.21616
First Law	Equal variances assumed	3.649	.057	-8.982	258	.000	-.23108
Second Law	Equal variances assumed	1.789	.182	-8.204	258	.000	-.22649
Third Law	Equal variances not assumed	6.229	.013	-9.304	258	.000	-.27177

Note. $*p < .05$ two-tailed

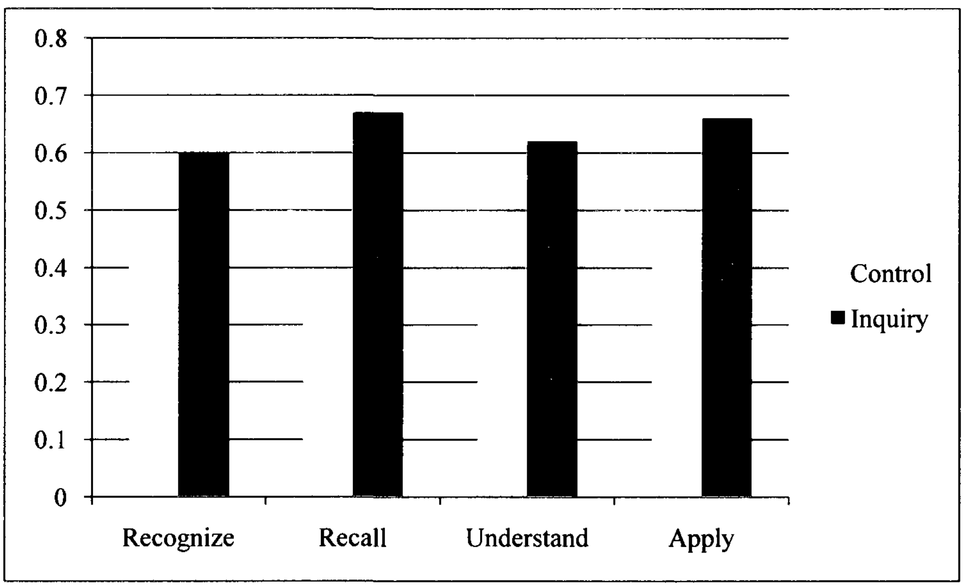
Differences in levels of learning. Next, each level of Bloom's Revised Taxonomy (remember [recognize, recall], understand, apply) were analyzed using independent samples t-tests to determine significant differences between each level and independent variables. Descriptive statistics suggest a significant difference between means (Table 18). Figure 5 displays the mean differences in graphical form.

Table 18

Descriptive Statistics for Bloom Level T-test

	Strategy	M	SD	*n*
Recognize Post Mean	Control	.46	.186	118
	Inquiry	.60	.195	142
Recall Post Mean	Control	.39	.162	118
	Inquiry	.67	.159	142
Understand Post Mean	Control	.37	.159	118
	Inquiry	.62	.210	142
Apply Post Mean	Control	.46	.196	118
	Inquiry	.66	.221	142

Figure 5. Mean Scores for Bloom's Level



An independent-samples t-test was conducted to compare the first three levels of Bloom's Revised Taxonomy for control and inquiry conditions. Analysis of the recognize level of Bloom's Revised Taxonomy for control and inquiry conditions revealed a significant difference in the scores for control ($M = .39$, $SD = .16$) and inquiry ($M = .675$, $SD = .15$); $t(258) = -14.071$, $p < .05$ showing a 71.668 percent difference in favor of inquiry. There was also a significant difference in the scores for control ($M = .46$, $SD = .18$) and inquiry ($M = .60$, $SD = .19$); $t(258) = -5.953$, $p < .05$ showing a 30.74 percent difference in favor of inquiry at the recall level. Analysis of the understand level of Bloom's Revised Taxonomy for control and inquiry conditions revealed a significant difference in the scores for the control ($M = .37$, $SD = .15$) and inquiry ($M = .62$, $SD = .21$); $t(258) = -10.471$, $p < .05$ showing a 65.66 percent difference in favor of inquiry. Last, analysis of the apply level of Bloom's Revised Taxonomy for the control and inquiry conditions revealed a significant difference in the scores for control ($M = .46$, $SD = .19$) and inquiry ($M = .66$, $SD = .22$); $t(258) = -7.439$, $p < .05$ showing a 41.93 percent difference in favor of inquiry. The subsequent results suggest the inquiry group scored better on the Remember, Understand and Apply levels of Bloom's Revised Taxonomy than the control group as a result of the treatment (Table 19).

Table 19

Independent T-Tests for Achievement

		Levene's Test for Equal Variances		t-test for Equality of Means			
		F	*P*	*t*	*df*	**p*	MD
Recognize Post Mean	Equal variances assumed	.654	.419	-5.953	258	.000	-.14198
Recall Post Mean	Equal variances assumed	.056	.812	-14.071	258	.000	-.28178
Understand Post Mean	Equal variances not assumed	7.561	.006	-10.471	258	.000	-.24712
Apply Post Mean	Equal variances assumed	1.258	.263	-7.439	258	.000	-.1950

Note. $*p < .05$ two-tailed

Examination with covariates. A factorial ANCOVA was used to determine if there was a significant effect on any of the dependent variables related to achievement while holding prior knowledge and attitude constant as covariates. Significance was established to be alpha = .05, $p < .05$. Each model included the main effects for prior knowledge and attitude (negative and positive) (Tables 19-22). The factor of inquiry was significant on all four dependent variables indicating a significant difference between control and treatment groups for the first three levels of Bloom's Revised Taxonomy (remember [recognize, recall], understand, apply).

There was a significant main effect for inquiry at the recognize level of Bloom's Revised Taxonomy after controlling for prior knowledge and attitude, $F(1, 255) = 33.791$, $p < .05$, $\eta^2 = .117$. There was no significant main effect for positive attitude after parceling out prior knowledge, negative attitude and inquiry, $F(1, 255) = .477$, $p > .05$, $\eta^2 = .002$, nor for negative attitude after parceling out prior knowledge, positive attitude and inquiry, $F(1, 255) = 1.006$, $p > .05$, $\eta^2 = .004$, nor for prior knowledge after parceling out attitude and inquiry, $F(1, 255) = .682$, $p > .05$, $\eta^2 = .003$ on the recognize level of Bloom's Revised Taxonomy (Table 20).

Table 20

Analysis of Covariance for Recognize

Source	*df*	*F*	*p*	η^2
Positive Attitude	1	.477	.490	.002
Negative Attitude	1	1.006	.317	.004
Prior Knowledge	1	.682	.410	.003
Inquiry	1	33.791	.000	.117
Error	255			

There was a significant main effect for inquiry at the recall level of Bloom's Revised Taxonomy after controlling for prior knowledge and attitude, $F(1, 255) = 131.631$, $p < .05$, $\eta^2 = .340$ and for prior knowledge after parceling out attitude and inquiry, $F(1, 255) = 9.186$, $p < .05$, $\eta^2 = .340$. There was no significant main effect for positive attitude after parceling out prior knowledge, negative attitude and inquiry, $F(1, 255) = .664$, $p > .05$, $\eta^2 = .003$, nor for negative attitude after parceling out prior knowledge, positive attitude and inquiry, $F(1, 255)=0.210$, $p > .05$, $\eta^2 = .001$, on the recall level of Bloom's Revised Taxonomy (Table 21).

Table 21

Analysis of Covariance for Recall

Source	*df*	*F*	*p*	η^2
Positive Attitude	1	.664	.416	.003
Negative Attitude	1	.210	.647	.001
Prior Knowledge	1	9.186	.003	.035
Inquiry	1	131.631	.000	.340
Error	255			

There was a significant main effect for inquiry on the understand level after controlling for prior knowledge and attitude, $F(1, 255) = 89.286$, $p < .05$, $\eta^2 = .259$. There was no significant main effect for positive attitude after parceling out prior knowledge, negative attitude and inquiry, $F(1, 255) = .096$, $p > .05$, $\eta^2 = .000$, nor for negative attitude after parceling out prior knowledge, positive attitude and inquiry, $F(1, 255) = .602$, $p > .05$, $\eta^2 = .002$, nor for prior knowledge after parceling out attitude and inquiry, $F(1, 255) = 0.039$, $p > .05$, $\eta^2 = .001$ on the recognize level of Bloom's Revised Taxonomy (Table 22).

Table 22

Analysis of Covariance for Understand

Source	*df*	*F*	*p*	η^2
Positive Attitude	1	.096	.756	.000
Negative Attitude	1	.602	.439	.002
Prior Knowledge	1	.039	.844	.000
Inquiry	1	89.286	.000	.259
Error	255			

There was a significant main effect for inquiry at the apply level of Bloom's Revised Taxonomy after controlling for prior knowledge and attitude, $F(1, 255) = 55.000$, $p < .05$, $\eta^2 = 0.177$. There was no significant main effect for positive attitude after parceling out prior knowledge, negative attitude and inquiry, $F(1, 255) = 1.382$, $p > .05$, $\eta^2 = 0.005$, nor for negative attitude after parceling out prior knowledge, positive attitude and inquiry, $F(1, 255) = 0.008$, $p > .05$, $\eta^2 = 0.000$, nor for prior knowledge after parceling out attitude and inquiry, $F(1, 255) = 2.247$, $p > .05$, $\eta^2 = 0.010$ on the recognize level of Bloom's Revised Taxonomy (Table 23).

Table 23

Analysis of Covariance for Apply

Source	*df*	*F*	*p*	η^2
Positive Attitude	1	1.382	.241	.005
Negative Attitude	1	.008	.931	.000
Prior Knowledge	1	2.479	.117	.010
Inquiry	1	55.000	.000	.177
Error	255			

Attitude and Achievement

The third research question, "What is the relationship between attitude and achievement in science delivered using the 5E instructional model?", was addressed using a factorial MANCOVA examining the effects of strategy type (Control, Inquiry), prior knowledge, and prior attitude on attitude and achievement.

First, a Pearson product-moment correlation coefficient analysis was computed to assess the relationship between dependent variables. Strength regarding correlations is apparent when the correlation coefficient gets closer to +1 or -1 (Mertler & Vannatta, 2005). Correlations among the dependent variables appear in Table 10 as Apply, Understand, Recall, Recognize, Positive Attitude, and Negative Attitude. The Pearson r correlations indicated a positive relationship between all variables. Regarding achievement, a medium correlation was revealed between the variables of recognize and understand, $r = .575$, n = 260, $p < .05$. Weak correlations were revealed for apply and understand, $r = .473$, n = 260, $p < .05$, recall and apply, $r = .258$, n = 260, $p < .05$, recognize and apply, r = .477, n = 260, p < .05, and recognize and recall, *r* = .288, n = 260, p < .05. A weak correlation coefficient exists for positive and negative attitudes, *r* = .151, n = 260, p < .05 (Table 24).

Table 24

Correlation Coefficient Analysis

		Apply	Understand	Recall	Recognize	Positive Attitude	Negative Attitude
Apply	Pearson Correlation	1	.473**	.258**	.477**	.057	.019
	Sig. (2-tailed)	-	.000	.000	.000	.358	.765
Understand	Pearson Correlation	.473**	1	.432**	.575**	.061	.020
	Sig. (2-tailed)	.000	-	.000	.000	.326	.745
Recall	Pearson Correlation	.258**	.432**	1	.288**	.019	.145*
	Sig. (2-tailed)	.000	.000	-	.000	.764	.019
Recognize	Pearson Correlation	.477**	.575**	.288**	1	.053	.046
	Sig. (2-tailed)	.000	.000	.000	-	.395	.460
Positive Attitude	Pearson Correlation	.057	.061	.019	.053	1	.151*
	Sig. (2-tailed)	.358	.326	.764	.395	-	.015
Negative Attitude	Pearson Correlation	.019	.020	.145*	.046	.151*	1
	Sig. (2-tailed)	.765	.745	.019	.460	.015	-

Note. **. Correlation is significant at the 0.01 level *. Correlation is significant at the 0.05 level (2-tailed).
n = 260 for all variables

Next, a Box's test of the homogeneity of variance-covariance assumption was run. Significant results revealed a violation (F(21, 260) = 1.675, p < .05, thus, the Pillai's Trace multivariate significance test was used instead of the more common Wilk's

Lambda (Mertler & Vannatta, 2005; Tabachnick & Fidell, 2007). Results from the MANCOVA analysis indicated significant results for the dependent variable of achievement for the independent variable inquiry (Pillai's Trace = 0.470, $F(6, 250) = 36.999$, $p < .05$, partial $\eta^2 = 0.470$). The covariates of positive attitude (Pillai's Trace = 0.013, $F(6, 250) = 0.553$, $p > .05$, partial $\eta 2 = 0.013$), negative attitude (Pillai's Trace = 0.007, $F(6, 250) = 0.303$, $p > .05$, partial $\eta 2 = 0.007$) or prior knowledge (Pillai's Trace = 0.047, $F(6, 250) = 2.064$, $p > .05$, partial $\eta^2 = 0.047$) did not reach significance as a main effect on the dependent variables (Table 25).

Table 25

Main MANCOVA Results

Variables	Value	*F*	Hypothesis df	Error df	*p*	η^2
Positive Attitude	.013	.553[a]	6.00	250.00	.767	.013
Negative Attitude	.007	.303[a]	6.00	250.00	.935	.007
Prior Knowledge	.047	2.064[a]	6.00	250.00	.058	.047
Inquiry	.470	36.999[a]	6.00	250.00	.000	.470

Note. Test statistic was Pillai's Trace.

Five significant main effects were found in the analysis of covariance from the main MANCOVA analysis: (1) prior knowledge on recall $F(1,255)=9.186$, $p < .05$, partial $\eta^2 = 0.035$; (2) inquiry on recognize $F(1,255) = 33.791$, $p < .05$, partial $\eta^2 = 0.117$; (3) inquiry on recall $F(1,255) = 131.631$, $p < .05$, partial $\eta^2 = 0.340$; (4) inquiry on understand $F(1,255) = 89.286$, $p < .05$, partial $\eta^2 = 0.259$; and (5) inquiry on apply $F(1,255) = 55.00$, $p < .05$, partial $\eta^2=0.177$ (Table 26). There were no post-hoc tests conducted resulting from the MANCOVA due to the absence of a third independent variable. Univariate analysis examining the significant results for inquiry and achievement are presented in the examination of research question number two.

Table 26

Univariate Analysis in Main MANCOVA

Source	Dependent Variable	*SS*	*df*	*F*	*p*	η^2
Positive Attitude	Recognize Post Mean	.018	1	.477	.490	.002
	Recall Post Mean	.017	1	.664	.416	.003
	Understand Post Mean	.003	1	.096	.756	.000
	Apply Post Mean	.061	1	1.382	.241	.005
	Positive Attitude	4.194	1	.119	.730	.000
	Negative Attitude	8.007	1	.047	.829	.000
Negative Attitude	Recognize Post Mean	.037	1	1.006	.317	.004
	Recall Post Mean	.005	1	.210	.647	.001
	Understand Post Mean	.022	1	.602	.439	.002
	Apply Post Mean	.000	1	.008	.931	.000
	Positive Attitude	28.379	1	.091	.764	.000
	Negative Attitude	6.079	1	.316	.575	.001
Prior Knowledge	Recognize Post Mean	.025	1	.682	.410	.003
	Recall Post Mean	.231	1	9.186	.003	.035
	Understand Post Mean	.001	1	.039	.844	.000
	Apply Post Mean	.109	1	2.479	.117	.010
	Positive Attitude	115.218	1	.002	.964	.000
	Negative Attitude	.139	1	1.282	.259	.005
Inquiry	Recognize Post Mean	1.240	1	33.791	.000	.117

	Recall Post Mean	3.308	1	131.631	.000	.340
	Understand Post Mean	3.234	1	89.286	.000	.259
	Apply Post Mean	2.428	1	55.000	.000	.177
	Positive Attitude	101.809	1	.950	.331	.004
	Negative Attitude	63.678	1	1.133	.288	.004
Error	Recognize Post Mean	9.360	255			
	Recall Post Mean	6.409	255			
	Understand Post Mean	9.237	255			
	Apply Post Mean	11.255	255			
	Positive Attitude	22918.253	255			
	Negative Attitude	17090.014	255			

ANCOVAs examining significant results for inquiry and achievement are displayed in tables 19-22 related to research question number two. A separate ANCOVA was run to examine the significant results found for the main effects of prior knowledge on recall in the MANCOVA. The model included the main effect for strategy and prior knowledge and prior attitude. Results indicated a significant main effect for prior knowledge $F(1, 255) = 8.489$, $p < .05$, $\eta^2 = 0.032$, and inquiry $F(1, 255) = 129.593$, $p < .05$, $\eta^2 = 0.337$ indicating that prior knowledge and inquiry affected achievement in the area of recall (Table 27).

Table 27

ANCOVA Results for Prior Knowledge and Recall

Source	*df*	*F*	*p*	η^2
Prior Knowledge	1	8.489	.004	.032
Positive Attitude	1	.952	.330	.004
Negative Attitude	1	1.784	.183	.007
Inquiry	1	129.593	.000	.337
Error	255			

Summary of Results

Descriptive statistics for attitude (positive, negative) showed slight differences between the control and treatment group mean scores. Subsequent t-tests were not significant between the control and treatment groups on the dependent variables of positive and negative attitudes toward science. Descriptive statistics for achievement revealed differences in control and inquiry groups on Force and Motion topics and the first three levels of Bloom's Revised Taxonomy. Inquiry groups demonstrated higher mean scores on all variables associated with achievement and subject matter. The t-tests revealed a significant difference between the control and treatment groups for each topic.

The results from each achievement ANCOVA, while controlling for prior knowledge and prior attitude (positive, negative), showed a significant difference for inquiry and achievement supporting the conclusion that there was not a significant main effect for prior knowledge and attitude associated with the dependent variable of achievement. In other words, inquiry, as the main independent variable, was significantly related to each dependent variable of achievement (remember [recognize, recall], understand, apply) while controlling for the two covariates but not for prior knowledge and prior positive and negative attitude. The correlation coefficient indicated a strong relationship between achievement and a weak relationship between attitudes (positive, negative) and prior knowledge for the dependent variable.

The results from the MANCOVA, while controlling for prior knowledge and prior positive and negative attitudes, support the conclusion that control and inquiry groups significantly differed regarding the topic and Bloom's Revised Taxonomy level of achievement. Additionally, a significant relationship was found in the univariate analysis between prior knowledge and the recall level of Bloom's Revised Taxonomy.

Chapter V

Discussion

The purpose of the study was to determine the differential effects of the 5E instructional strategy on fifth-grade students' attitude and achievement. NASA's Digital Learning Network infrastructure was used to recruit and deliver instruction to participants for the study. The Biological Sciences Curriculum Study 5E instructional model was used as a guide to develop treatment group modules and a traditional lecture-based format was used for the control group module development. Content modules were delivered by a certified science teacher with over 15 years of experience and five years of experience delivering instruction via interactive television. Participants (n =260) consisted of fifth-grade students from three suburban elementary schools, two of which had four fifth grade classes and one with three fifth grade classes. Each intact classroom was assigned to the treatment or control group with no more than two classes assigned to each category at each school. Out of the eleven classes participating in the study, six were designated as the treatment group and five were designated as the control group.

Three research questions were posed for this study: (1) What are the differential effects of the 5E versus a traditional instructional model on fifth graders' attitude taking into account prior knowledge and attitudes? (2) What are the differential effects of the 5E versus a traditional instructional model on fifth graders' achievement, taking into account prior knowledge and attitudes? and (3)What is the relationship between attitude and achievement in science delivered using the 5E instructional model?

Attitude was measured with a content assessment based on the *Force and Motion* modules used for the study and attitudes were measured using the Science Attitude

Inventory II (Moore, & Foy, 1997). Achievement scores were determined via a content assessment developed by the researcher and other science professionals. Both attitude (Cronbach's alpha = .781) and content assessment (Cronbach's alpha = .756) instruments were statistically valid for social science research. Prior knowledge and prior attitude (positive, negative) were controlled in the form of covariates (pre-tests) for this study due to potential effects on the dependent variables of attitude and achievement (Fontichiaro, & Green, 2010; Gunel, 2008).

Results have implications for the effective use of instructional strategies via interactive television. Treatment group scores were significantly different regarding the topics of Gravity, Friction, and Newton's First, Second and Third Law of Motion. Additionally, the treatment group scores were also higher on the first three levels of Bloom's Revised Taxonomy (remember [recognize, recall], understand, apply). However, a significant difference was not evident in the attitudes of the control and treatment groups based on instructional strategy, although overall mean scores did increase. This chapter presents (1) discussion and conclusions drawn from the analysis of each research question, (2) implications for related literature, (3) limitations of the study and (4) recommendations for future research.

Research Questions

Inquiry and attitudes. The study did not reveal significant results when examining the first research question, "What are the differential effects of the 5E versus a traditional instructional model on fifth grader's attitude, taking into account prior knowledge and prior attitudes?". Mean scores were mixed in favor of both lecture and inquiry groups when examining positive and negative attitudes.

One explanation for lack of significant difference as it related to attitude could be that the participants randomly selected the SAI II answer choice items when completing the survey instrument instead of reading and thoughtfully answering each question. Such an action would skew the results of both research question one and three negating the attitude results for the study.

Another plausible explanation for the lack of significant difference as it relates to attitude could be the inventory may have been unable to elicit a personal response from the participant because the instrument measures attitudes *about* science as opposed to attitudes about *learning* science. Moore and Foy (1997) posit the SAI II was designed to distinguish between beliefs and feelings; beliefs are thought to require cognitive learning but feelings are not. They also assert that science learning could possibly be more about feelings.

The possibility that SAI II may not be valid for use in the study is another explanation for the marginal difference in attitude. The researcher chose the SAI II after comparing it to another well-known science attitude inventory. Although the *Test of Science Related Attitudes* (TOSRA) (Frasier, 1978) is considered a more reliable instrument than the SAI II, it was developed for high school learners (Coll, Dalgety, & Salter, 2002). Revising the TOSRA to make it suitable for primary grades was not feasible for the study due to time and resources. Thus, the SAI II was deemed the best fit for this study.

In light of the attitude results, the researcher recommends either a different assessment be used alongside the SAI II instrument to determine a more appropriate instrument for measuring science attitudes or the TOSRA instrument be modified for the elementary grade level.

Inquiry and achievement. The second research question examined the differential effects of the 5E versus a traditional instructional model on fifth grader's achievement, taking into account prior knowledge and prior attitudes. Independent t-tests and ANCOVAs were conducted to identify any significant differences between control and treatment groups.

The independent samples t-tests indicate that participants from the treatment group performed significantly better than the control group for both topic (Friction, Gravity, Newton's 1st Law, Newton's 2nd Law, Newton's 3rd Law) and Bloom's level (Remember, Understand, and Apply). Scores among Bloom's levels were the highest for remember-level questions showing better achievement for the first level of the taxonomy.

Analysis through ANCOVAs for each Bloom's Level (Tables 19, 20, 21 and 22) revealed no significant main effect for prior attitudes or for prior knowledge for inquiry strategy but a significant main effect was found for all three levels of Bloom's Revised Taxonomy (remember [recognize, recall], understand, apply). Results show that prior knowledge and attitudes did not significantly affect performance as they related to instructional strategy. Furthermore, results from this study based on the Bloom's level scores, indicate inquiry-based instruction delivered through an interactive television medium could significantly increase overall achievement for the first three levels of the taxonomy.

Although results for achievement were significant, the researcher must note that mean scores for both topic and learning level were below researcher expectations based on the standard grading scales that all three participating schools used. The highest mean score attained was .67 for recall-level questions but the rest (recognize, understand, and apply) were .66 or below which shows that all mean scores on achievement levels were below passing. One might question the instructional strategy and content assessment alignment. However, this threat was initially addressed through the pilot of the content modules the spring before the study took place along with a validity check of the assessment indicating a Cronbach's alpha of .756. Additionally, the professional educators involved in developing the module content also examined the content assessment for inter-rater reliability.

The researcher believes that the low achievement scores were due to the frequency and relevance of the content to participants. The six-week period consisting of once-per-week instruction was supplemental and participants were not technically responsible for learning the material. To control for confounding variables, teachers were asked not to supplement participant learning outside of the context of the interactive television sessions. Thus, the researcher questions the participant's intrinsic motivation for retaining the information during the course of the study. Despite the mean scores of each group, a significant difference was found in favor of inquiry-based instruction. Such results highlight the effectiveness of inquiry-based instruction through an interactive television environment. Thus, content providers can feel comfortable using the 5E instructional model as a better alternative to lecture-based strategies.

Attitude and achievement. The third research question examined the relationship between attitude and achievement in science delivered using the 5E instructional model. A correlation coefficient and a MANCOVA were conducted to examine attitude and achievement while holding prior knowledge and prior attitude (positive, negative) constant.

The Pearson product-moment correlation coefficient analysis indicated a positive relationship between all variables. Regarding achievement, a medium correlation was found between the variables of recognize and understand. Weak correlations were found for apply and understand, recall and apply, recognize and apply, recognize and recall. Finally, a weak correlation coefficient was found for positive and negative attitudes (Table 23).

The main MANCOVA analysis indentified a significant difference for inquiry. Results did not reveal a significant main effect for positive and negative attitudes or prior knowledge. Further univariate analysis revealed a significant main effect for prior knowledge and recall and significant main effects were found for all three Bloom's Taxonomy levels (remember [recognize, recall], understand, apply) (Table 28).

Table 28

Univariate Results for Attitude and Achievement

Source	Dependent Variable	*Df*	*F*	*P*	η^2
Positive Attitude				Ns	
Negative Attitude				Ns	
Prior Knowledge	Recall Post Mean	1	9.186	.003	.035
Inquiry	Recognize Post Mean	1	33.791	.000	.117
	Recall Post Mean	1	131.631	.000	.340
	Understand Post Mean	1	89.286	.000	.259
	Apply Post Mean	1	55.000	.000	.177
	Positive Attitude			ns	.004
	Negative Attitude			ns	.004

Note. ns = no significant difference

Based on the MANCOVA results, inquiry-based strategies were significant with all three levels of Bloom's taxonomy supporting this strategy having impact on achievement scores in a meaningful way. With the exception of prior knowledge and recall, there was no significant difference found for the covariates, prior knowledge and prior attitude, with the dependant variables. These results echo previous findings from research questions one and two indicating no significant result for attitude and a significant result for achievement. This result further validates the use of inquiry-based instructional methods through interactive television as opposed to instruction that is more didactic. Lastly, the researcher believes the significant results found between prior knowledge and recall may have occurred by chance due to the number of statistical analysis performed. The absence of a discernable pattern from the results of this study lead the researcher to believe a false significant result was due to the five percent chance that the results could be the result of a type I error (Mertler & Vannatta, 2005).

Literature Implications

The current study's statistical significance related to achievement for topic area and Bloom's first three levels of learning further support the well documented use of inquiry-based strategies related to increasing student achievement (Alkar, 2005; Balci, Cakiroglu & Tekkaya, 2006; Boddy, Watson, & Aubusson, 2003; Cylan & Geban, 2009; Duschl, Schweingruber, & Shouse, 2007, Ergin, Kanli, & Unsal, 2008; Overbaugh, & Lin, 2006). Campbell (2006) found similar results to those of this study for the subjects of Force and Motion also suggesting the 5E instructional model as a more formidable alternative than lecture-based approaches. Liu, Peng, Wu and Lin (2009), found results that increased elementary students' knowledge and understanding using the 5E learning cycle via a case study. This study also relates closely to Connor et al. (2010) results in student achievement increases for elementary students. Their study examined pre/post-achievement scores after a six-week period of instruction resulting in a higher level of learning and more thorough answers through narratives.

Elementary science literature. Other literature examining primary grade levels have shifted towards a peer- reviewed anecdotal utilitarian format encouraging practitioners to use the 5E model in a guided inquiry fashion opposed to researching its effectiveness. Specific areas include the circulatory system (Cardak, Dikmenli, & Saritas, 2008), static electricity (Nabb & Henry, 2010), scientific instruments (Sorey, Willard, & Kim, 2010) and mass and volume (Vincent, Cassel, & Milligan, 2008). These articles serve as guides for educators to utilize the 5E instructional model when teaching science to elementary learners. Given a similar audience, this study can serve as a foundation and reference for those examining the 5E instructional model. Supplemental ITV content providers looking to choose a strategy to employ through interactive television can also use this study to further their knowledge of effective strategies through ITV.

Interactive television. The diffusion rate of interactive television in primary and secondary schools has increased 30 percent in the past three years (Greenberg, 2009). An increase in supplemental interactive television content providers, Heath, Hines, Veal, Zanetis, and Barshinger (2003), members of the Clearinghouse Working Group, listed approximately 92 supplemental sources of interactive television where educators can find content related to multiple subjects. More recently, the Polycom Content Access Program (2010) boasts having over 200 supplemental providers available for educators in order to extend the reaches of their classrooms. This study provides empirical evidence of a strategy that can aid in the choice of instructional methodology, resource allocation, or educational philosophy.

Limitations

Although useful to those looking for interactive television strategies, this study has a number of limitations that should be taken into consideration when replicated. The following limitations apply to this study:

1. Attitude Instrument. The use of the SAI II instrument should be reconsidered due to the instrument not fully examining student's feelings towards science (Foy & Moore, 1997). Although there was no empirical evidence, participant fatigue may have also caused participants to arbitrarily answer questions in the interest of hurrying through

the instrument. A more comprehensive approach to examining attitude would be to develop an instrument that examined science attitude directly related to the content matter. Specific questions related to the topic, in this case force and motion, would give the researcher a more accurate indication of how participants feel about their attitudes related to those topics. Such an instrument would help the researcher validate participant's attitudes toward the content being studied instead of generalizing in the context of science as a whole.

2. Learner motivation. Overall, low mean scores are thought to be a by-product of inadequate learner motivation to retain content information. In an effort to control for confounding variables, the instructional modules were delivered once per week over the six-week period and teachers were asked not to cover the content outside of the context of the interactive television sessions. This limitation can be overcome by directly linking future supplemental content to subjects that are actively being covered during the course of study for participants.

3. Frequency of instruction. The research study took place over a period of six-weeks. Although consistent with a typical reporting period for progress at each school, each student only participated in one module session per week. This limitation can be addressed by increasing the frequency that students participate in instructional modules throughout the research study (Stohr-Hunt, 1996).

Recommendations for Future Research

Using this study as a starting point, five recommendations for future research provide direction for additional research on examining instructional strategies through interactive television. Length of instructional time and number of participants is a recurring theme for each of the following recommendations resulting from this study.

1. The amount of time committed to developing inquiry-based instruction versus lecture-based instruction can help service providers determine budgets as well as return on investment for instructional strategy. The ratio between investment and instructional strategy can help organizations project resource allocations as well as efficiency concerns. Thus, future studies should focus on recording the amount of time spent on developing and comparing instructional strategies through interactive television.

2. Future studies should also focus on the impact of inquiry-based instruction through interactive television from late elementary through middle school grades. This type of study will show changes in participants' attitude and or achievement as they matriculate providing a more accurate picture of how the strategy can influence a particular population over a period of time.

3. Further studies should also examine the difference between instructor led interactive television sessions and asynchronous sessions. Quantitative studies should be conducted to examine the difference in satisfaction between asynchronous (via the web) and synchronous (via interactive television) inquiry-based learning strategies. This analysis would provide insight on the necessity of a real time presence of the instruction in inquiry-based instruction based on participant satisfaction and achievement.

4. Finally, further studies should examine the types of inquiry-based instruction as they relate to student achievement and retention through interactive television. Quantitative studies should record data based on the three main types or styles (open, guided, structured) of inquiry. Such an analysis would add to the body of knowledge

examining the relationship of prior knowledge and inquiry-based strategies through interactive television.

Conclusion

This quasi-experimental quantitative study explored the differential effects of the 5E instructional model on attitude and achievement while holding prior knowledge and attitude constant. The theoretical framework proposed that instructional strategy was linked to attitude and the first three levels of Bloom's Revised Taxonomy. A review of the literature related to the 5E instructional model provides strong support for this method. Empirical studies have shown positive effects on both attitude and achievement. Additionally, interactive television was suggested to be an effective supplemental education delivery mechanism. Results of this study revealed the 5E instructional strategy improved science achievement but not attitude. The covariates of prior knowledge and prior attitude did not have a significant effect on achievement or attitude. Thus, the underlying conclusion of this research study is that content developed using the 5E instructional model delivered through interactive television can improve science topic areas in addition to levels of learning.

Findings support research that suggests the 5E instructional model as a viable alternative other than direct lecture strategies to improve achievement further validating the use of the model. Attitudes towards science did not significantly differ resulting from the treatment. The covariates of prior knowledge and prior attitude did not significantly affect the dependant variables when introduced into statistical models. New information has been added to the body of literature examining instructional strategies through interactive television providing future researchers with a foundation for other studies at the primary grade level. Thus, additional research is suggested for the areas of attitude and prior knowledge associated with achievement, learner attitudes over a longer sustained period, and the exploration of learner motivation related to choosing supplemental instruction.

BIBLIOGRAPHY

Akar, E. (2005). Effectiveness of 5E learning cycle model on students' understanding of acid-base concepts. *Dissertation Abstracts International.*

Allen, M., et al. (2004). Evaluating the effectiveness of distance learning: A comparison using meta-analysis. *Journal of Communication.54*, 402–420.

Amaral, O. M., Garrison, L., & Klentschy, M. (2002). Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal, 26*, 213–239.

Amirian, S. (2003). *Pedagogy & videoconferencing: A review of recent literature.* Paper presented at the First NJEDge.NET, Plainsboro, NJ.

Anderson, T. D. (2003). Getting the mix right again: An updated and theoretical rationale For interaction. *The International Review in Open and Distance Learning, 4,* 1-14. Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/149/230.

Anderson, T., & Rourke, L. (2005). *Video conferencing in kindergarten-to-grade12 settings: A review of the literature*. Calgary, Alberta: Paper Presented to the Province of Alberta Minister of Education.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching and assessing:* A revision of Bloom's Taxonomy of educational objectives: Complete edition, New York: Longman.

Appleton, K. (1997). Analysis and description of students' learning during science classes using a constructivist-based model. *Journal of Research in Science Teaching, 34*, 303–318.

Appleton, K. (2006). Science pedagogical content knowledge and elementary school teachers. In K. Appleton (Ed.), *Elementary science teacher education: International perspectives on contemporary issues and practice* (pp. 31-54). Mahwah, NJ: Erlbaum.

Appleton, K., & Asoko, H. (1996). A case study of a teacher's progress toward using a constructivist view of learning to inform teaching in elementary science, *Science Education,* 80(2), 165-180.

Baker, D. R. (1985). Predictive value of attitude, cognitive ability, and personality to science achievement in the middle school. *Journal of Research in Science Teaching, 22,* 103–113.

Balci, S., Cakiroglu, J., & Tekkaya, C. (2006). Engagement exploration, explanation, extension, and, evaluation (5E) learning cycle and conceptual change text as learning tools. *Biochemistry and Molecular Biology Education, 34(3),* 199-203.

Barfurth, M. (2002). LearnCanada: Final summative evaluation report. Retrieved from http://www.learncanada.ca.

Barron, D. D. (1987). Faculty and student perceptions of distance education using television. *Journal of Education for Library and Information Science*, *27*, 257–271.

Beeth, M. E., & Hewson, P. W. (1999). Learning goals in an exemplary science teacher's practice: Cognitive and social factors in teaching for conceptual change. *Science Education, 83(*7), 738-760.

Biological Sciences Curriculum Study. (1993). *Developing biological literacy.* Colorado Springs, CO: Author.

Biological Sciences Curriculum Study and International Business Machines Corporation. (1989). *New designs for elementary science and health: A cooperative project between Biological Sciences Curriculum Study (BSCS) and International Business Machines (IBM).* Dubuque, IA: Kendall/Hunt.

Blank, L. M. (1999). A metacognitive learning cycle: A better warranty for student understanding. *Science Education, 84*, 486-506.

Bloom, B., Englehart, M., Furst, E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* New York, Toronto: Longmans, Green.

Blumenfeld, P., Krajcik, J., Marx, R., & Soloway, E. (1994). Lessons learned: A collaborative model for helping teachers learn project-based instruction. *Elementary School Journal, 94*, 539–551.

Boddy, M., Watson, K., & Aubusson, P. (2003). A trial of the five Es: A referent model for constructivist teaching and learning. *Research in Science Education, 33*, 27-42.

Bracht, G. H., & Glass, G. V. (1968). The external validity of experiments. *American Education Research Journal, 5,* 437-474.

Brainerd, C. J. (2003). Jean Piaget. Learning, research, and American education. In B. J. Zimmerman & D. H. Schunk (Eds.), *Educational psychology: A century of contributions* (pp. 251–258). Mahway, NJ: Lawrence Erlbaum.

Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes: A quantitative synthesis. *Review of Educational Research, 53*(4), 499-518.

Bruner, J. (1960). The process of education. Cambridge, MA: Harvard University Press.

Bryan, L. A., Hannafin, M. J., & Kim, M. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education, 91*(6), 1010–1030.

Biological Sciences Curriculum Study & International Business Machines. (1989). *New designs for elementary science and health: A cooperative project between Biological Sciences Curriculum Study (BSCS) and International Business Machines (IBM).* Dubuque, IA: Kendall/Hunt Publishing Company.

Biological Sciences Curriculum Study. (1994). *Middle school science & technology* (first edition). Dubuque, IA: Kendall/Hunt Publishing Company.

Biological Sciences Curriculum Study. (2006). *BSCS science: An inquiry approach.* Dubuque, IA: Kendall/Hunt.

Busch, H. (2005). Is science education relevant? *Europhysics News, 36*(5), 162-167.

Bybee, R. W. (1997). *Achieving scientific literacy.* Portsmouth, NH: Heinemann.

Bybee, R. W., et al. (1989). *Science and technology education for the elementary years: Frameworks for curriculum and instruction.* Washington, DC: National Center for Improving Instruction.

Bybee, R. W., et al. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*. Colorado Springs, CO: Biological Sciences Curriculum Study and National Institutes of Health.

Camins, A. (2001). Dimensions of inquiry. *Full Option Science System Newsletter, 18,* 8–13.

Campbell, M. A. (2006). The effects of the 5E learning cycle model on students' understanding of force and motion concepts (Doctoral Dissertation). Retrieved from ProQuest Digital Dissertations (AAT 1433537).

Cardak, et al. (2008). Effect of 5E instructional model in student success in primary school 6th year circulatory system topic. *Asia-Pacific Forum on Science Learning and Teaching, 9*(2), 1-12.

Cavallo, A. (2005). Cycling through plants. *Science and Children, 42*(7), 22-27.

Cavanaugh, C. (2001). The effectiveness of interactive distance education technologies in K-12 learning: A meta-analysis. *International Journal of Educational Telecommunications, 7,* 73-88.

Cavanaugh, C. S., Gillan, K. J., Kromrey, J., Hess, M., & Blomeyer, R. (2004). *The effects of distance education on k–12 student outcomes: A meta-analysis.* Naperville, IL: North Central Regional Educational Laboratory.

Ceylan, E., Geban, O. (2009). Facilitating conceptual change in understanding state of matter and solubility concepts by using 5E learning cycle model. *Hacettepe Universitesi Journal of Education, 36*(4), 41-50.

Clark, C., & Abbott., K. (2004). Notre Dame tablet PC initiative. Retrieved from http://www.nd.edu/~learning/tabletpc/purdue-handout.pdf

Clow, K. E. (1999). Interactive distance learning: Impact on student course evaluations. *Journal of Marketing Education, 21*, 97-105.

Colburn, A. (2004). Inquiring scientists want to know. *Educational Leadership; Teaching for Learning, 62*, 63-67.

Coll, R.K., Dalgety, J., & Salter, D. (2002). The development of a chemistry attitudes and experiences questionnaire *(CAEQ). Chemistry Education Research and Practice in Europe Science Education, 3*, 19-32.

Committee on Science and Technology. (2007). The America creating opportunities to meaningfully promote excellence in technology, education, and science act. Retrieved from http://science.house.gov/legislation/leg_highlights_detail.aspx?NewsID=1938

Connor, C. M., et al. (2010). Content area literacy: Individualizing student instruction in second-grade science. *The Reading Teacher, 61*(6), 474-485.

Coulson, D. (2002). BSCS science: An inquiry approach-2002 evaluation findings. Arnold, MD: PS International.

Cyrs, T. E. (2001). Instructional skills specific to instructional television. *Educational Development Associates*. Retrieved from wwww.zianet.com/edacyrs/itvspec.htm

Davis, E. A., Petish, D., & Smithey, J. (2008). Beginning teachers moving toward effective elementary science teaching, *Science Education, 93*, 745-770.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education, 22*(6), 557-570.

Dennison, J., & Haydock, P. (2004). Assessing the needs of the K-12 audience in synchronous educational videoconferencing. *Proceedings of the 20th Annual Conference on Distance Teaching and Learning.* Madison, WI.

Dewey, J. D. (1902). The child and the curriculum. *Middle Works, 2*, 271-291.

Dewey, J. D. (1910). *How we think.* Boston: D.C. Health.

DiPasquale, D. M., Mason, C. L., & Kolkhorst, F. W. (2003). Exercise in inquiry. *Journal of College Science Teaching, 32*(6), 388–393.

Donovan, M. S., & Bransford, J. (2005). How students learn: Science in the classroom. Washington, DC: National Academies Press.

Dorph, R., et al. (2007). The status of science education in the Bay Area: Research Study e-report. Lawrence Hall of Science, University of California, Berkeley, California.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades k–8.* Washington DC, National Academics Press.

Edelson, D., Gordon, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences, 8*(3&4), 391-450.

Ergin, I., Kanli, U., & Unsal, Y. (2008). An example for the effect of 5E model on the academic success and attitude levels of students': Inclined projectile motion. *Journal of Turkish Science Education, 5*(3), 47-59.

Farenga, S. J., & Joyce, B. A. (1999). Intentions of young students to enroll in science courses in the future: An examination of gender differences. *Science Education, 83,* 55-75.

Finson, K. D., & Enochs, L. G. (1987). Student attitudes toward science-technology-society resulting from visitation to a science-technology museum. *Journal of Research in Science Teaching, 24,* 593-609.

Fisher, D., Cornwell, P., & Williams, J. (2007). Teaching dynamics using interactive tablet PC instruction software. Paper presented at the 37th meeting of the American Society for Engineering Education ASEE/IEEE Frontiers in Education Conference, Milwaukee, WI, October.

Fontichiaro, K., Green, J. (2010). Jump-start inquiry: How students begin when they don't know. *School Library Monthly, 26*(5), 22-23.

Foy, R. L. H., & Moore, R. W. (1997). The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*, 327-336.

Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*, 509-15.

Friedler, Y., & Tamir, P. (1990). Sex differences in science education in Israel: An analysis of 15 years of research. *Research in Science and Technological Education, 8*, 21-34.

Gage, J., Nickson, M., & Beardon, T. (2002). Can videoconferencing contribute to teaching and learning? The Experience of the Motivate Project. Annual Conference of the British Research Association. Retrieved from http://www.leeds.ac.uk/educol/documents00002264.htm

Gagné, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of Instructional Design (4th ed.). Fort Worth, TX: Harcourt Brace Jovanovich College Publishers.

Gardner, D. P., et al. (1983). *A Nation at Risk: The imperative for educational reform. An open letter to the American people. A report to the nation and the secretary of education.* Washington, DC: National Commission on Excellence in Education.

Gardner, P. L. (1998). The development of males' and females' interests in science and technology. In L.Hoffmann, A. K. Krapp, A. Renninger, & J. Baumert (Eds.), Proceedings of the Sea on Conference on Interest and Gender (pp. 41 – 57). Kiel, Germany: IPN.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*, 1-41.

Geelan, D. R., & Fiege, K. M. (2004). Professional development. Edmonton: University of alberta. Retrieved from http://www.racol.ualberta.ca/documents/pdfs/C%20Professional%20Developmet.pdf.

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571-589.

Gerber, B. L. (1996). *The relationships among informal learning environments, teaching procedures and scientific reasoning ability*. Unpublished doctoral dissertation, University of Oklahoma, Norman.

Gerber, B. L., Cavallo, M. L., & Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education*, 23(5), 535-549.

Gerstein, R. B. (2000). Videoconferencing in the classroom: Special projects toward cultural understanding. *Computers in the Schools, 16*(3), 177-186.

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*(5), 693-705.

Glen, J. et al. (2000). Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21st century. Retrieved from http://www2.ed.gov/inits/Math/glenn/report.pdf

Greenberg, A. D. (2009). *The 2009 update: Taking the wraps off videoconferencing in the U.S. classroom* [White paper]. Retrieved from http://www.wrplatinum.com/Content.aspx?CID=10122

Greenfield, T. A. (1997). Gender and grade level differences in science interest and participation. *Science Education, 81*(3), 259-276.

Greenwood, A. (1998). Learning science at a distance: Using interactive television to work with schools. *Education, 118*, 249–352.

Gunel, M. (2008). Critical elements for the science teacher to adopt a student-centered approach: The case of a teacher in transition. *Teachers and Teaching: Theory and Practice, 14*(3), 209-224.

Hanuscin, D. and Lee, M. H. (2008). Using the learning cycle as a model for teaching the learning cycle to pre-service elementary teachers. *Journal of Elementary Science Education, 20*(2), *51-66.*

Harris, C. J., & Marx, R. W. (2006). No child left behind and science education: Opportunities, challenges and risks. *Elementary School Journal, 106*, 457–477.

Hawkins, D. (1994). Constructivism: Some history. In P. Fensham, R. Gunstone, & R. White (Eds.). *The content of science*. (pp. 9–13). Washington, DC: Falmer Press.

Haydock, P., & Dennison, J. (2004). Assessing the needs of the K-12 audience in synchronous educational videoconferencing. *Proceedings of the 20th Annual Conference on Distance Teaching and Learning.* Madison, WI.

Heath, M., Holznagel, D., deFord, K., & Dimock, K. V. (2002). Interactive videoconferencing: A literature review and a policy Issues Review." *K-12 Videoconferencing*. Retrieved from http://neirtec.terc.edu/k12vc/resources/research.cfm

Heath, M., Hines, S., Veal, K., Zanetis, J., & Barshinger, T. (2003). Content providers for k-12 interactive videoconferencing. Retrieved from http://www.netc.org/digitalbridges/images/pdf/ivc.providers.pdf

Hillman, D. C., Willis, D. J., & Gunawardena, C. N. (1994). Learner-interface interaction in distance education. *American Journal of Distance Education*, *8*(2), 30-42.

Hodson, D. (1988). Toward a philosophically more valid science curriculum. *Science Education*, *72*, 19–40.

Hoffmann, L. (2002). Promoting girls' interest and achievement in physics classes for beginners. *Learning and Instruction*, *12*, 447-465.

Hoffmann, L., & Haussler, P. (1998). An intervention project promoting girls' and boys' interest in physics. In L. Hoffmann, A. K. Krapp, A. Renninger, & J. Baumert (Eds.), Proceedings of the See on Conference on Interest and Gender (pp. 301-316). Kiel, Germany: IPN

Howes, E. V., Lim, M., & Campos, J. (2008). Journeys into inquiry-based elementary science: Literacy practices, questioning and empirical study. *Science Education*, *93*(2), 189-217.

Hung, D., & Tan, S. (2004). Bridging between practice fields and real communities through instructional technologies. *International Journal of Instructional Media*, *31*(2), 167-175.

Investing in America's future. Barack Obama and Joe Biden's plan for science and innovation. (2008). Retrieved from http://www.barackobama.com/pdf/issues/FactSheetScience.pdf

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education, 23*(1), 41-57.

Johnson, K. (2004). The role of field paleontology on teachers' attitudes toward inquiry science. *NOVAations Journal*, Retrieved from http://novationsjournal.org/content/article.pl?sid=04/05/04/0024254

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*(2), 180-192.

Kam, R., Lee, H., & Songer, N. B. (2002). Technology rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy? *Journal of Research in Science Teaching, 39*, 128-150.

Kant, I. (1983). Critic of Pure Reason. (F. Haywood, Trans.). London, William Pickering. (Original work published in 1781).

Kahle, J. B., Parker, L. H., Rennie, L. J., & Riley, D. (1993). Gender differences in science education: Building a model. *Educational Psychologist, 28*(4), 379-404.

Karplus, R. J., & Their, H. D. (1967). *A new look at elementary school science*. Chicago: Rand McNally.

Keegan, D. (1990). *Foundations of distance education*. London: Routledge.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, *38*, 631-645.

Kim, M., Hannafin, M.J., & Bryan, L. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education, 96*(6), 1010-1030.

Kinginger, C. (1999). Videoconferencing as access to spoken French. *Canadian Modern Languages Review, 55*(4), 468-490.

Kirschner, P. A., Sweller, J., & Clark, R. A. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86.

Klahr, D. & Nigam, M. (2004). The equivalence of learning paths in early science instruction: effects of direct instruction and discovery learning. *Psychological Science*, *15*(10), 661-667.

Klentschy, M., Garrison, L., & Amaral, O. M. (2002). Helping english learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal*, *26*(2), 213-239.

Knowles. M. (1980). *The modern practice of adult education*. New York: Adult Education.

Koballa, T. R. (1988). Attitude and related concepts in science education, *Science Education*, *72*, 115-126.

Krajcik, J., & Rivet, A. (2004). Achieving standards in urban systemic reform: An example of a sixth grade project-based science curriculum. *Journal of Research in Science Teaching, 41*, 669–692.

Krathwol, D. R. (2002). A revision of blooms taxonomy: An overview. *Theory Into Practice, 41*, 212–218.

Kubasko, D., Jones, M. G., Tretter, T., & Andre, T. (2007). Is it live or is it Memorex? Students' synchronous and asynchronous communication with scientists. *International Journal of Science Education, 30*, 495-514.

Kubicek, J. P. (2005). Inquiry-based learning, the nature of science, and computer technology: New possibilities in science education. *Canadian Journal of Learning and Technology, 31*, 1–11.

Kuder, G. F., & Richardson, M. W. (1937). The theory of the estimation of test reliability. *Psychometrika, 2*(3), 151-160.

Kyle, W. C., Jr., Bonesetter, R. J., McCloskey, J., & Fults, B. A. (1985). What research says: Science through discovery: Students love it. *Science and Children, 23*, 39–41.

Laurillard, D. (1997) Learning formal representations through multimedia. In: Marton, F., Hounsell, D., Entwistle, N. (eds) *The experience of learning: implications for teaching and studying in higher education*. 2nd edition, Scottish Academic Press, Edinburgh.

Lavonen, J., Juuti, K., Uitto, A., Meisalo, V., & Byman, R. (2005). Attractiveness of science education in the Finnish comprehensive school. In A. *Manninen, K. Miettinen, & K. Kiviniemi (Eds.)*, Research findings on young people's perceptions of technology and science education (pp. 5-30). Helsinki: Technology Industries of Finland.

Lawson, A. E. (1995). *Science Teaching and the Development of Thinking.* Belmont, CA: Wadsworth Publishing Company.

Layman, J. (1996). *Inquiry and learning: Realizing the science standards in the classroom*. New York: College Entrance Examination Board.

Leonard, A. A., & Minogue, J. (2004). The effect teaching experience has on perceived effectiveness of interactive television as a distance education model for elementary school science teacher's professional development: Another digital divide? *Journal of Science Education and Technology, 13*, 485-594.

Lindberg, D. H. (1990). What goes round comes round doing science. *Childhood Education*, *67*(2), 79–81.

Lindgren, J., Bleicher, R. E. (2005). Learning the learning cycle: The differential effect on elementary preservice teachers. *School Science and Mathematics*, *105*(*2*), 61-72.

Lindgren, J., & Bleicher, R. E. (2005). Learning the learning cycle: The differential effect on elementary preservice teachers. *School Science and Mathematics*, *105*(*2*), 61-72.

Liu, T., Peng, H., & Wu, W.(2009). The effects of mobile natural-science learning based on the 5E learning cycle: A case study. *Educational Technology & Society*, *12*(4), 344-358.

Lou, Y., Bernard, R., & Abrami, P. (2006). Media and pedagogy in undergraduate distance education: A theory-based meta-analysis of empirical literature. *Educational Technology Research and Development, 54*(2), 141–176.

Luera, G. R., & Otto, C. A. (2005). Development and evaluation of an inquiry-based elementary science teacher education program reflecting current reform movements. *Journal of Science Teacher Education, 16*, 241-258.

Lutkehaus, N. C., & Greenfield, P. (2003). From *The Process of Education to The Culture of Education*: An intellectual biography of Jerome Bruner's contributions to education. In B. J. Zimmerman & D. H. Schunk, *Educational psychology: A century of contributions* (pp. 409–430). Mahwah, NJ: Lawrence Erlbaum.

Magnusson, S., Krajcik, J., & Borko, H. (2001). Nature, sources, and development of pedagogical content knowledge for science. In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogical content knowledge: The construct and its implications for science education (pp. 95 – 132).Dordrecht, The Netherlands: Kluwer.

Maidon, C. H., & Wheatley, J. H. (2001). *Outcomes for students using a model elementary science curriculum*, North Carolina State University.

Marek, A. E. (2008). Why the learning cycle? *Journal of Elementary Education*, *20*(3), 63-69.

Marlowe, B. E., & Page, M. E. (1988). *Creating and sustaining the constructivist classroom*. Thousand Oaks, CA: Corwin Press.

Martin, M. (2005). Seeing is believing: The role of videoconferencing in distance learning. *British Journal of Educational Technology, 36*(3), 397-405.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., & Soloway, E. (2004).

Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching*, (*41*),1063-1080.

Mayer, R. E. (2004). Should there be a three-strike rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, *59*, 14-19.

Mertler, C. A., & Vannatta, R. A. (2005). *Advanced Multivariate Statistical Methods (3rd ed.): Practical Application and Interpretation*. Glendale: Pyrczak Publishing.

McCombs, G. B., Ufnar, J. A., & Shepherd, V. L. (2007). The virtual scientist: Connecting university scientists to the k–12 classroom through videoconferencing. *Advances in Physiology Education, 31*, 62-66.

Miller, P. H., Slawinski Blessing, J., & Schwartz, S. (2006). Gender differences in high-school students' views about science. *International Journal of Science Education*, *28*(4), 363-381.

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (1998). *Teaching science for understanding: A human constructivist view*. San Diego, CA: Academic Press.

Montgomery, J. (1969). *A comparison of BSCS versus traditional teaching methods by testing student achievement and retention of biology concepts*. Muncie, IN: Ball State University.

Moore, M. G. (1989). Distance education, a learner's system. *Lifelong Learning*, *12*(8), 8-11.

Moore, M. G., & Kearsley, G. (2005). *Distance education: A systems view*. Second Edition. Belmont, CA: Wadsworth.

Muirhead, B. (2001a). Enhancing social interaction in computer-mediated open distance learning. *United States Distance Learning Association*, *15*(4). Retrieved from http://www.usdla.org/html/journal/APR01_Issue/article02.html

Muirhead, B. (2001b). Interactivity research studies. *Educational Technology & Society, 4*(3). Retrieved from http://ifets.ieee.org/periodical/vol_3_2001/muirhead.html

Murphy, P., & Whitelegg, E. (2006). Girls in the physics classroom: A review of the research into the participation of girls in physics. London: Institute of Physics.

Naab, L., & Henry, D. (2009).Why static clings. *Science and Children, 47*(4), 32-36.

National Committee on Science Education Standards and Assessment; National Research Council. (1996). National science education standards. Retrieved from http://www.nap.edu/openbook.php?record_id=4962

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *How people learn: Brain, mind, experience, and school* (expanded ed.). Washington, DC: National Academy Press.

National Science Teachers Association. (2002). *Position statement on elementary science*. Retrieved from: http://www.nsta.org/about/positions/elementary.aspx

Newman, W., et al. (2004). Dilemmas of teaching inquiry in elementary methods. *Journal of Science Teacher Education, 15*, 257–279.

Newman, D. (2008). The impact of multimedia videoconferencing on children's learning: Positive outcomes of use. In, D. L. Newman, S. S. Silverman, J. F. Falco, & P. Barbanel (Eds.), *Videoconferencing technology in k-12 instruction: Best practices and trends* (pp. 227–239). Hershey, PA: Information Science Reference.

No Child Left Behind Act of 2001. (2002). Pub. L. No 107-110,115 Sat. 1425.

Novodvorsky, I. (1997). Constructing a deeper understanding. *The Physics Teacher, 35*, 242-245.

Nuthall, G. (1999). The way students learn: Acquiring knowledge from an integrated science and social studies unit. *Elementary School Journal, 99*, 303–341.

Office of Science and Technology Policy Executive Office of the President. (2009). Preparing our children for the 21st century economy. Science, technology, engineering and mathematics (STEM) education in the 2010 budget. Retrieved from www.ostp.gov

Osborne, M. D. (1995). Science for all americans? Critiquing science education reform efforts. Retrieved from http://margeryosborne.weebly.com/uploads/1/4/2/3/1423738/science_for_all_americans

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: A focus group study. *International Journal of Science Education, 23*(5), 441-467.

Overbaugh, R. C. & Lin, S. (2005). Problem-based learning and fourth grade: Who really benefits? *The Constructivist, 16* (1).

Pachnowski, L. M. (2002). Virtual field trips through videoconferencing. *Learning & Leading with Technology, 22*(6), 10-13.

Palmer, D. H. (2009). Student interest generated during an inquiry skills lesson. *Journal of Research in Science Teaching, 46*(2), 147-165.

Perkins, D. N. (1991). Technology meets constructivism: Do they make a marriage? *Educational Technology, 13*, 18-23.

Petracchi, H. E., & Patchner, M. E. (2001). A comparison of live instruction and interactive televised teaching: A 2-year assessment of teaching an MSW research methods course. *Research on Social Work Practice, 11*, 108-117.

Piaget, J. (1970). *Genetic epistemology*. New York: Columbia University Press.

Pine, J., et al. (2005). Fifth graders' science inquiry abilities: A comparative study of students in hands-on and text book curricula. *Journal of Research in Science Teaching*, *43*, 467–484.

Plourde, L.A., & Alawiye, O. (2003). Constructivism and elementary preservice science teacher preparation: knowledge to application. *College student journal*, *37*(3), 334-342.

Polycom. (2010). Content access program. Retrieved from http://www.polycom.com/solutions/industry/education/programs_resources/content_access_program.html

Rakow, S. J. (1986). *Teaching science as inquiry. Fastback 246*. Bloomington, IN: Phi Delta Kappa Educational Foundation.

Rath, J. (2002). Improving instruction. *Theory Into Practice*, *41*(4), 233-237.

Rees, F. J., & Downs, D. A. (1995). Interactive television and distance learning. *Music Educators Journal*, *82*(2), 21–25.

Reigeluth, C. M. (1999). The elaboration theory: Guidance for Scope and Sequences Decisions. In R. M. Reigeluth, (Ed.), *Instructional-design theories and models: An new paradigm of instructional theory, Volume II*, pp. 425-454. Mahwah, NJ: Lawrence Erlbaum Associates.

Renner, J.W., Abraham, M.R., & Birnie, H.H. (1988). The necessity of each phase of the learning cycle in teaching high school physics. *Journal of Research in Science Teaching*, *25*, 39-58.

Roblyer, M. D. (1996). The constructivist objectivist debate: Implications for instructional technology research. *Learning and Leading with Technology, 24*, 12-16.

Roblyer, M. D., Edwards, J., & Havriluk, M. A. (1997). Integrating educational technology into teaching (2nd ed.). Upper Saddle River, NJ: Prentice-Hall.

Rogers, T., & Irwin, R. L. (1997). Video-conferencing for collaborative educational inquiry. *Art Education, 49*(5), 57-62.

Rose, D. A., et al. (2000). Videoconferencing for speech and language therapy in schools. *BT Technology Journal, 18*, 101-105.

Ross, A. R. (1996). The influence of computer communication skills on participation in a computer conferencing course. *Journal of Educational Computing Research, 15*, 37-52.

Ruby, A. (2006). Improving science achievement at high-poverty urban middle schools. *Science Education*, *90*(6), 1005-1027.

Rumble, G. (1989). Open learning, distance learning, and the misuse of language. *Open Learning*, *4*, 28-36.

Science Accountability Act of 2009. (2009). H.R. 2511. Retrieved from http://www.govtrack.us/congress/billtext.xpd?bill=h111-2511

Schreiner, C. (2006). Exploring a ROSE-garden: Norwegian youth's orientations towards science-seen as signs of late modern identities. Unpublished doctoral thesis, University of Oslo, Oslo, Norway.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton-Mifflin.

Shymansky, J. A., Hedges, Larry V., Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance, *Journal of Research on Science Teaching*, *27*(2), 127-144.

Shymansky, J., Kyle, W. Jr., & Alport, J. (2003). The effects of new science curricula on student performance. *Journal of Research in Science Teaching, 40*, S68–S85.

Shymansky, J. A., Yore, L. D., & Anderson, J. O. (2004). Impact of a school district's science reform effort on the achievement and attitudes of third-and fourth-grade students. *Journal of Research in Science Teaching*, *41*, 771–790.

Simon, B., Anderson, R., Hoyer, C., & Su., J. (2004). Preliminary experiences with a tablet PC based system to support active learning in computer science courses. In *Proceedings of the 9th Annual Conference on Innovation and Technology in Computer Science Education*, 213-217. New York: Association for Computing Machinery.

Simonson, M. (1995). Does anyone really want to learn at a distance? *Tech Trends, 40*(3),12.

Sjøberg, S. (2000). Science and scientists: The SAS study. Oslo, Norway: University of Oslo. Retrieved from http://folk.uio.no/sveinsj/SASweb.htm.

Sjøberg, S., & Schreiner, C. (2002). ROSE handbook: Introduction, guidelines and underlying ideas. Oslo, Norway: University of Oslo. Retrieved from http://folk.uio.no/sveinsj/ROSE%20handbook.htm

Smithey, J. (2008). *The development of preservice elementary teachers' knowledge about learners' science ideas*. Unpublished doctoral dissertation, University of Michigan, Ann Arbor.

Smolkin, L. B., McTigue, E. M., Donovan, C.A., & Coleman, J.M. (2001). Explanation in science trade books recommended for use with elementary students. *Science Education. 93*, 587-610.

Sorey, T., Willard, T., & Kim, B. (2010). Make your own digital thermometer! Using the 5E learning cycle to design and calibrate a scientific instrument. *The Science Teacher, 77*(3), 56-60.

Spall, K., Barrett, S., Stanisstreet, M., Dickson, D., & Boyes, E. (2003). Undergraduates' views about biology and physics. *Research in Science & Technological Education, 21*(2), 193-208.

Stark, R., & Gray, D. (1999). Gender preferences in learning science. *International Journal of Science Education, 21*(6), 633-643.

Staver, J. R., & Bay, M. (1987). Analysis of the project synthesis goal cluster orientation and inquiry emphasis of elementary science textbooks. *Journal of Research in Science Teaching, 24*, 629–643.

Stohr-Hunt, P. M. (1996). An analysis of frequency of hands-on experience and science achievement. *Journal of Research in Science Teaching*, 33, 101-109.

Sullivan, L., & Smith, S. A. (2001). Charting your journey to distance learning.

Multimedia Schools October 2001. Retrieved from http://infotoday.com/MMSchools/oct01/sullivan&smith.htm

Sutton, L. A. (2001). The principle of vicarious interaction in computer-mediated communications. *International Journal of Educational Telecommunications,* 7(3), 223-242.

Tabachnick, B. G., & Fidell, L. S. (1996). Using multivariate statistics. New York: Harper Collins.

Tabachnick, B. G., & Fidell, L. S. (2007). Using multivariate statistics. (5th ed.). Boston: Allyn and Bacon.

Talley, D., & Cherry, G. (2009). Reaching beyond the conventional classroom: NASA's digital learning network. *Distance Learning*, *6*(4), 1-7.

Tobin, K., Tippins, D., & Gallard, A. J. (1994). Research in instructional strategies for teaching science. In D. Gabel (Ed.), Handbook of research on science teaching and learning (pp. 43–93). New York: Macmillan.

Townes-Young, K. L, & Ewing, V. R. (2005). Creating a global classroom. *T.H.E. Journal, 33* (4), 43-5.

Trumper, R. (2006). Factors affecting junior high school students' interest in biology. *Science Education International*, *17*, 31-48.

Tsui, A. M., & Ki, W. W. (1996). An analysis of conference interactions on Telenex: a computer network for ESL teachers. *Educational Technology Research and Development*, *44*(4), 23-44.

Udovic, D. D., et al. (2002). Workshop biology: Demonstrating the effectiveness of active learning in an introductory biology course. *BioScience, 52*(3), 272-281.

Vincent, D., Cassel, D., & Milligan, J. (2008). Will it float? *Science and Children, 45*(6), 36-39.

Vygotsky, L.S. (1978). Mind in Society. Cambridge, MA: Harvard University Press.

Wagner, E. D. (1994). In support of a functional definition of interaction. *The American Journal of Distance Education*, *8*(2), 6-29.

Wallace, C. S., & Kang, N. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing beliefs sets. *Journal of Research in Science Reaching*, *41*(9), 936-960.

Ward Melville Heritage Organization. (2002). Videoconferencing exposes students to new worlds. *Technological Horizons in Education Journal*, *29*(8), 52-54.

Welch, W., Klopfer, L., Aikenhead, G., & Robinson, J. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education*, *65*, 33–50.

West, G.B. (1999). Teaching and technology in higher education: Changes and challenges. *Adult Learning, 10*(4), 16-18.

Wilder, M., & Shuttleworth, P. (2004). Cell inquiry: A 5E learning cycle lesson. *Science Activities*, *41*, 25-31.

Winnie, W., & Kong, S. (2007). Approaches of inquiry learning with multimedia resources in primary classrooms. *Journal of Computers in Mathematics and Science Teaching*, *26*(4), 329–354.

Wise, K.C., (1996), Strategies for teaching science: What works? *The Clearing House*, *69*(6) 337-338.

Wolf, S. J., & Fraser, B. J. (2008). Learning environment, attitude, and achievement among middle-school science students using inquiry-based laboratory activities. *Research in Science Education, 38*, 321–341.

Woodward, C., & Woodward, N. (1998). Girls and science: Does a core curriculum in primary school give cause for optimism? *Gender and Education, 10*(4), 387-400.

Wynia, L. (2000). How do students really feel about interactive television? *Tech Trends, 44*(4), 39–41.

Young, B. J., & Lee, S. K. (2005). The effects of a kit-based science curriculum and intensive science professional development on elementary student science achievement. *Journal of Science Education and Technology, 14*, 471–481.

Zohar, A. (2003). Her physics, his physics: Gender issues in Israeli advanced placement physics classes. *International Journal of Science Education, 25*(2), 245-268.

APPENDICES

APPENDIX A

FIVE E INSTRUCTIONAL MODEL SUMMARY

Taken from:

Bybee, et al. (2006) *The BSCS 5E Instructional Model: Origins, Effectiveness, and Application*, Colorado Springs, CO: Biological Sciences Curriculum Study and National Institutes of Health

Phase	Summary
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

APPENDIX B

FORCE AND MOTION RUNDOWNS

National Science Standard 5-8.2 Physical Science

Gravity

Video	Audio	5E
DLN Open	Welcome to your center Go over rules of video conferencing • Raise hands • Respect peers • Have fun	Engage
PPT #1 Opening	Ask students: • Who likes Science? • Do you know what gravity is? • Do you experience gravity every day?	Engage, Explore
	Presenter ask: • Male students to stand up and jump and stay in the air for a count to 3 • Female students stand up and jump, stay in the air for a count of 3 (Use an average of 10 inches for later use) • Why couldn't they do it? • Students explain gravity • Students define matter in one word? • Students define mass in one word? • State the difference between mass and weight?	Engage/explain
Slide #3	Presenter ask students: • What about other planets? Does gravity exit? • Explain that the amount of mass of planets affects the gravity	Explain, Elaborate

	• Which planet has the most gravitational force? Why? Explain • Sun's gravity keeps planets in alignment Do you think you can jump higher on other planets? Have students create hypothesis proposing a relationship between gravity and their jump height	
PPT #4,5	Mercury • Share basic facts about Mercury ○ Using their previous jump height let students calculate what their jump height would be on Mercury • Compare their Mercury Jump Height to that of Earth.	Explore
Slide #6,7	Jupiter • Ask students about the largest planet in our solar system (Jupiter) Share basic facts about Jupiter ○ Using the same previous jump height, calculate your jump height on Jupiter.	Explore
	Do you think you weigh more or less on those planets? Explain the difference between weight and gravity.	Explain
Slide #8	**Presenter says** • *What* about astronauts in space?	Engage
Slide #9	• Explain what happens when astronauts and satellites orbit earth	Explain
Slide #10	**Presenter ask:** If you drop two objects at the same time in on the planet which one would hit the ground first?	Extend
	Demonstrate dropping two objects at the same time.	Elaborate

Slide #12	Do you think that astronauts are weightless on the Moon?	Engage
Slide #13	Presenter says Explain how the astronauts are not completely weightless on the moon because the moon has gravity. It is just reduced gravity.	
Slide #14	How do we train for this type of environment in on earth? Refer to the NBL as one source of training	Explain
	Gravity attracts us at different rates on earth. You are being attracted to your seats right now. Let's try something.	Engage
	ACTIVITY **The Super Glue Chair:** • Sit in a straight-back armless chair, keeping your back against the back of the chair and your feet flat on the floor. • Fold your arms across your chest. • Keeping your feet flat and your back straight, try to stand up. Are you glued to your chair? **The Science:** In this sitting position, the center of gravity is at the base of your spine. By trying to stand up with your back straight, you prevent the center of gravity from moving to a position above your feet, which would be necessary to stand up. Therefore, you remain glued to your chair!	Expand
	Closure • Ask students where they observe gravity in everyday life. • Ask students to explain what the difference between weight and gravity is	Evaluate

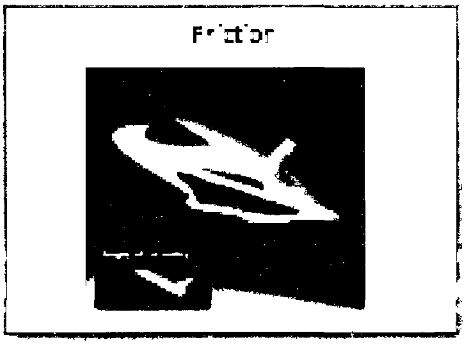
Gravity PowerPoint

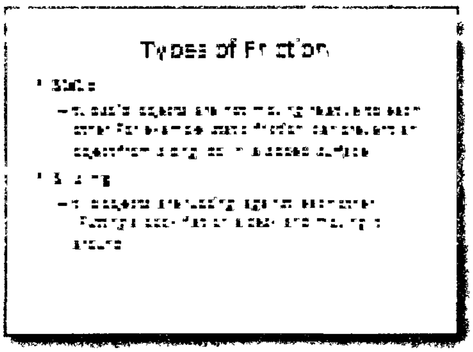
Friction

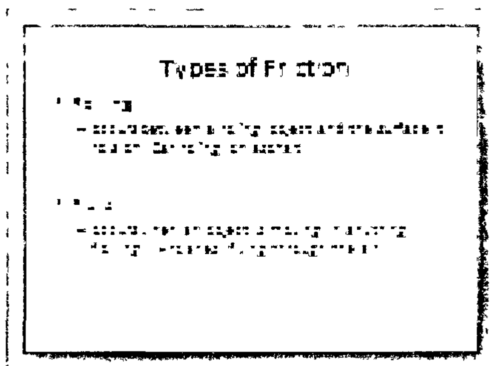
Video	Audio	5E
DLN Open	Welcome to your center Go over rules of video conferencing • Raise hands • Respect peers • Have fun	Engage
PPT #1	Ask students: • What is happening in this picture? • Do you know what Friction is? • How have you experienced Friction?	Engage, Explore
PPT #2	Presenter State: • Explain what is happening in the re-entry picture. • Explain how space shuttle tiles prohibit heat from the friction of Earth's atmosphere from coming into the space shuttle. • Explain how the space shuttle tiles are inspected one by one before and after each mission.	Explain
PPT 3&4	Presenter ask students: • How often do you experience Friction? • There are four different types of friction o Address each type according to the ppt. (We are only going to talk about static and sliding friction today.	Elaborate
	Friction Activity Start by making an inclined plane at a shallow angle using a flat piece of plywood. Place a coffee cup on the board on its side. Ask the students to predict what will happen when the plane is slowly raised to a steeper angle. You can then perform the experiment. Next, place the same	Explore

	coffee cup on the board upright. Ask the students to predict what will happen when the plane is slowly raised to a steeper angle.	
	Closure Ask students if they can explain what makes the cup side slide down when it is on its' side while the cup on its bottom does not (until you increase the plane to a steeper angle). The point is to give students only a basic definition of friction and then let them see what they can find out about it for themselves. Depending on their prior knowledge, they may answer that the force of gravity makes the smooth cup slide, but that gravity isn't strong enough to make the rough cup slide until you make the angle steeper. You can point out that the force of gravity must be great enough to overcome another force, the force of friction, in order for the cups to move. Friction is a force that occurs between two surfaces, and it acts to impede motion.	Explain
	Presenter ask: • Can you name some instances where you have experienced static and sliding friction?	Evaluate
	• What is the difference between static and sliding friction?	

Friction PowerPoint







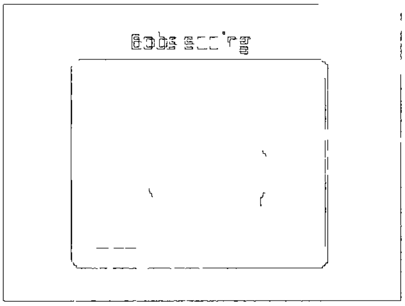
Newton's First Law

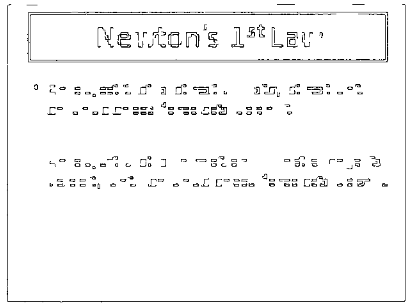
Video	Audio	5E
DLN Open	Welcome Go over rules of video conferencing • Raise hands • Respect peers • Have fun	Engage
Slide #1	**Ask Students:** **Show the bobsled video** Ask students where they observed Newton's 1st Law	Engage
Slide #2	**Presenter asks:** Do you remember Newton's 1st Law? How does Newton's first law impact us on a daily basis?	Engage
Slide #3 **Slide #4**	**Presenter says:** A force is a pushing or pulling of another object. We have talked about two forces (Gravity and Friction) Presenter asks: • Do you remember what Gravity is • Do you remember what Friction is? When the forces on an object are balanced the object doesn't move.	Elaborate

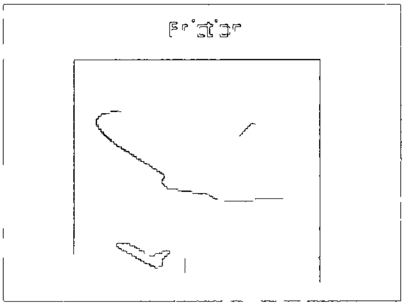
Slide #5	**Presenter asks:** (Pass out the ping pong balls and have them set them on their tables or on the floor right in front of them) What would happen to a ball that you place carefully on perfectly slippery ice? (Pass out the wooden dowels and have them just set them on their tables.) What is happening to the dowel rods? Now imagine it sitting on slippery ice. What would it be doing then? What would you have to do to get it moving?	Explore
PPT #6	**Presenter Says** The dowel rod, sitting on the table, is not moving If the dowel rod were on slippery ice, it would still not be moving. (To get the dowel rod moving someone or something would need to push or pull it.) **This is an example of Newton's 1st Law ……..** **Refer back to the bobsled video.**	**Elaborate**

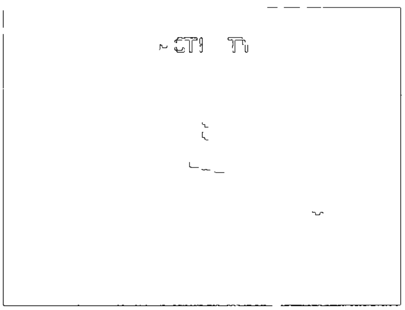
	Presenter asks: Ask students to picture that ball on perfectly slippery ice again, but now imagine someone or something push it. What happens to the ball now? Will it ever stop? Remember, the ice is perfectly slippery.	Explore
Overhead Camera with Paper and Pencil	**Presenter asks students to:** (Using Paper and Pencil) Draw the ball at rest 9and in motion on your paper, with the appropriate arrows. Roll a ball on the table. Didn't we just say that an object in motion stays in motion? So why did this ball come to a stop? What else could you do to make the ball come to a stop? What are all of these things examples of? **Presenter Says:** We have discovered Newton's 1^{st} Law of Motion: An object at rest stays at rest and an object in motion stays in motion unless acted on by a force.	Explore
	Closure Ask students to give an example where they have experienced Newton's first law in everyday life.	Evaluate

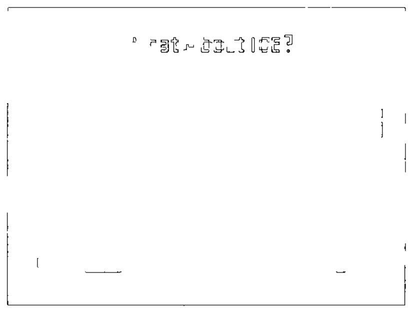
Newton's 1st Law

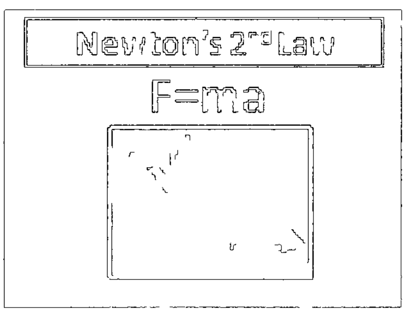


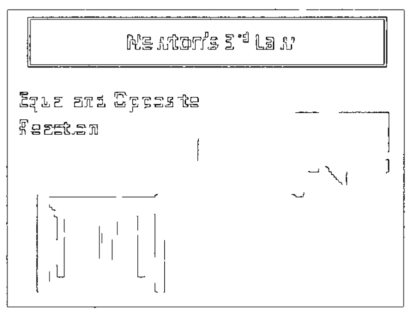












Newton's Second Law

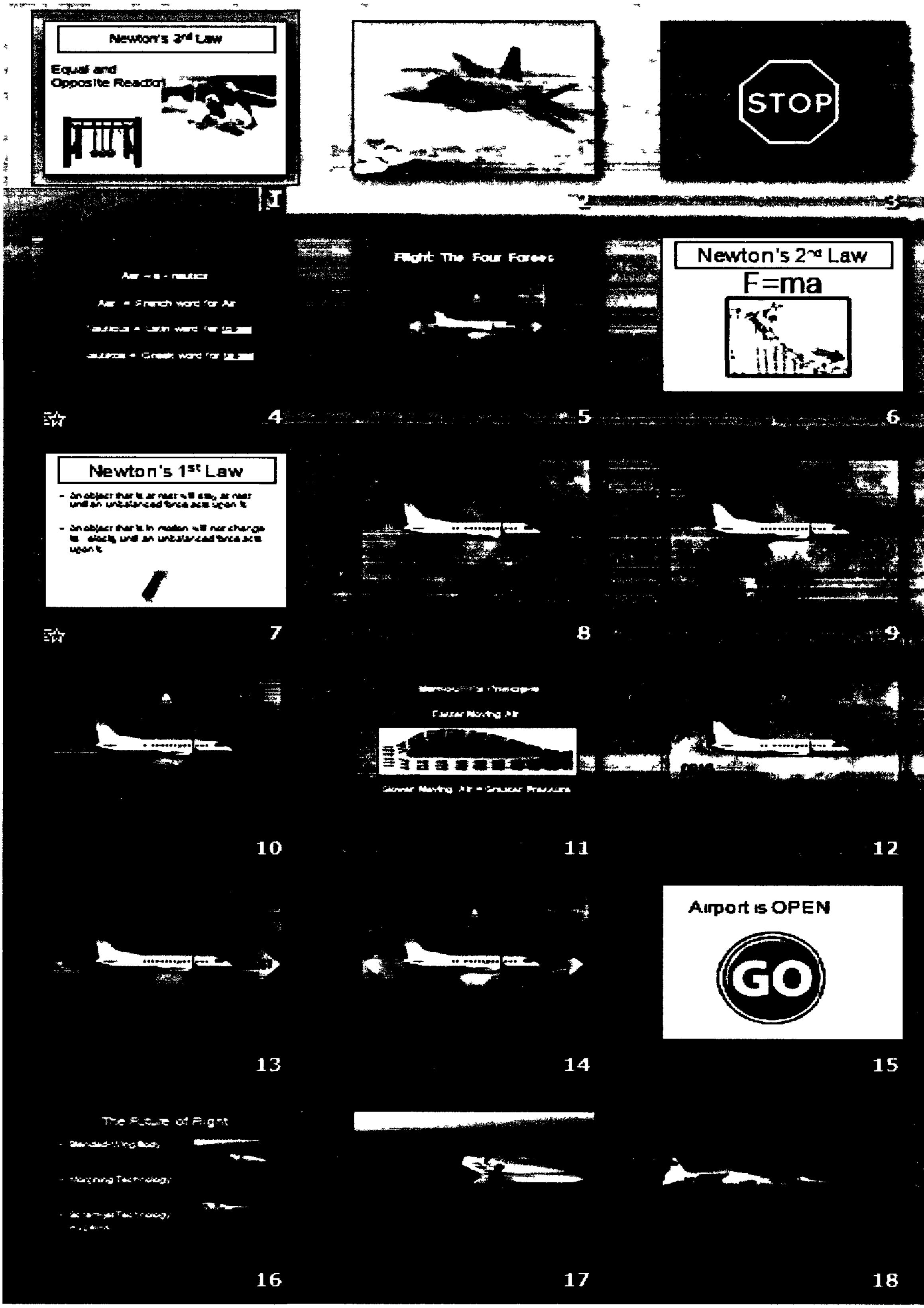
Video	Audio	5E
DLN Open	Welcome Go over rules of video conferencing • Raise hands • Respect peers Have fun	Engage
Slide #3,	**Presenter asks:** What makes an airplane fly? Have students create an airplane in approximately 30 seconds. (Airport is closed)	Engage
	Presenter says: Countdown from 10 and have students fly their airplanes from one side of the room to the other.	Explore
Slide #5	Presenter asks: What made your airplane fly? What does aeronautics mean?	Engage
Slide #6	Presenter says: • Introduce the four forces of flight • Introduce Newton's 2^{nd} law of motion The more inertia an object has, the more difficult it is to accelerate it. So, by increasing the inertia of a spaceship, it accelerates at a smaller rate. Now it would be really nice if we could figure out ***exactly*** how you are changing the inertia of an object and ***exactly*** (as in being able to assign numbers) how that affects the object's acceleration with a given force. To do that, we're going to introduce a new word- *mass*. An object's ***mass*** is a ***measure*** of the object's inertia. The equation that expresses the relationship between total force, mass, and acceleration is f=ma. The F represents the total force, m represents the mass, and a represents the	Explanation

	acceleration. This relationship is expressed as Newton's Second Law. • (refer back to the 1st law, gravity, and friction where applicable) Slide #7	
Slide #9	Presenter says: • Weight (Gravity) Weight is present because of gravity. Gravity is a natural force that pulls the plane down towards the earth. Therefore, the direction of weight is down.	Elaborate
Slide #10, 11	Presenter says: • Lift • Explain what an airfoil is The force that pushes an object up against the weight is lift. On an airplane or a bird, the lift is created by the movement of the air around the wings. Air moves over the top and bottom of the wing at different speeds to create lift. There are two ways to do this. The wing itself can have a curved upper surface and flatter lower surface. This forces the air flowing over the top of the wing to move faster. This creates lift. Another way is to use a flat wing and fly at an angle to the wind. The slanted wing causes the air to move more quickly over the top of it, creating lift. • Paper wing activity According to Newton's Third Law, for every action there is an equal, but opposite reaction. Therefore, if the airfoil deflects the air down, the resulting opposite reaction is an upward push. Deflection is an important source of lift. Planes with flat wings, rather than cambered, or curved wings must tilt their wings to get deflection. Generally, the faster you go, more lift is created. If speed is doubled, lift increases four times! Race cars can use lift to help them. It is called negative lift because the shape of the airfoil produces lift that points downward. This helps the race car stay on the track as it goes	Elaborate

	around high speed turns.	
Slide #12	Presenter says: • Drag There are four types of drag: 2,3,4 are optional 1. **Friction drag** - As an airplane goes through the air, the air must go around the plane. The air is "rubbing" against the metal skin of the aircraft. This tends to slow the aircraft. 2. **Form drag** - The shape of the airplane can make more or less drag. If the plane is "streamlined" the air will pass around it with less drag. Think of a truck or a bus. The flat front is not streamlined. This creates more drag, and more fuel is used. Put your hand out the window of a car, palm forward, this is an example of the form of a bus or truck. Feel the drag! 3. **Induced drag** - When lift is created around a wing, drag is also created. 4. **Wave drag** - When an airplane is flying near or faster than the speed of sound the air flow around the aircraft changes and becomes an additional drag.	Elaborate
Slide #13	**Presenter says:** • Thrust Thrust is created by airplane engines (or birds flapping wings). The engines can turn a propeller at high speed or can be a jet engine that pushes hot gases out the back. If the thrust is powerful enough it will overcome weight and drag and the plane will fly. **Presenter asks:** How can you make your airplane fly further than before? (targeted response of giving it more thrust or throwing it harder) Refer back to Newton's second Law F=ma What modifications can you make to your airplane that would make it fly further or faster?	Elaborate

Slide #15	**Activity** • Build airplane again with students • Remind them of the concepts that can make their airplanes fly further • (Airport Open) o Have students line up on one side of the room. Release Airplanes (countdown from 10) Ask students if they have any further questions.	Extend
Slide #16,17,18	**Closure** **Presenter Says:** What is the future of Aeronautics?	Engage

Newton's 2nd Law

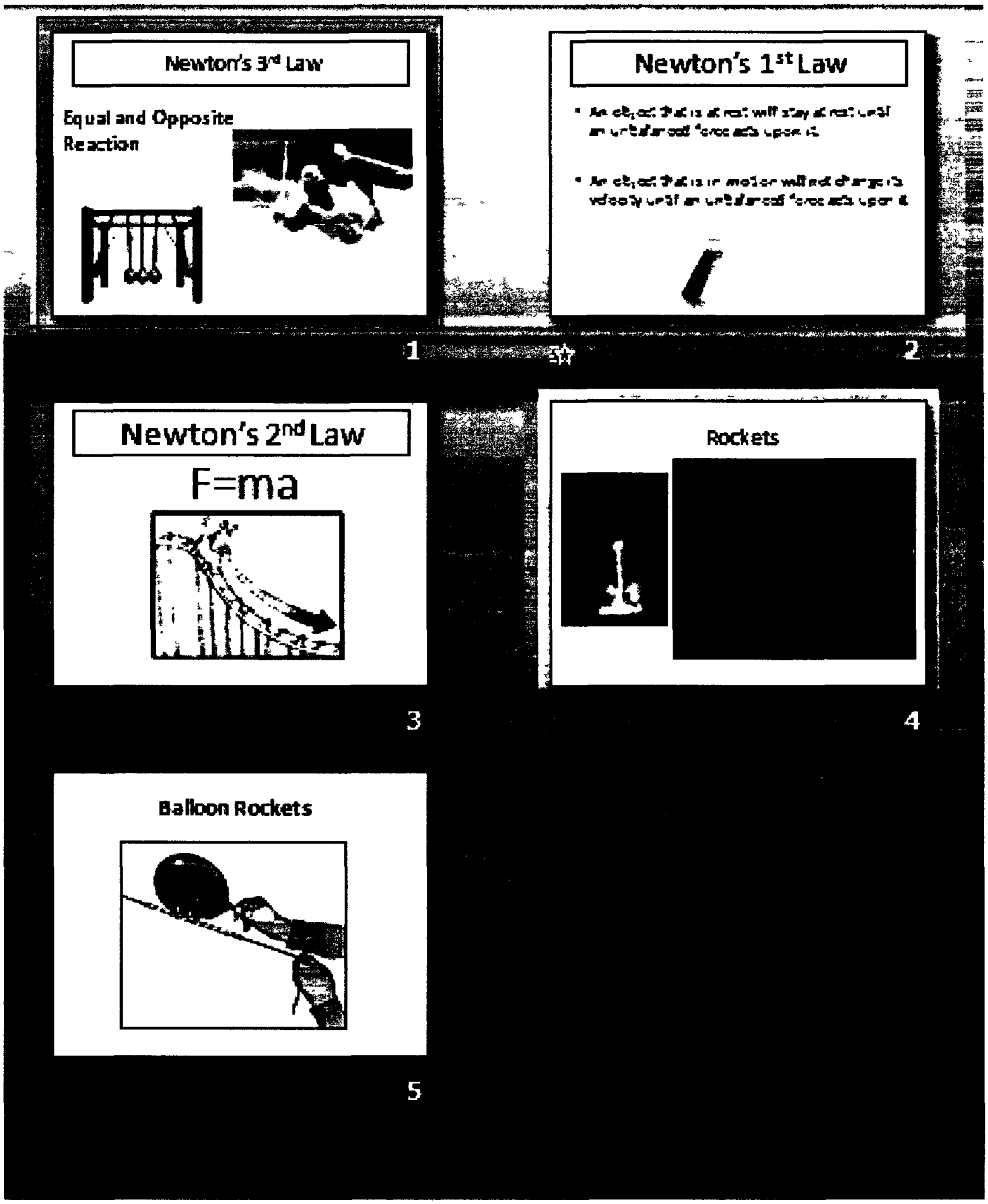


Newton's 3rd Law

Video	Audio	5E
DLN Open	Welcome Go over rules of video conferencing • Raise hands • Respect peers Have fun	Engage
Slides 2 and 3	**Presenter asks:** • Does anyone remember Newton's Laws • Review 1st and 2nd laws • Does anyone remember what Newton's third law says?	Engage
	Presenter says: • Have students push their hand against the edge of the desk. • Ask them to describe what the skin around where the contact is being made looks like. Is it different than if you were not pushing against the desk? • Why does the edge of your hand look distorted if you are pushing on the desk? *Because the desk is pushing on you. Anything you can feel is something else pushing on you.* **Reintroduce Newton's 3rd Law**	Explaination
	Presenter says: (Have students try the following problems give help as needed) Problem: Identify the action-reaction pairs in the following situations using words, and draw a diagram labeling forces with arrows and correct subscripts. a snowball hits someone in the back a baseball player catches a ball a gust of wind strikes a window	Explain

Slide 4	**Presenter asks** • What type of impact do you think that Newton's 3rd Law has on Rockets? Show Discovery Launch	Extend
	Discuss Newton's third law and rockets	Explaination
	ACTIVITY Build the balloon rocket Ask students what they have observed as they launched their rockets?	Elaborate
	Closure What does Newton's third law tell us about moving objects? When have you observed Newton's third law in action?	Evaluation

Newton's 3rd Law



APPENDIX C

FORCES OF FLIGHT

Newton's 2nd Law (Lecture)

Materials:

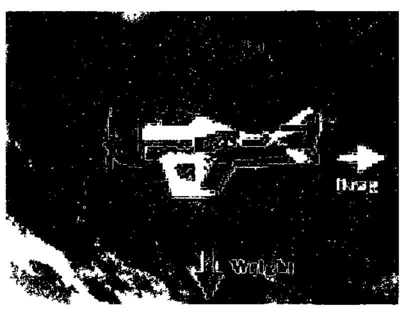
- Plain piece of paper
- Pencil
- Tape
- Paper clip
- Power Point
- Videos

Lesson objective(s):

Students will be able to:

- recognize how lift, weight, thrust, and drag relate to airplane flight
- illustrate how Bernoulli's Principle affects an airplane wing
- determine how Newton's 2nd Law affects airplane flight.

"There are, basically, four forces of flight: lift, drag, thrust and weight. The figure below shows how these four forces are related for straight and level flight. Lift force point upward, opposite to the weight. Thrust pushes the plane forward, as drag slows it down. The lift force must be greater than the weight and the thrust more powerful than the drag for the plane to fly."



Direction of Forces in Straight and Level Flight

Weight

"Weight is present because of gravity. Gravity is a natural force that pulls the plane down towards the earth. Therefore, the direction of weight is down."

Lift

"The force that pushes an object up against the weight is lift. On an airplane or a bird, the lift is created by the movement of the air around the wings. Air moves over the top and bottom of the wing at different speeds to create lift. There are two ways to do this. The wing itself can have a curved upper surface and flatter lower surface. This forces the air flowing over the top of the wing to move faster. This creates lift. Another way is to use a flat wing and fly at an angle to the wind. The slanted wing causes the air to move more quickly over the top of it, creating lift."

"Modern aircraft have a curved upper surface on the wing. The figure below shows two streamlines; one is going over the wing and the other under the wing. The faster air leads to low pressure on top of the wing and the slower stream under the wing creates a higher pressure. The two together produce lift."

"According to Newton's Third Law, for every action there is an equal, but opposite reaction. Therefore, if the airfoil deflects the air down, the resulting opposite reaction is an upward push. Deflection is an important source of lift. Planes with flat wings, rather than cambered, or curved wings must tilt their wings to get deflection.

Generally, the faster you go, more lift is created. If speed is doubled, lift increases four times!

Race cars can use lift to help them. It is called negative lift because the shape of the airfoil produces lift that points downward. This helps the race car stay on the track as it goes around high speed turns."

Thrust

"Thrust is created by airplane engines (or birds flapping wings). The engines can turn a propeller at high speed or can be a jet engine that pushes hot gases out the back. If the thrust is powerful enough it will overcome weight and drag and the plane will fly."

Drag

"Drag works against thrust to slow an aircraft.

There are four types of drag:

5. Friction drag - As an airplane goes through the air, the air must go around the plane. The air is "rubbing" against the metal skin of the aircraft. This tends to slow the aircraft.
6. Form drag - The shape of the airplane can make more or less drag. If the plane is "streamlined" the air will pass around it with less drag. Think of a truck or a bus. The flat front is not streamlined. This creates more drag, and more fuel is used. Put your hand out the window of a car, palm forward, this is an example of the form of a bus or truck. Feel the drag!
7. Induced drag - When lift is created around a wing, drag is also created.
8. Wave drag - When an airplane is flying near or faster than the speed of sound the air flow around the aircraft changes and becomes an additional drag."

Closure

"The four forces of flight, weight, lift, thrust and drag are well known by pilots. Stunt pilots use these forces to entertain crowds with their amazing tricks. They may stall (stop the lift) the plane in midair and let it fall and then at the last minute "pull out" and fly straight. Or, the pilot may point the airplane straight up and fly until the weight overcomes the thrust and the plane falls back toward the ground. The pilot then brings the plane in line to gain lift to fly straight again."

APPENDIX D

FORCES OF FLIGHT

Newton's Second Law (5E)

Materials:

- Plain piece of paper
- Pencil
- Tape
- Paper clip
- Power Point
- Videos

Lesson objective(s):

Students will be able to:

- recognize how lift, weight, thrust, and drag relate to airplane flight
- illustrate how Bernoulli's Principle affects an airplane wing
- determine how Newton's 2^{nd} Law affects airplane flight.

ENGAGEMENT

- Ask students to build a paper airplane in 30 seconds.
- Ask students do they like flying on an airplane.
- Ask how many have actually flown on an airplane.

EXPLORATION

- Students will have the opportunity to build their own airplane without the assistance from the instructor.
- Students will be expected to explain how their airplane flies and why do they think that some fly further than others.
- List "big idea" conceptual questions of forces of flight that will be used to encourage and/or focus students' exploration (i.e. Lift, Thrust, Drag, Weight).

EXPLANATION

- Student explanations should precede introduction of terms or explanations by the instructor.
- Instructor should link concepts the students come up with to their explanation of the concepts of lift, drag, thrust, and weight.
- Higher order thinking questions which teachers will use to solicit *student* explanations and help them to justify their explanations are:

  - What do you think ailerons have to do with an airplane flying?
  - Do you think that a plane traveling faster has more thrust than one that does not fly as fast?

ELABORATION

- Students will develop a more sophisticated understanding of the concept after the instructor goes through Bernoulli's principle and demonstrates through a paper blowing activity
- Ask the students how we are experimenting with different airplane styles to build new and improve old airplanes. (i.e. show pictures of Boeing 787, and winglets).

EVALUATION

- Students will build a paper airplane and label the parts of the plane according to the module.
- Students will also be asked to express their thoughts through questions throughout the lesson regarding the concepts.

APPENDIX E

SAI II ATTITUDE STATEMENTS

These are the position statements and corresponding attitude statements of the SAI II. The position statements are labeled with a number and a letter: for example, 1-A. The letter designates whether the position statement is positive (A) or negative (B). The position statements are in pairs, where the pair 1-A and 1-B are intended to be opposite positions regarding the same point of view. The numbers in front of each attitude statement indicates its number in the SAI II.

1-A. The laws and/or theories of science are approximations of truth and are subject to change.

4. Scientists are always interested in better explanations of things.

16. Scientific ideas can be changed.

34. Scientists believe that nothing is known to be true for sure.

1-B. The laws and/or theories of science represent unchangeable truths discovered through science.

11. When scientists have a good explanation, they do not try to make it better.

15. Scientists discover laws which tell us exactly what is going on in nature.

35. Scientific laws have been proven beyond all possible doubt.

2-A. Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.

10. Scientists cannot always find the answers to their questions.

19. Some questions cannot be answered by science.

33. The senses are one of the most important tools a scientist has.

2-B. The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.

2. Anything we need to know can be found out through science.

7. We can always get answers to our questions by asking a scientist.

26. If a scientist cannot answer a question, another scientist can.

3-A. To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.

17. Scientific questions are answered by observing things.

18. Good scientists are willing to change their ideas.

25. Scientists must report exactly what they observe.

3-B. To operate in a scientific manner one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.

3. It is useless to listen to a new idea unless everybody agrees with it.

5. If one scientist says an idea is true, all other scientists will believe it.

32. Scientists should not criticize each other's work.

4-A. Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.

20. A scientist must have a good imagination to create new ideas.

21. Ideas are the important result of science.

28. Science tries to explain how things happen.

4-B. Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses.

9. Electronics are examples of the really valuable products of science.

24. A major purpose of science is to produce new drugs and save lives.

31. A major purpose of science is to help people live better.

5-A. Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.

12. Most people can understand science.

23. People must understand science because it affects their lives.

29. Every citizen should understand science.

5-B. Public understanding of science would contribute nothing to the advancement of science or to human welfare; therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them.

6. Only highly trained scientists can understand science.

8. Most people are not able to understand science.

38. Scientific work is useful only to scientists.

6-A. Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.

1. I would enjoy studying science.

27. I would like to work with other scientists to solve scientific problems.

30. I may not make great discoveries, but working in science would be fun.

36. I would like to be a scientist.

40. Working in a science laboratory would be fun.

6-B. Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work.

13. The search for scientific knowledge would be boring.

14. Scientific work would be too hard for me.

22. I do not want to be a scientist.

37. Scientists do not have enough time for their families or for fun.

39. Scientists have to study too much.

APPENDIX F

FORCE AND MOTION CONTENT ASSESSMENT

Friction

Objectives:

1a. Define friction as a force that slows motion. (Remember/Factual Knowledge)
Noun: force that slows motion **Verb:** define
Questions: 1 (Recognize), 3 (Recall)

1b. Recall the correct definition of Friction. (Remember/Factual Knowledge)
Noun: definition of Friction **Verb:** identify
Questions: 2 (Recognize), 4 (Recall)

1c. Identify how and where friction occurs. (Understand/Conceptual Knowledge)
Noun: friction occurs **Verb:** recognize
Questions: 5, 6

1d. Choose the best answer that describes how friction occurs (Apply/Conceptual Knowledge)
Noun: friction occurs **Verb:** choose
Questions: 7

The Knowledge Dimension	The Cognitive Domain						
	Remember						
	Recognize	Recall	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	LO1a. Q1,Q2	LO1b. Q3,Q4					
Conceptual Knowledge			LO1c. Q5,Q 6	LO1d. Q7			
Procedural Knowledge							
Metacognitive Knowledge							

Assessment Questions

Remember/Recognize

1. Friction is best described as a force that: _______

   a. cools objects down.
   b. causes an object to move faster over a period of time.
   c. causes an object to continue to move forward when contacted by another object.
   d. one surface exerts on another when the two rub against one another.

2. Friction can:______
   a. pull something out of the air.
   b. speed something up.
   c. make something bigger.
   d. slow something down.

Remember/Recall

3. One of the results of an increase in friction is an increase in __________.

   heat (Fill in Question)

4. Friction always moves in the ______ direction to the sliding movement of an object.

   opposite (Fill in Question)

Understand

5. Friction is caused by: _________

   a. two surfaces moving past one another without touching.
   b. two surfaces being pulled apart without rubbing.
   c. two surfaces rubbing together.
   d. one surface sitting on top of another surface.

6. Which one of the following is an example of reducing friction?

   a. Using the brakes on a car
   b. Waxing Skis
   c. Using sandpaper
   d. Putting on rough soled boots

Apply

7. Why is Space Shuttle tiles glowing when reentering Earth's atmosphere an example of friction?

a. Heat is generated from Earth's atmosphere rubbing against the tiles causes them to glow.
b. Heat is spread out from the speed of the shuttle moving through the air.
c. The Earth's atmosphere causes an increased amount of pressure on the tiles.
d. The movement of the tiles causes Earth's atmosphere to heat up.

Gravity

Objectives:

2a. Define weight. (Remember/Factual Knowledge)
Noun: weight **Verb:** define
Questions: 8 (Recognize), 10 (Recall)

2b. Define gravity. (Remember/Factual Knowledge)
Noun: gravity **Verb:** define
Questions: 9 (Recognize), 11 (Recall)

2c. Recognize the statement that explains how gravity affects the space shuttle while orbiting the Earth. (Understand/Conceptual Knowledge)
Noun: statement that explains how satellites orbit Earth **Verb:** recognize
Questions: 12

2d. Identify the difference between gravity and weight. (Understand/Conceptual Knowledge)
Noun: the difference between gravity and weight **Verb:** recognize
Questions: 13

2e. Choose the correct explanation that describes how gravity behaves in Space. (Apply/ Conceptual Knowledge)
Noun: gravity behaves in Space **Verb:** choose
Questions: 14

The Knowledge Dimension	The Cognitive Domain						
	Remember						
	Recognize	Recall	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	LO2a. Q8, Q9	LO2b. Q10, Q11					
Conceptual Knowledge			LO2c. Q12 LO2d. Q 13	LO2e. Q14			
Procedural Knowledge							
Metacognitive Knowledge							

Assessment Questions

Remember/Recognize

8. Which of the following statements defines **weight**?

   a. A gravitational force on a mass.
   b. How big an object is.
   c. The amount of matter in an object.
   d. The amount of space an object takes up.

9. Which force is responsible for keeping objects on the ground on Earth?

   a. Gravity
   b. Friction
   c. Speed
   d. Acceleration

Remember/Recall

10. Your _______ equals your mass times acceleration due to gravity.

    Weight (Fill in Question)

11. The force that keeps objects on the ground on Earth is called_________.

    Gravity (Fill in Question)

Understand

12. Why is the space shuttle falling instead of floating when in orbit around the Earth?

    a. The shuttle is traveling so fast that it misses the earth.
    b. The gravity of Earth pushes the shuttle away.
    c. The shuttle is weightless.
    d. Other planets pull on the Earth.

13. As astronauts travel away from Earth through Space, their weight:_______

    a. decreases because gravity decreases.
    b. decreases because their mass decreases.
    c. increases because gravity increases.
    d. remains the same because their mass remains the same.

Apply

14. When comparing two items that may have different weights such as a feather and a hammer, how is it possible for both to fall at the same rate on the Moon?

    a. Both the feather and hammer are equally affected by gravity.
    b. The feather gains weight because of acceleration.
    c. The hammer slows down because of the weightless environment.
    d. Someone threw the hammer up in the air and dropped the feather.

Newton's First Law Module

Objectives:

3a. Memorize how inertia is described. (Remember/Factual Knowledge)
Noun: inertia **Verb:** memorize
Questions: 15(Recognize), 16 (Recognize)

3b. Recall the definition of Newton's First Law. (Remember/Factual Knowledge)
Noun: Newton's First Law **Verb:** define
Questions: 17 (Recall), 18 (Recall),

3c. Identify Newton's First Law in action (Understand/Conceptual Knowledge)
Noun: Newton's First Law **Verb:** identify
Questions: 19, 20

3c. Choose the correct answer that describes Newton's First Law in action. (Apply/Conceptual Knowledge)
Noun: Newton's first law in action **Verb:** choose
Questions: 21

The Knowledge Dimension	The Cognitive Domain						
	Remember						
	Recognize	Recall	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	LO3a. Q Q15, Q16	LO3b. Q17, Q18					
Conceptual Knowledge			LO3c. Q19, . Q20	LO3e. Q21			
Procedural Knowledge							
Metacognitive Knowledge							

Assessment Questions

Remember/Recognize

15. The greater the mass of an object, the:_______

  a. less force it can exert.
  b. more space it takes up.
  c. more balanced it is.
  d. greater the inertia.

16. The tendency of an object to resist any change of motion is ____.

  a. weight
  b. mass
  c. inertia
  d. balance

Remember /Recall

17. An object at rest will remain at rest until an _________ force acts upon it.

unbalanced (Fill in question)

18. Newton's ______ Law states that every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

First (Fill in question)

Understand

19. Which one of Newton's Laws governs when a tablecloth is pulled out from under a set of dishes without damaging them?

    a. First
    b. Second
    c. Third

20. Which law is in control of a spacecraft that is cruising through space at constant speed without using any fuel?

    a. Third
    b. Second
    c. First
    d. None of the above

Apply

21. John slid a block of wood on a table and the block of wood stopped shortly after he released it. Jane poured oil on the table and slid her block of wood and it slid much further than John's block. Which answer choice best explains what caused the difference?

    a. The oil on the table causes Jane's block to speed up.
    b. The oil on the table reduced the amount of friction between Jane's block and the table.
    c. John's block was heavier than Jane's.
    d. Air resistance made John's block stop sliding.

Newton's Second Law Module

Objectives:

4a. Recognize acceleration. (Remember/Factual Knowledge)
Noun: acceleration **Verb:** remember
Questions: 22

4b. Recall Newton's Second Law. (Remember/Factual Knowledge)
Noun: Newton's First Law **Verb:** recall
Questions: 24, 25

4c. Identify Newton's Second Law in action. (Understand/ Conceptual Knowledge)
Noun: Newton's Second Law in action **Verb:** identify
Questions: 26, 27, 28

4d. Choose the correct impact of Newton's Second Law. (Apply/Conceptual Knowledge)
Noun: the formula for Newton's Second Law **Verb:** identify
Questions: 23

The Knowledge Dimension	The Cognitive Domain						
	Remember						
	Recognize	Recall	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	LO a. Q15, Q16	LOb. Q17, Q18					
Conceptual Knowledge			LO3c. Q26, Q27	LO3e. Q28			
Procedural Knowledge							
Metacognitive Knowledge							

Assessment Questions

Remember /Recognize

22. Which statement best describes acceleration? Something that exerts:________

a. a force on another object.
b. a balanced force on another object.
c. an unbalanced force on another object.
d. a force that changes the speed or direction of an object.

23. Newton's Second Law explains how the:________

a. velocity of an object changes when a force is applied to it.
b. mass of an object changes when it is dropped.
c. weight of an object changes when it is in Space.
d. acceleration of an object changes when a drag is applied to it.

Remember /Recall

24. The formula f = ma represents Newton's ________Law?

Second (Fill in Question)

25. Newton's ______ Law relates force to acceleration?

Second (Fill in Question)

Understand

26. Choose the best example of Newton's Second Law in action.

a. A rocket on the launch platform pushing gasses through the sides of a vent.
b. A rocket sitting on the ground preparing for takeoff but it needs an outside force to
overcome its inertia.
c. A rocket exerting a large amount of force because its' acceleration has increased.
d. A rocket slowing down because it is traveling through Earth's atmosphere.

27. Identify what will happen to an airplane when more thrust is added. The airplane will:_____

    a. change direction because of the extra force exerted.
    b. speed up based on the amount of extra force exerted.
    c. continue at the height because of the extra force exerted.
    d. dive towards the ground because of the extra force exerted.

Apply

28. You are pulling a cart down the street when a friend begins to pull in the same direction, doubling the force on the wagon. What happens to the wagon's acceleration?

    a. It quarters.
    b. It doubles.
    c. It halves.
    d. It stays the same.

Newton's Third Law Module

Objectives:

6a. Recognize instances associated with Newton's Third Law (Remember/Factual Knowledge)
Noun: Newton's Third law **Verb**: recognize
Questions: 29, 30, 31, 32

6b. Identify Newton's Third Law in action. (Understand/Conceptual Knowledge)
Noun: Newton's Third Law in action **Verb:** identify
Questions: 33, 34

6c. Determine what action-reaction means when acting between different objects. (Apply/Conceptual Knowledge)
Noun: forces acting between different objects **Verb:** determine
Questions: 35

The Knowledge Dimension	The Cognitive Domain					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	LO6a. Q29, Q30					
Conceptual Knowledge	LO6a. Q31, Q32	LO6b.Q 33, Q34	LO6c. Q35			
Procedural Knowledge						
Metacognitive Knowledge						

Assessment Questions

Remember/Recall

29. Forces always occur in______?

pairs (Fill in Question)

30. Newton's __________Law states, "For every action there is an equal and opposite reaction."

Third (Fill in Question)

Remember/Recognize

31. An example of a balanced force is a:_________

    a. car sliding on ice.
    b. tug-of-war game in which no one wins.
    c. car hitting a telephone pole.
    d. roller coaster going down the first drop.

32. Choose the best example of Newton's Third Law in action.

    a. A rocket taking off from earth pushing gasses in one direction and the rocket in the other.
    b. A rocket sitting on the ground preparing for take-off.
    c. A rocket accelerating through space at a high speed.
    d. A rocket orbiting the earth.

Understand

33. According to Newton's Third Law of Motion, when a hammer strikes and exerts a force on a nail, the nail exerts: _________

    a. an unbalanced force on the hammer.
    b. less force on the hammer.
    c. more force on the hammer.
    d. an equal and opposite force back on the hammer.

34. Why does a rocket take off from the earth when it burns rocket fuel?

    a. The rocket will remain still until the rocket fuel is ignited.
    b. The equal and opposite force from the burning fuel sends the rocket in the air.
    c. The force of the fuel makes the rocket go up in the air.
    d. The temperature of the mixture of fuel causes the rocket to go up in the air.

Apply

35. While driving down the road, a bug strikes the windshield of a bus and makes an obvious mess in front of the face of the driver. This is a clear case of Newton's Third Law of Motion. The bug hit the bus and the bus hits the bug. Which one of the two forces is greater, the force on the bug or the force on the bus?

    a. The bug, because it exerts a stronger force on the bus.
    b. The bus, because it exerts a stronger force on the bug.
    c. Neither because they have equal forces against one another.
    d. The bus, because it is so much larger than the bug.

APPENDIX G

INVITATION FOR PARTICIPATION

Dear Educator,

My name is Gamaliel Cherry, a PhD. candidate at Old Dominion University in Instructional Design and Technology soliciting your school's participation in a research study. The objective of this research project is to attempt to understand the differences between instructional strategies delivered through interactive television. A more in-depth explanation is attached. This research project utilizes NASA's Digital Learning Network to deliver content for approximately six weeks. Through your participation, I eventually hope to understand the difference between the Five E inquiry and didactic lecture-based strategies to further develop best practices for educators who use videoconferencing. Your school must meet the following criteria in order to participate:

1. Participating teachers will have to gain approval from their principals before procedures can begin.
2. Each school will have a technology coordinator facilitating ITV sessions.
3. Each school must have similar science standards required by their respective state authority.
4. Participating classes must have 40 to 60 minutes of uninterrupted time per school week for a six-week period devoted to ITV sessions.
5. Participants must have conducted at least three ITV sessions with a content provider prior to volunteering to participate in the study.
6. Participating classes must have access to a computer laboratory for all assessments.
7. Students' primary instructional method for science instruction cannot be the 5E instructional model.

If you choose to participate, please notify me at gcher001@odu.edu within one week of your receipt of this email. Without the help of people like you, this type of research could not be conducted. Your participation is voluntary and there is no penalty if you do not participate.

If you have any questions or concerns about participating in this study, you may contact me at (757) 223-8426 or at gcher001@odu.edu. If you have any questions about the rights of your students, you may contact the Old Dominion University Institutional Review Board (IRB) by mail at Old Dominion University Office of Research 4111 Monarch Way Norfolk, Virginia 23529, by phone at (757) 683-3460, or by e-mail at. This study (IRB #) was approved by the IRB on ______, 2010.

Sincerely,

Gamaliel Cherry
Ph.Candidate Instructional Design and Technology
Old Dominion University

APPENDIX H

FORMAL RESEARCH STUDY EXPLAINATION

Gamaliel Cherry
MS 309 Langley Blvd
Hampton VA, 23681
225-223-8426
___________, 2010
Re: (Dissertation Study)

Recipient Information

Dear ___________

Thank you for your interest in my dissertation study examining the effectiveness of instructional strategies through videoconferencing. This letter is to inform you of the details involving the study regarding structure, time commitment and content as we have previously spoken about during our phone and email conversations. Students will be exposed to pre and post-tests along with six modules covering Force and Motion concepts. The total amount of involvement will be eight weeks from the pre to post-tests including the instruction beginning on _________, 2010.

Two instruments will be used in conjunction with the study. First, the Science Attitude Index II (More and Foyer, 1987) will be used to gauge learner's interest in science before and after the six week instructional period has begun and ended for pre/post analysis. The SAI II has been widely used in educational research. The second will be a pre/post-test component to examine the students' level of understanding of content matter before and after the instruction. This content assessment is directly related to the instruction covered in the modules and will have no bearing on your student's school achievement metrics from the researcher's standpoint. Both links for the instruments are included below.

Two types of instructional methods will be used in the study. The first method (Control Group) will be traditional lecture with graphics and question and answers. The second method (Treatment Group) will be the same content using the BSCS Five E instructional model. The content covered will be similar between the modules with a difference in delivery methods. Classes will be randomly assigned to either group before the beginning of the first videoconference. All instructional content will be delivered by Caryn Long (DLN Manager) with Karen Ricks (Langley DLN Coordinator) serving as a backup. I will email you to establish a time for a test connection prior to the start of the videoconferencing sessions.

A schedule has been included for your review. Each class will need access to a computer lab to take the pre-assessments prior to the first instructional content module delivered. A link for both instruments will be disseminated to a coordinator at your school for the pre and post tests. You are not required to schedule through the DLN website. I have scheduled all of the sessions with the instructor. Any adjustments due to holidays and times will be adjusted prior to the study beginning and on an as needed basis. All required materials will be mailed at the end of this week along with instructions for the facilitating teacher in the room during each module.

Your school will receive enough NASA bags, lithographs, posters, stickers, pens, and other hand-outs for each student to have one in each class for your participation in the study. Other forms of gratitude are being examined for the staff. All gifts will be mailed at the conclusion of the study.

I look forward to the data that will result from the study in an attempt to improve the quality of services through the DLN as well as other content providers.

Please do not hesitate to contact me if you have any questions, concerns or even suggestions about the study.

Sincerely,

Gamaliel Cherry
225-223-8426
Gcher001@odu.edu

VITAE

Gamaliel R. Cherry

EDUCATION:

May, 2011 — **OLD DOMINION UNIVERSITY**, Norfolk, VA. Doctor of Education (Major in Instructional Design and Technology). Darden College of Education, Old Dominion University, St# 218, Norfolk, VA 23529. Dissertation Title: "Analysis of Attitude and Achievement using the 5E Instructional Model in an Interactive Television Environment"

May, 2005 — **OLD DOMINION UNIVERSITY**, Norfolk, VA. Master of Arts in Education (Major in Instructional Design and Technology). Thesis Title: "Improving Mathematic Self-Efficacy in Middle School Students through the Use of Hand-Held Computers."

December, 2002 — **Elizabeth City State University**, Elizabeth City, NC Bachelors of Science in Education (Minor in General Science). Honors program Thesis Title: "Determining the Most Effective Classroom Management Technique: A Case Study."

EXPERIENCE:

2009-Present Office of Human Capital Management, NASA Langley Research Center.

Responsibilities include: resident instructional design consultant, junior organization development consultant, and executive coaching liaison.

2005-2009 Student Career Experience Program, NASA Langley Research Center.

Responsible for videoconferencing production, training, curriculum development, technical support of onsite computer lab, NASA Explorer Schools videoconferencing help desk contact, hand held computer classroom integration and professional development, film acquisitions for editing, setting up and maintaining workshops between education entities and the office of education.

PUBLISHED PAPERS:

Talley, D., & Cherry, G. (2009). Reaching beyond the conventional classroom: NASA's digital learning network. *Distance Learning*, *6*(4), 1-7.