COMPUTER ANIMATION IN TEACHING SCIENCE: EFFECTIVENESS IN TEACHING RETROGRADE MOTION TO 9TH GRADERS

BY

KRISTIN ELMSTROM KLENK

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KRISTIN ELMSTROM KLENK

APPROVED:

Dissertation Committee

Major Professor __Betty Young__________________________________

__Minsuk Shim___ ________________________________

__Susan Gracia__________________________________

__Glenisson de Oliveira___________________________

RIC: _________Alexander Sidorkin_________________________
Dean, Feinstein School of Education – RIC

URI: _________Nasser Zawia______________________________
Dean, The Graduate School - URI

Abstract

The purpose of this study is to determine whether an instructional approach which includes computer animations is more effective than a traditional textbook-only approach in helping ninth grade students learn an abstract concept, in this case planetary retrograde motion. This investigation uses a quasi-experimental design with convenient sampling. The independent variable is the type of instruction provided to students; traditional text-based instruction (control group) compared to traditional instruction which also includes the viewing of 4 computer animations (treatment). Two conditions of the treatment examine the relative advantage of the order of the presentation of the animations and text-based instruction, as well as the quality of understanding and the retention of the learning over time. The dependent variable is student achievement which is measured using an instrument designed specifically for this study. Comparison of the independent variable to the dependent variable based upon the results from a Repeated Measure Factorial Design in ANOVA indicates that the treatment is an effective instructional technique. The posttest1 mean score of the treatment groups was significantly greater than the posttest1 mean score of the control group. Further posthoc tests indicate that there was no significant difference between the two treatments (1 and 2); read/animation versus animation/read. However, there was a significant difference in the mean score depending on the pathway, students enrolled in the A pathway achieved a significantly higher mean score after the treatment than students in the B pathway. The A pathway ($n = 185$) represent the larger heterogeneous population of students as compared to the B pathway ($n=16$) which includes students with lower cognitive abilities and special needs. When all of

the students are included in the analysis the results indicate that students do not retain their understanding of the concept. However, when the students in the B pathway are removed from the data set the analysis changes, the posttest1 and posttest2 means are not significantly different. Students in the A pathway did retain their understanding of the concept and were able to demonstrate it on the assessment. A detailed item analysis of the multiple choice question suggest that students in the B pathway were much more likely to guess on the multiple choice questions than students in the A pathway who show no evidence of guessing. The outcome of this study suggests that an instructional approach with includes viewing computer animations is an effective strategy for teaching and learning an abstract concept in a ninth grade Earth Science classroom.

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There were also many friends, too many to name, who gave encouraging words of support, usually when most needed. I would like to thank them all; they may not appreciate how much their words of encouragement kept me moving forward. One friend, Barbara Crudale, was especially supportive at all the right times. I would like to thank her for being a terrific friend and PhD coach.

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This dissertation is dedicated to the memory of my parents,
Clarence L. Elmstrom and Margit S. Elmstrom

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CHAPTER 1: INTRODUCTION

Purpose of the Study

For 28 years science reform has been on the national agenda starting with the publication of *A Nation at Risk* (1983). Recently, that call has been revitalized through President Obama's education plan in which Education Secretary Arne Duncan (2009) vows to, "Make math and science education a national priority … work to ensure that all children have access to a strong science curriculum at all grade levels." Traditional teaching methods, based upon text-based learning and teacher lectures, have been ineffective as shown through American students' poor achievement on national tests such as the NAEP and TIMSS (Gonzales, Guzmán, et al., 2004; Santapau, 2001). The purpose of this study is to investigate the question of whether student achievement will improve in science when classroom instruction includes the use of computer visualization as an instructional tool.

Using Visualization in Scientific Research

With the increase of computers in schools, a tool long used by scientists is now readily available for teachers and students to use in classroom instruction. Scientists have been using the concept of visualization for many years, in all types of research, from medicine to atmospheric science, as a tool to unravel complex problems. The invention of sonar and radar in the 1940's immediately improved scientists' ability to perceive the natural world through a technological invention that provides observations not possible to discern with the naked eye or through magnification. Radar and sonar allow scientists to see through the clouds in the atmosphere and peer into the deep ocean; they are examples of technologies used to interpret the environment. Today, oceanographers create models of phenomena such as El Nino, an intricate oceanographic process, using computer simulations based upon complex mathematical models. Graphical models and simulations of El Nino are used to make sense out of numerical data, providing a visual picture of oceanographic changes that occur in the Pacific Ocean during an El Nino event. Computers provide the technological capacity needed to collect and interpret information about the natural world that is not limited by the five senses. Gordon and Pea (1995) believe there is a need to incorporate this type of visualization into science education.

Research on Technology in Schools

Research in the literature investigating student achievement gains when using computer technology is not prevalent, as noted by Songer (2007). Songer promotes the need for a shift in the type of research conducted, from studies focusing on computer access to studies concerning the quality and the character of computer use, as this study addresses.

Research studies investigating access to technology – counting studies (Songer, 2007), program evaluation (Dusewicz et al., 1988), and curriculum evaluation (Cohen, Raudenbush & Ball, 2000; Marx et al., 2004), are prevalent in the literature. Most of the research on computer use in schools takes two forms. The first is based upon evaluation studies of district and school-wide reform initiatives to incorporate technology in schools (Songer, 2007), and the second is evaluating the effectiveness of computer-assisted programs (CAI) such as PLATO™ (Kulik & Kulik, 1991). CAI programs are used for rote learning tasks where the computer is used as a tutor. For example, PLATO™ is used by students needing remediation, outside of the traditional math curriculum, to improve basic math skills. These programs do not examine specific student learning outcomes and achievement based upon the incorporation of computers used as an instructional tool.

In the past, research investigating the relationship between student achievement and technology use has most often taken place at the school-wide or district level (Honey, Culp & Spielvogel, 1999; Conte, 1997; Heinecke et al., 1999), focusing on improvements in student scores based upon standardized tests. Honey et al. (1999) point out that improvement in student learning through the use of technology comes in other forms that are often not measured by standardized tests; therefore, how one defines learning can impact the type of assessment used to measure achievement (Heinecke et al., 1999).

Marx et al. (2004) report an improvement in student achievement in science using an inquiry-based and technology-infused curriculum taught to middle school students in the Detroit public school system. The problem with the Marx et al. (2004) study is that there was no control group. All of the students in the study were taught using the same curriculum. The authors conclude that the curriculum is effective at teaching students science because there was a significant difference in pre and post test scores. However, it appears that this study was testing the ability of students to learn science through a particular curriculum, rather than evaluating student achievement gains using the curriculum since there was no comparison to students who did not use the curriculum.

Recently there has been a shift in the research to a focus on student achievement and instructional materials. Siegle and Foster (2001) found an improvement in student achievement when students used laptop computers to view an Animated Dissection of Anatomy for Medicine (A.D.A.M) in a high school Anatomy and Physiology class. Marbach-Ad, Rotbain & Stavy (2008) also found the use of computer animations to improve student achievement of 11th and 12th grade students learning molecular genetics. Escalada and Zollman (1997) investigated outcomes in student learning and attitudes based upon the use of interactive digital video tools and activities in an introductory college physics classroom. The authors incorporate computer technology into their hands-on inquiry model of instruction. In their study the authors did not find the treatment group, those using the digital video equipment, to outperform the control group. The control group used a traditional inquiry-based physics laboratory experience without the benefit of the video equipment. Escalada and Zollman (1997) believe that the final exam, used in years prior to their experiment, was designed to test for mastery of the material presented, regardless of the experience created by the digital equipment. Thus, it lacked the instructional sensitivity to measure changes in student understanding that might emerge if a more open-ended form of assessment had been utilized.

Research measuring student learning with regard to specific content areas derived from individual classroom instruction using computer technology and constructivist techniques has been found to be more difficult to evaluate because many of the variables in these environments cannot be controlled (Bodilly & Mitchell, 1997). The present study is designed to offer more detailed insight than was found in previous studies by controlling the environment through scripting the treatments used during instruction, limiting the variables to one construct with a control group, and using an assessment that examines high levels of understanding.

Significance of the Study

School districts have ever-increasing constraints on budgets. As such, administrators must be assured of the benefit resulting from the cost of utilizing expensive instructional tools, such as computers and associated technologies. Over the last 25 years school districts have invested in “new technologies” (Cuban, 2001, p. 12) in order to modernize the infrastructure of schools, similar to the revolution that took place in the workplace, and to update instructional practices taking into account the flow of information made available through the Internet. Cuban’s (2001) term “new technologies” refers to the many forms of technology commonly found in schools (e.g., computers, networks and servers, phone systems, video conferencing equipment, cameras, microscopes, overhead LCD machines and Smart Boards™). These forms of technology allow teachers and students to access sophisticated visualization materials, such as computer animations, streaming videos, graphics and pictures.

In order to justify the expense of placing computers in schools, educators have assumed that computers improve student learning especially in the process of learning science. In *Oversold and Underused: Computers in the Classroom*, Cuban (2001) asks if the investment in technology is worth the cost to school districts. Have teaching and learning changed as a result of the infusion of “new technologies?” How do students and teachers use computers in the classroom? These questions merit careful research and evaluation.

This study is important because it adds information to the literature regarding student achievement in science. Educators are looking for ways to improve student understanding of science concepts which are realized through achievement gains. The outcome of this study may further promote the use of instructional strategies using computer animations in the classroom, and provide information regarding student achievement gains for schools districts to review when considering whether to continue investing in technology.

Research Questions

Five research questions are investigated in this study. Students participating in the study represent a convenience sample (Fraenkel & Wallen, 2009) of 9th graders based upon the researcher's access to the student population. Sixteen 9th grade Earth Science classes in the same high school are divided into three groups, control (C), treatment 1 (T_1) or treatment 2 (T_2), using a random number table. Students in the control group are instructed in the content (i.e., Retrograde Motion of Mars) through a traditional method of instruction using a teacher presentation along with a reading from the textbook with a diagram. The two treatment groups are instructed with the traditional teaching methods; however the treatment groups also view four different computer animations visually showing the concept of retrograde motion. The difference between the two treatment groups is the order in which the students see the visualization and read the text.

- Question one: Is the control (text and diagram) less effective than either of the two treatments: read/animation (T_1) or animation/read (T_2)?
- Question two: Which treatment is most effective, T_1 or T_2?
- Question three: Are there differences in the effectiveness of each approach based upon the aptitude of the students?
- Question four: Do the different instructional approaches result in different levels of long-term retention?
- Question five: Are there specific patterns of error evident in the student's understanding of the concept based upon an item analysis of the multiple choice questions?

Summary

This study examines the efficiency of using technology, specifically computer animations, to improve high school student's ability to learn and understand science. Orion and Ault (2007) recommend the use of modern approaches to teaching Earth Science that include visualizations to improve student conceptualization of abstract concepts. This study investigates whether students in 9th grade Earth Science demonstrate greater understanding and more long-term retention of an abstract concept through an instruction approach that includes using four computer animations, compared with the traditional textbook-only approach. Specifically, the study investigates whether computer animations combined with supporting text, increase student understanding of Planetary Retrograde Motion. Additionally, the order effects of using animations and reading about the phenomenon are examined. The underlying assumption is that using computer animations during classroom instruction allows students to visualize an abstract concept that might otherwise be inaccessible using traditional teaching methods, such as reading a textbook, viewing a diagram or hearing a teacher-delivered lecture. Thus, it is hypothesized that students who experience the computer animations describe and retain an understanding of Planetary Retrograde Motion in more depth and detail than students using the traditional textbook approach. The learning differences dependant on the order of presentation remains an open question (Figure 1).

Figure 1.*Research Design*

<table>
<tr><th colspan="5">Research Design</th></tr>
<tr><td>Pre Test
(Prior Knowledge)</td><td colspan="3">Post Test 1
(Instruction)</td><td>Post Test 2
(Retention)</td></tr>
<tr><td rowspan="4">All Students</td><td>Control</td><td colspan="2">Treatment</td><td rowspan="4">1 month later
All students</td></tr>
<tr><td>Read-Diagram
μ_C</td><td>Read-Diagram/View Animation
μ_{T1}</td><td>View Animation/Read-Diagram
μ_{T2}</td></tr>
<tr><td>5 A’s
μ_{CA}</td><td>4 A’s
μ_{T1A}</td><td>4 A’s
μ_{T2A}</td></tr>
<tr><td>1 B
μ_{CB}</td><td>2 B’s
μ_{T1B}</td><td>0; B
μ_{T2B}</td></tr>
</table>

CHAPTER 2: LITERATURE REVIEW

Introduction

In the 21st century it is difficult to imagine the pursuit of scientific knowledge at any level without using technology as part of the process. And in fact, scientists have always used emerging technologies as part of the pursuit of scientific knowledge, but it was not until the second half of the Twentieth Century that technology become available for use in science education at the K-12 level. The integration of technology in education came gradually as school districts slowly invested in new technologies, initially considered a burden on already excessive budgets. Today technology is part of the fabric of schools and as such research regarding the benefits of this expensive component of the school budget is an important part of the literature.

This study is informed by two areas of research; the first is a brief review of the reform movement in science education which speaks to the need for change in methods of instruction, and the second is a compilation of studies investigating the effectiveness of integrating technology into education to improve student learning.

Research on Science Education

Conceptual Learning in Science

According to Abell and Lederman (2007) a principal goal of science education research is to improve teaching and learning. The questions asked by researchers must reflect the issues and concerns of teachers, as well as students, to meet this goal, and ultimately the findings from the research needs to be translated from theory into practice. The conceptual change research tradition has a long and influential history in the science research community, tracing its roots back to the developmental work of

Piaget who questioned how students make sense of the world. Anderson (2007) begins a conversation about science literacy and research by asking two questions: "Why don't students learn what we are trying to teach them?" and "Why does the achievement gap persist?" (p. 5), where the achievement gap refers to the differences in achievement found between students from different ethnic background, socio-economic status and gender.

Snir, Smith & Raz (2003) designed a study based upon the conceptual change tradition to investigate the misconceptions that students from a 5th and 6th grade science class face when learning about the model of matter. The data from this study showed that students in the experimental group, those who used a computer simulation program, understood the concepts presented and retained their knowledge better than students in the control group. In general, conceptual change research begins to answer the first question. Students fail to learn what is taught because they come to school with prior knowledge and the school setting does not change student misunderstandings through the taught curriculum (Anderson, 2007). The research findings of Snir et al. (2003) provide productive answers to questions regarding how to improve student learning of abstract concepts which have been muddied by the learner's prior conceptual framework, as well as methodological tools to follow to improve student learning.

Scott, Asoko & Leach (2007) build on this work by reviewing research that suggests answers to the question posed by Anderson (2007), "Why don't students learn what we are trying to teach them?" Scott et al. (2007) describe a scenario where a student struggles with her conceptual understanding of the concept of energy as it relates to her everyday experiences, as opposed to the scientific meaning of the conservation of energy. Theoretically, her lack of understanding originates from her inability to make meaning of the scientific viewpoint. Individually, she is not creating the correct mental model based upon her prior learning. Teaching science content out of context limits a student's ability to "think scientifically" and make sophisticated meaning of the content.

Sfard (1998) proposed two different metaphors to describe conceptual learning; acquisition and participation, where acquisition refers to "the idea of learning as gaining possession over some commodity" (p.6), and commodity is a concept which is stored in the learner's head. The second metaphor participation suggests that "[L]earning a subject is now conceived of as a process of becoming a member of a certain community" (Sfard, 1998, p. 6). In the second metaphor learning takes on a more social context which views learning from two different perspectives, one focuses on the individual learner and the other on the "social aspects of the learning process and of knowledge itself" (Scott et al., 2007, p. 33). Scott et al. (2007) suggest that while the research to date on how students learn science is extensive, the challenge for the future is to translate that research to practice suggesting that the instruction of science needs to change to mirror our understanding of how students learn science.

Learning Earth Sciences

Orion and Ault (2007) present a review of the current teaching practice used to instruct students in Earth Science and propose a paradigm shift from the traditional teaching method to a holistic approach to teaching Earth Science. The holistic approach incorporates a systems view with constructivist learning rather than the traditional discipline-centered method. Many obstacles stand in the way of reform, most especially teacher beliefs about instruction and teachers' lack of background in the field of Earth Science.

Earth Science is a multi-disciplinary subject, but the content is often taught in isolation without making the appropriate connections necessary for deep understanding. Teaching Earth Science requires students to "learn about complex systems on many scales in time and space" (Orion & Ault, 2007, p. 655) which presents obstacles to student understanding. Instructional practices that do not allow students to form connections result in numerous misconceptions about the earth system. One example is the water cycle. The authors investigated teaching practice concerning the water cycle and found that most teachers concentrate on the atmospheric component (i.e., evaporation, condensation, precipitation) without including the ground water aspect and the biological aspect (i.e., plant transpiration). The outcome is that students develop an incomplete, simplistic understanding of the water cycle, lacking the connections necessary to understand the environmental aspects that affect the community.

Traditionally Earth Science has not been given the same weight in the curriculum as physics, biology and chemistry. The importance of individuals developing a basic understanding of the Earth system is being recognized within the scientific community as indicated in *Science for All Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993). Orion and Ault (2007) suggest that "citizens with knowledge of earth sciences clearly have some capacity to choose (or hold leaders accountable for choosing) policies in light of their consequences for earth systems and for society to exist in profitable harmony with earth resources" (p. 658).

Misconceptions about the earth system are found worldwide in all age groups, kindergarten through college, and cultures across the world where research has taken place. The research indicates both teachers and students often have a weak understanding of the complex interactions that take place within the earth system. Geospheric change, the Earth's interior, geologic deep time and the hydrosphere are four areas where misconceptions occur. Montagnero (1996) found a difference in the ability of high school (9^{th} grade) students and middle school (7^{th} grade) students to understand geologic phenomena through "diachronic thinking" where diachronic thinking is defined as the capacity to represent transformations over time.

Curriculum has been developed to improve the way students learn Earth Science. "The Blue Planet" is an example of a curriculum developed to teach the water cycle based upon a "design research" model. Design research requires that " the study of learning takes place in the context of designing and revising curriculum material based upon careful study of student response to these materials" (Orion & Ault, 2007, p. 675). Students who participated in "The Blue Planet" program did not develop a comprehensive understanding of all aspects of the water cycle, which the Orion and Ault (2007) suggest is due to instruction of the curriculum. Teachers did not use activities that promote systems thinking which resulted in the lack of student understanding. The authors suggest that teachers need to change their approach to teaching earth science, their goals for student learning, and the content of curricula in order for students to effectively learn about earth systems.

Digital Resources versus Cognitive Tools

Songer (2007) investigates the use of technology as a cognitive tool in the science classroom and provides examples of how technology can be employed to improve student learning. The research to date indicates that while technology is ubiquitous in classrooms, it is still underutilized. The author points out that most of the research has focused on counting studies, or how available technology is in classrooms, and not how the technology is used to improve learning. Technology can be used in three different roles to improve learning, including improving reasoning ability (e.g. WorldWatcher); the development of explanations (e.g. Explanation Constructor) and reflection (e.g. WISE). The author suggests that "[s]hifting the research on technology from counting studies to quality and character of use is a major undertaking and shift in research emphasis" (Songer, 2007, p.474).

The use of technology is divided into two distinct ways, first as a **digital resource** and the second as a **cognitive tool**. A Digital Resource is defined as "any computer-available information source containing facts, perspectives, or information on a topic or interest" (Songer, 2007, p. 475). A Cognitive Tool "is defined as a computer-available information source or resource presenting focused information specifically tailored for particular learning goals on a particular topic of interest for learning by a particular target audience" (Songer, 2007, p. 476). The author compares the two constructs on the basis or three areas, audience/knowledge, learning activities, and learning performance. By using these three components Songer proposes a method for transforming a Digital Resource into a Cognitive Tool for the purpose of enhancing the learning experience and increasing student understanding of the science construct being taught.

Four areas of scientific knowledge are considered to be enhanced through the appropriate use of technology: critical thinking, communication of scientific ideas, creating explanations from evidence, and gathering, analyzing and interpreting data. Each area is linked to a specific technology. Models, simulations and visualization tools can enhance critical thinking, online critiques help students communicate their own ideas more effectively, online scaffolding tools provide opportunities to formulate scientific explanations from evidence and computer-based data collection help students gather analyze and interpret data. Songer (2007) suggests that research in technology should move away from counting studies and delve into research about how teachers use technology to improve the quality of science education.

General Instructional Methods and Strategies

Research on student learning indicates that specific instructional strategies can promote student understanding of scientific content (Anderson & Helms, 2001: Duit & Treagust, 1998). Treagust (2007) investigates the use of six instructional strategies used in the science classroom: demonstrations, classroom explanations, questioning, forms of representations, group and cooperative learning, and deductive-inductive approaches. These six approaches range from teacher-centered on one end to student-centered on the other.

According to Treagust (2007), for over a century demonstrations have been a mainstay in the science classroom mainly due to the simplicity of the instructional strategy. Demonstrations are prepared by the teacher, require a minimum of expense, and are safe ways to illustrate scientific principles. However, the research indicates that demonstrations do not directly improve a student's understanding of science (White, 1996). Demonstrations do develop student motivation to learn due to their "colorful, surprising, or dramatic effects – such as burning a piece of magnesium ribbon" (Treagust, 2007, p. 375). A Predict-Observe-Explain (POE) instructional strategy used with demonstrations has been found to enhance student learning through a more student-centered approach (Champagne, Sunstone, & Klopfer, 1985; White & Gunstone, 1992; and Gunstone, 1995). Recently, the use of technology in science classrooms has been found to improve student understanding of genetic reasoning (Tsui & Treagust, 2003); and principles in chemistry (Kozma, 2000). Instructional strategies that incorporate POE with computer simulations "foster classroom social interactions conducive to co-construction of knowledge (Treagust, 2007, p. 376).

A teacher's ability to effectively explain scientific concepts through words is an important component of learning science (Yore, Bisanz & Hand, 2003). Teacher's employ both deductive and inductive strategies when explaining certain phenomena and often make pictures through words and gestures. Ogborn, Kress, Martins & McGillicuddy (1996) considered four roles of making meaning through language in the science classroom: (1) creating differences, (2) constructing entities, (3) transforming knowledge and (4) putting meaning into matter. The first two roles use deductive reasoning while the last two use a combination of inductive and deductive reasoning (Treagust, 2007).

Questioning is another instructional strategy that has a long history in the science classroom. Research on questioning has shown that wait time is an important component when using this strategy effectively (Rowe, 1974). Also the types of questions used by teachers and the way teachers use questions impact student understanding. Lemke (1990) found that questioning beyond the triadic dialogue is necessary to stimulate higher order thinking. Teachers who initiate a dialogue among students which includes student questioning along with teacher questions promote higher order thinking in the classroom.

Scientific phenomena are often beyond the student's ability to visualize in both time and space (Kozma, 2000). As a result the science teacher needs to make use of representations that allow students to access these abstract concepts through the use of models, pictures, diagrams and simulations (Treagust, 2007). Another complication is scale; many scientific phenomena take place on the macro or micro scale which is not directly visible to students. Teachers need to be cognizant of the difficulties students face when learning abstract concepts typical in fields such as chemistry.

Inductive and deductive reasoning are used by practicing scientists and are both components of effective science instruction in the classroom. Deductive reasoning (i.e., cause to effect, or if-then) is used more often in the science classroom while many scientists use inductive reasoning (effect to cause) in experimentation (Treagust, 2007). Introducing inductive reasoning in the science classroom dates back to the late 1950's with the Learning Cycle Approach designed by Robert Karplus through the Science Curriculum Improvement program (Abraham & Renner, 1989). The research indicates that the inquiry-based approach provides students with authentic opportunities to think and work like scientists while constructing their own knowledge (Abraham, 1998).

Summary

The research on science education provides important findings about how students learn science through new initiatives related to classroom practice, theories of learning, and teacher instruction. Implementation of innovative curriculum and measurements of assessment are an important part of the process to improvement science literacy for all students. The goal of science research is to improve science learning (Abell & Lederman, 2007) which is measured through various tests such as TIMMS and PISA, at the worldwide level, and the New England Collaborative Assessment Program (NECAP) at the local level. The data from these tests are used to make claims about scientific literacy. While the research separates studies related to three themes; teaching, learning, and curriculum and assessment, the topics are interrelated when analyzing the overall effectiveness of science education to promote scientific literacy. Several outcomes are apparent from the research such as the continuous need for teacher professional development along with the need to translate the positive findings from the research literature into practice in the classroom.

Scott, Asoko & Leach (2007) suggest that while the research to date on how students learn science is extensive, the challenge for the future is to translate that research into practice, meaning instruction of science needs to change to mirror our understanding of how students learn science. Computer simulations are being used more frequently in the science classroom as both the technology and the simulations have become more available to teachers, even though the research indicates that technology is still underutilized in the science classroom (Songer, 2007). The findings of the research suggest that the use of representations such as computer simulations, models and graphics to teach abstract concepts improve student understandings.

Research on the Integration of Technology in Education

Historical Context in Schools

The words technology and computer are often used as synonyms in the education literature, however, technology is a much broader term than computer; its roots go back to the Greek word "tekhnologi", meaning the systematic treatment of an art or craft. The word has evolved from its original connotation to mean the application of knowledge, resources and tools in designing products for a practical purpose, often linked to a commercial or industrial objective. Technology refers to more than just a computer. Cuban's (2001) term "new technologies" refers to the many forms of technology commonly found in schools, such as, computers and their respective networks and servers, phone systems, video conferencing equipment, cameras, microscopes, overhead LCD machines and Smartboards™. Computer, on the other hand, is a word that refers specifically to a sophisticated device that computes. It is a programmable electronic machine that is used to perform calculations and process information.

Over the years, the computer has gone through a series of changes before reaching the version familiar to so many homes, work places and schools today. The computer that is confused with "technology" is really one type of technological device. Prior to the creation of the small personal computer, computers were large cumbersome machines known as "main frames." They were expensive and mainly found in institutions and businesses. Technological advances in the 1970's reduced the size of the computer, along with increases in speed, efficiency and improved performance, the cost to the consumer decreased. Suddenly the computer became a commodity that the average person could buy (Molnar, 1997). By the 1980's, computers were cropping up in schools on a limited basis, with an average of 125 students to one computer in 1981, compared to 5 students per computer in 2000 (Cuban, 2001).

The use of computers in the K-12 school setting lagged behind their use in higher education, especially in science and engineering departments. The American participation in the Cold War and the launching of Sputnik by the Russians in 1957, spurred government action and the initiation of what Molnar calls the "golden age" of education reform (1997, p. 2). A major shift in the philosophy of education at the national level changed how government viewed and sought to influence educational practices in schools. While reform in education is not a new idea, dating back to Dewey and the Progressive movement of the 1920's, government intervention in educational reform was new. Technology was introduced into educational reform in the 1960's along with the science reform movement, beginning with Bruner (1960) followed some years later with the publication of the *National Science Education Standards* (1996). The *National Science Education Standards* (1996) drew heavily on the work of Rutherford and Ahlgren (1990) who outlined the need for science literacy in their book *Science for All Americans*. Inherent in the science reform movement is the need for technology integration in the teaching of science and mathematics.

The dawn of the "computer age" in the K-12 school setting begins when small personal computers like the Apple 1, and somewhat later, the IBM PC's began appearing in schools. The practices involved in the early use of these computers in schools evolved from instructional strategies originating in the field of educational technology. Researchers in the field of educational technology developed a "systems approach" to education based on the idea of cybernetics (Romiszowski, 1970, p. 11). Romiszowski (1970) defines cybernetics as an "interdisciplinary approach to problems of control and organization in exceedingly complex probabilistic systems" (p. 18) where probabilistic means a system that does not behave in a predictable way, given the environmental conditions at work within the system. Romiszowski (1970) believes that the educational system responds according to this principle. James Lovelock (1979) says, "the primary function of many cybernetic systems is to steer an optimum course through changing conditions towards a predetermined goal" (p. 44). In the case of the educational system, the predetermined goal is learning which is measured through a student's achievement.

By 1980, the use of computers in education had evolved in three distinct directions that Taylor (1980) describes as tutor, tool and tutee. The tutor and tutee modes were considered to be the most useful for education and the direction that computer use in schools should take. The use of the computer as a tool itself was considered important, but not as important in the actual process of teaching, a view that changed in the ensuing 20 years.

The tutor and tutee functions evolved from the educational technology instructional method of "programmed instruction" and computer-assisted instruction (CAI) (Suppes, 1980, George, 1970). Donald Bitier designed PLATO™, in 1959, at the University of Illinois. PLATO™ was the first CAI program created to use the computer as a tutor in an educational setting (Molnar, 1997). Patrick Suppes (1980), an innovator in CAI, developed drill-and-practice computer programs in the early 1960's at Stanford University, to supplement teacher instruction in mathematics at the elementary level. He also developed tutorial systems to help students understand new concepts.

Using CAI a student individually interacts with the computer in a dynamic environment, using graphics, and word problems (Taylor, 1980). The student is able to control the pace of their learning in an individualized environment (Bork, 1980) which from a curriculum standpoint is based upon the behaviorism frame. This process conceptually connects to the idea of cybernetics and the self-controlling system regulated by positive and negative feedback in the interaction between the student and the computer program. PLATO™ has survived the test of time and is used in many schools as a supplement to the traditional curriculum, especially for students who require remediation in mathematics.

Most people are familiar with using the computer as a tool. In the early days of computer integration in schools, the tool mode stood out as the most practical function of the machine at the administrative level. Word processing quickly replaced type writers, spread sheets and data processing programs took over the process of scheduling students, processing payrolls, and conducting other administrative chores in schools. However, the tool function was not operating in the classroom, and while it was considered a useful function it was not considered a teaching tool. This was prior to the rise of the Internet and the information overload that accompanied this new technology.

Using the computer as a tutee requires students to learn to talk to the computer in its own language (Taylor, 1980) and as such is based upon the structural cognitive curriculum frame. Taylor (1980) sites the work of Dwyer, Luehrmann & Papert, in the book *The Computer in the School: Tutor, Tool and Tutee,* as innovators in designing instructional materials that use the computer as a tutee. The authors believed that the tutee format allows students to change the way learning occurs and move beyond the lecture format where children are disassociated from the learning process. Papert (1980) designed the language LOGO™ to teach children to be mathematical using higher order cognitive processes rather than simply using the computer to reinforce basic mathematical skills.

Initially, technology came into schools with a focus on hardware, the equipment. The idea was to get the computers into the schools along with the networks and wiring needed to connect the schools to the Internet. There was very little thought to how the computers would be used (Bork, 1997). Software like the type developed by the early CAI innovators (Taylor, 1980) is very expensive and not commonly found in schools. Most software purchased for computers in schools is the type that comes with the system, such as Microsoft Office™. This software uses the computer as a tool rather than as a tutor or tutee. The tutee and tutor function are not commonly found in the daily school setting today, at least not at the high school level.

According to Cuban (2001), "after twenty years of heavy promoting, serious investments of funds, and unswerving support from a disparate coalition of parents, corporate executives, public officials, and educators, computers are ubiquitous in schools" (p. 176). Today the computer is mainly used as a tool in the school setting.

Cuban believes that the costs to date have not justified the means required to modernize the infrastructure of schools. A second interpretation is the cost to school districts had to be incurred to modernize the antiquated infrastructure of schools and upgrade the archaic business of schooling. The question to be addressed in this review is whether the literature supports the hypothesis that student learning improves through the various uses of computer technology in the school setting, and this improvement is reflected in student achievement gains.

Methods: Types of Research Reviewed

Fifteen studies encompassing a nineteen year period from 1986 to 2005 are analyzed using a qualitative narrative methodology (Table 1). In order to be included in this review of the literature the study had to provide specific evidence about student achievement which was associated with some type of technology use within the school setting. Program evaluations and policy papers were not included. Papers were culled from the research base via the search engine Google™ scholar using the following keywords: computers and student achievement, or technology and student achievement.

The papers are organized into two categories, the first is the type of paper and the second is based on subject matter. There are two types of papers, individual studies and meta-analyses. Meta-analysis refers to the methodology first proposed by Glass (1976) which combines the outcomes of a large number of studies through a statistical analysis in order to provide a picture of the various outcomes relating to a defined problem. The statistical analysis produces a variable called "effect size" which is defined by Glass, McGaw & Smith (1981) "as the difference between the mean scores of two groups divided by the standard deviation of the control group" (Kulik & Kulik, 1991, p.78). One group is the control group and the other is the treatment. Effect sizes are then related to the standard deviation of a norm referenced assessment such that a .30 effect is equivalent to a move from the 50th percentile to the 62nd percentile (Kulik & Kulik, 1991).

TABLE 1: *Fifteen papers on the integration of technology in schools.*

Author	Type of paper	Subject	Findings
Bayraktar, S. (2002)	Meta-analysis quantitative	CAI	Positive
Christmann, E. and Badgett, J. (1997)	Meta-analysis quantitative	CAI	Positive
Christmann, E. and Badgett, J. (1999)	Meta-analysis quantitative	CAI	Positive
Cotton, K., (1991)	Meta-analysis qualitative	CAI/CBI	Positive
Escalada, L. T. and Zollman, D. A. (1997)	Single study	Digital video use in Physics	Negative
Fuchs, T. and Wobmann, L. (2005)	Single study	Computer use at home and school	Negative and Positive
Goldberg, A., Russell, M., & Cook, A. (2003)	Meta-analysis quantitative and qualitative	Computer use and student writing	Positive
Hopson, M.H., Simms, R.L., & Knezek, D.A. (2002)	Single study	Developing higher order thinking skills	Positive
Johnson, R.T. Johnson, D.W. & Stanne, M.B. (1986)	Single study	CAI	Positive
Kulik, C.C. and Kulik, J.A., (1991)	Meta-analysis quantitative	CAI/CBI	Positive
Mann, D., Shakeshaft, C., Becker, J., & Kottkamp, R. (1999).	Single study	Basic skills/computer education	Positive
Marx, R., Blumenfeld, P., et. al., (2004)	Single study	Inquiry science and computers	Positive
Schacter, J. (1999)	Meta-analysis	Impact of technology	Positive
Siegle, D. and Foster, T. (2001).	Single study	Using laptops in science	Positive
Wenglinsky, H. (1998).	Single study	Technology in math	Positive

The subject matter category is varied, including papers that analyze the effects of Computer Assisted Instruction, CAI, the use of computers in mathematics, using laptops in a science classroom, cooperative groups and computer use, computer availability in schools and the home setting, writing using a computer and developing higher order thinking skills through computer use (See Table 1). Seven of the papers included are meta-analyses, both quantitative and qualitative, with five of the meta-analysis papers based on the analysis of Computer Assisted Instruction, CAI and/or CBI, Computer-based Instruction. According to Cotton (1991) CBI is a broader category than CAI, referring to "any kind of computer use in educational settings, including drill and practice, tutorials, simulations, instructional management, supplementary exercises, programming, database development, writing using word processors, and other applications (p. 2)." CAI is a narrower term most often referring to drill and practice or tutorial type applications. The two other meta-analyses fall into one of the other subject categories including effects of computers on student writing, gender variations and overall student achievement. The eight other papers are based on individual studies corresponding to a variety of the subjects mentioned above.

This review is different from many of the meta-analyses found in the literature because at least six applications of computer technology other than CAI are identified and compared. The compilation of data from a broad array of technology applications provides a better interpretation of the effects of computer technology on student achievement in the school setting than that represented solely by CAI.

Results: Findings from CAI meta-analysis studies

Five papers, based on meta-analyses of CAI and CBI, are reviewed in this study, and in each case positive findings were reported. In a large meta-analysis of 254 papers Kulik and Kulik (1991) found an average positive effect size of .30 for students using CAI and CBI, indicating a change from the 50th to the 62nd percentile in achievement for students in all ages from kindergarten to adult which is considered a moderate, but significant effect. The effect size varied among the various studies included in the meta-analysis, but overall there was a positive correlation between effect size and higher student achievement related to post-treatment assessment. Cotton (1991) reported positive findings from a qualitative study of 35 papers using CAI and 24 papers using various other types of computer instruction methods reflecting broader applications of the technology. In general Cotton (1991) suggests "[t]he single best-supported finding in the research literature is that the use of CAI as a supplement to traditional, teacher directed instruction produces achievement effects superior to those obtained with traditional instruction alone (p. 3)." CAI improves student's writing ability, learning rate, and retention of material for students of all ages and settings. However, the benefits are more for younger students, decreasing with the age of the student. The impact decreases from elementary to post-secondary. CAI is more beneficial for lower achieving students and students from economically disadvantaged homes and CAI works better when reinforcing lower cognitive outcomes than higher order material.

Christmann and Badgett (1997) found a very small positive effect size of .187 in a meta-analysis of 26 papers from a 12 year longitudinal study involving students in

6^{th} to 12^{th} grades, representing various educational settings and subject areas. The study compared students using traditional curriculum to students using traditional curriculum along with CAI. In a second meta-analysis of 11 papers Christmann and Badgett (1999) evaluated student achievement in science across subjects; general science, biology, chemistry and physics in three educational settings, urban, suburban and rural. A positive finding was again reported with an effect of .266, indicating students using CAI out performed 60.4 % of students using only traditional instruction which correlates to an increase from the 50^{th} percentile to the 60.4^{th} percentile based on the graphical interpretation of average effect in SDx units of Wolf (1986). However, greater gains were found in general science and biology than physics, where little to no gain was noted.

The last CAI study derived from a compilation of 42 papers reviewing secondary and college science education in a longitudinal study conducted between 1970 and 1999 also reported an overall positive effect size on student achievement (Bayraktar, 2002). This study provided evidence of an average .273 effect size, indicating a move from the 50^{th} to 62^{nd} percentile range. This is considered to be a small positive effect. The study indicates that the most effective use of computers in science is for simulations and tutorial purposes, and also found CAI to be more effective when used by an individual student and as a supplement to learning, not as a substitute to traditional instruction.

Findings from other meta-analyses

Two other meta-analyses are included in this paper. Schacter (1999) analyzed five large scale studies using a narrative approach to determine the impact of technology on learning in schools. In each case, the overall finding indicated that the inclusion of technology produces a positive correlation with increased student achievement, suggesting that students who have access to computer technology show positive gains in achievement. However, there is some evidence to indicate that when the learning objective is not clear to begin with, the use of the technology is not as effective. Teacher professional development plays an essential role in the effective use of technology.

Goldberg, Russell & Cook (2003) conducted a combined quantitative and qualitative meta-analysis of 26 studies from 1992 to 2002 comparing student's ability to write using computers versus pencil and paper. An effect size of .50 for quantity of writing and .41 for quality of writing was reported equating to an achievement improvement of 0.40 of a standard deviation. The study suggests computer use engages and motivates students more in the writing process with the outcome of greater quantity and better quality of writing. Larger effects on middle and high school students than elementary age students are reported. Using computers makes writing a more social process for students and students tend to engage in the revision process while writing. Results indicate computers are a valuable tool for helping students to develop writing skills.

Findings from Single Study Papers

Eight single study papers are included; each study is unique in the methodology employed and the subject matter studied regarding technology and student achievement. In an early paper Johnson, Johnson, & Stanne (1986) compared computer-assisted cooperative, competitive, and individualistic learning situations versus student achievement, as well as, gender differences within the three groupings. The findings suggest that computer-assisted cooperative learning was beneficial to both male and female students, promoting higher daily achievement, improving higher order reasoning skills and complex problem solving while engendering greater success in operating a computer. The authors also noted that the status of female students increased in the cooperative groups when using the technology.

Escalada and Zollman (1997) investigated the "effects on student learning and attitudes of using interactive digital video tools and activities in an introductory college physics classroom" (p. 472). The treatment group incorporated computer technology into their hands-on inquiry model of instruction while the control group used a traditional inquiry based physics laboratory experience without the benefit of the video equipment. The authors did not report gains in student achievement based upon the treatment, they were not able to state that the treatment group, those using the digital video equipment, performed better than the control group.

In a large national study Wenglinsky (1998) reported on the impact of technology and mathematics achievement based upon student scores from the National Assessment of Educational Progress (NAEP) analyzed using the statistical method of structural equation modeling. Wenglinsky (1998) controlled for socioeconomic status, class size and teacher characteristics resulting in a relationship between technology and achievement that represents the value added by technology. The results suggest that "technology does matter to academic achievement, with the important caveat that whether it matters depends on how it is used" (Wenglinsky, 1998, p. 34). When computers are used by students to apply higher order concepts in combination with teachers who are confident users of the technology and keep students on task, student achievement improves at both the fourth and eight grade levels in mathematics. Another finding of this study is that teacher professional development is positively related to student achievement in mathematics at the eighth grade level. Home use of computers by eighth graders also correlates positively to mathematics achievement; however, the opposite is true at the fourth grade level.

Mann, Shakeshaft, Becker, & Kottkamp (1999) investigated the impact of technology use in West Virginia elementary schools. The authors analyzed the achievement of students taking the Stanford-9 state exam after students participated in the statewide West Virginia Basic Skills/Computer Education (BS/CE) program. The results show that achievement scores rose 11 % which was attributed to student participation in the BS/CE program, however, greater gains occurred for students who did not have computer access at home.

Siegle and Foster (2001) studied the use of laptop computers in a high school science class. The authors provide evidence to support the use of presentation software, PowerPoint™, as well as, Animated Dissection of Anatomy for Medicine, A.D.A.M. software in a high school Anatomy and Physiology class. Student achievement increased during the time that the computers and software were available to students for use in the class and at home. This study is limited in its overall generability due to the small sample size located in a rural setting.

Hopson, Simms, & Knezek (2002) provide evidence that sixth grade students taught in a technology rich environment show a significant difference in their ability to evaluate based upon the Ross Test of Higher Cognitive Processes than comparable students in a non-technology-rich environment. Students in the technology-rich environment scored higher on the test in the evaluation category than did students in the control environment. The data also showed an increase in the mean scores for student's ability to synthesize and analyze but these results were not significant at the $p < 0.01$ level using ANOVA. The findings suggest that a technology-rich environment improves student's higher order thinking skills.

Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, (2004) conducted a study of nearly 8000 middle school students in the Detroit school system as part of a larger program called the Center for Learning Technologies in Urban Schools (LeTUS). The authors designed 4 curriculum units that employed science inquiry and used technology with each unit. The results show that there is a reliable gain in achievement using a pre and post test methodology. The findings suggest that students from an urban setting benefit from a curriculum designed to teach science using inquiry and technology.

The last paper included in this review is a large international study based on bivariate and multivariate analyses of data collected using the Program for International Student Assessment (PISA) data base (Fuchs & Wobmann, 2005). The authors found conflicting findings based on the statistical analyses of the data with respect to computer availability at home and at school. Bivariate analysis indicates a positive correlation between student achievement and student's availability of computers at home; however, once family-background influences are controlled for using multivariate analysis, the positive correlation becomes statistically insignificant. The same phenomena occurred when school characteristics were controlled for when comparing computer availability in schools with student achievement. As soon as the school characteristics were included in the multivariate analysis, the positive correlation between student achievement and computer availability in schools became negligible.

The authors evaluated computer use as well, and found that students who use the Internet, email and educational software at home on a regular basis performed significantly better in math and reading than those who do not. However, a non-linear relationship exists between student use of the Internet at school and achievement. Students who hardly ever use the Internet achieved lower than students who use the Internet occasionally, but as Internet use increased at school student achievement decreased.

Discussion

A synthesis of the results gathered from 15 studies investigating the use of computer technology in schools and its effect on student achievement is presented in this review. Overall, the findings suggest that when students use computer technology in schools there is a positive correlation to improved student achievement. However, there are some negative findings as well, suggesting that the availability of computers alone is not enough to improve student achievement (Fuchs & Wobmann, 2005) and in certain applications technology may not produce a noticeable gain in student outcomes (Escalada & Zollman , 1997). The data indicate that the way computers are used in schools and teacher confidence in using technology are also important components and need to be analyzed when determining the effects of computer technology in the school setting.

The objective of this review is to analyze a group of studies conducted over a 25 year period representing a time of change in schools relative to the use of technology. The oldest study by Johnson et al. dates back to 1986, when computers were rarely found in schools, compared to the youngest study by Fuchs and Wobmann (2005) which reflects the present day. During this nineteen year period computers became ubiquitous in schools with an increase in computer availability from one computer for every 125 students in 1981, to 5 students per computer in 2000 (Cuban, 2001). Not only did computer availability increase in schools, the information explosion, associated with the development of the commercial Internet occurred during the same time period (Leiner, Cerf, Clark, Kahn, Kleinrock, Lynch … & Wolff, 2003).

The earliest use of computers in schools used the computer as a tutor as is discussed in the CAI literature. Effect size data from five meta-analyses and two single study papers indicate that the use of computers as a tutor improves student achievement, especially when used with low achieving students and students from lower socioeconomic status as well as for reinforcement of basic skills with students of all abilities (Christmann & Badgett, 1997, 1999; Cotton, 1991; Kulik & Kulik, 1991). CAI instruction is also beneficial when teaching writing to students, improving both the quality and quantity of student's writing (Goldberg, Russell, & Cook, 2003). While the effect size is not large in some of these studies, varying from a low of 0.186 (Christmann & Badgett, 1997) to a high of 0.5 (Goldberg, Russell, & Cook, 2003), the combined effects of these findings suggest that CAI is correlated to improved student achievement when used for specific tasks.

Eight other individual studies investigated various uses of computer technology in schools. The findings from these studies are not as conclusive as the CAI studies although the overall findings tend to indicate a positive correlation with student achievement gains. The single study papers analyzed the use of computers for tasks that require higher order thinking skills rather than lower order skill building tasks. In separate studies, Hopson et al. (2002)) and Marx et al. (2004) both found computer applications beneficial to student achievement in science when students were exposed to curriculum delivered in a technology rich environment. Escalada and Zollman (1997) however, did not find a positive correlation to student achievement when physics students used digital video equipment to enhance the curriculum in an entry level physics course. A close reading of Christmann and Badgett (1999) also suggests that using CAI did not improve student achievement in their meta-analysis of physics curriculum enriched with CAI. Christmann and Badgett (1999) noted a positive effect for both biology and general science, but not for physics. This suggests that computers may be more beneficial in some subjects than others. However, a limitation to the Escalada and Zollman (1997) study is that the end of course assessment was not modified from years past; therefore it did not assess the types of higher order skills students may have improved upon through the use of the technology. Escalada and Zollman (1997) believe that the final exam was designed to test for mastery of the material presented, regardless of the experience created by the digital equipment.

The push to make computers available in schools has led to research focused on computer availability and student achievement. Fuchs and Wobmann (2005) found that after controlling for family background and school characteristics the positive correlation between student achievement and computer availability in schools became negligible. However, the way that students used computers was related to achievement. Students who used the computer to communicate and acquire information performed better than students who do not use computers on a regular basis in either the school or home setting. The interesting point about this study is the data indicates that students who use the computers too frequently at home and school show a decrease in achievement, suggesting that using the computer as a toy may distract from academic achievement. One of the short comings of this study is that the data source for student use of computers is based upon student self report which may be biased.

The way students use computers at home and school has evolved during the nineteen year period addressed in this review. Early data using CAI was based upon a purely academic interaction between the computer and the student. Today computers are used in many ways: to communicate through email, chat rooms, and web pages such at Face Book; as a home shopping alternative; and to provide information about any topic through an array of web sites, some more reliable than others. In fact, students must learn how to filter through the vast amount of information available to them through the Internet, a task requiring higher order cognitive skills. Students who use computers at home are not necessarily using the technology for purely academic reasons, as was more often the case in the past. Therefore, the availability of computers may not be the best measure to compare against student achievement.

Summary

Computers and technology in schools are here to stay. The questions for the future are what are the best applications of the technology in schools, and how should computers be used in ways that justify the cost to school districts to maintain and upgrade these new technologies? Research to date indicates that appropriate use of technology in schools is beneficial to student learning as is reflected in student achievement gains. Teacher professional development is also an important component to effective use of technology in schools (Wenglinsky, 1998). Gerard, Varma, Corliss et al. (2011) found that student achievement in science inquiry significantly improved when teachers participated in professional development that lasted longer than one school year, and focused on a constructivist-oriented learning process while also considering the use of technology in the curriculum. Teachers who participated in technology-tool-oriented professional development were not successful at distinguishing good use of the technology from inefficient use. This type of professional development opportunity did not provide teachers with the skills needed to effectively embed the technology into their classroom instruction in a way that translated into improved science inquiry achievement for students. “For technology tools to be effectively utilized”, the authors suggest that “the professional development must be long term, be individualized, and involve evidence – based instructional refinement (Gerard, Varma, Corliss et al., 2011, p. 439).

Teachers must be competent users of the technology when they incorporate technology into their curriculum whether they are using the computer to reinforce lower order skills or develop higher order cognitive processes. Student achievement in mathematics, writing, and science has been shown to improve through effective use of computer technology in the school environment.

Today the computer is used more as a tool than a tutor in schools. The use of the computer as a tool requires monitoring of the use in the classroom environment so that the technology is used to enhance the educational experience and not detract from it. Further research should be aimed at the types of instructional strategies that enhances student learning while using technology.

This study considers the use of computer animations as an instructional tool to enhance student understanding of an abstract scientific concept adding to the extant literature on the subject. The study also has a fairly large sample size and considers students' ability to retain their learning which is not prevalent in the prior research.

CHAPTER 3: METHODOLOGY

Overview of the Study

The purpose of this study is to determine whether an instructional approach which includes viewing computer animations is more effective than a traditional textbook-only approach in helping ninth grade students learn an abstract concept, in this case planetary retrograde motion. This investigation uses a quasi-experimental design with convenient sampling due to the nature of the study which did not allow for random sampling of the population. A Repeated Measure Factorial Design is used to analyze the effectiveness of the treatment on the experimental group. Comparison of the independent variable to the dependent variable in ANOVA determines if there are significant benefits to using computer animations. The independent variable is the type of instruction provided to students; traditional text-based instruction (control group) compared to traditional instruction which also includes the viewing of 4 computer animations (treatment). Two conditions of the treatment examine the relative advantage of the order of the presentation of the animations and text-based instruction, as well as the quality of understanding and the retention of the learning over time. The dependent variable is student achievement which is measured using an instrument designed specifically for this study. Each group took a pretest to measure prior learning, a post-test directly after instruction, and a second delayed post-test one month later.

Quasi-experimental designs require techniques other than random sampling to control for threats to internal validity (Fraenkel and Wallen, 2009).   In this study one of the main threats to internal validity is implementation. This threat has been minimized by providing professional development to the participating teachers along with a specific script to follow during the experiment. Attitude of the subjects is unlikely to affect the internal validity due to the nature of the study. The content being taught is part of the regular curriculum, minimizing subject attitude issues. Maturation is a limitation for the B-pathway population due to excessive absences within that group. Fifty students began the study in the B-pathway group, but only 16 were included in the data analysis. However, maturation is not a problem for the larger A-pathway population as the time frame of the experiment is short.

Research Design

The retrograde motion of planet Mars as viewed from Earth is the scientific concept to be investigated by students in the study. The study tests students' knowledge and understanding of this concept. Sixteen classes of 9th grade Earth and Space Science were randomly assigned to one of three groups using a table of random numbers matched to the section number for each class: control i.e., (read textbook passage with diagram only), treatment 1(i.e., read textbook passage with diagram, then view computer animations), and treatment 2 (i.e., view computer animations, then read textbook with diagram). Thirteen classes are designated as A-pathway (college prep) and three classes are B-pathway (career and/or college). Five A-pathway classes and 1 B-pathway class were assigned to the control group. Four A-pathways and 2 B-pathway classes were assigned to Treatment 1 and 4 A-pathway classes were assigned to Treatment 2. There were no B-pathway classes assigned to Treatment 2 because of the low number of students enrolled in the B-pathway class. All participants took the pre-test to determine prior knowledge and understanding of the concept before the instruction took place. Each group (control, treatment 1 and treatment 2) was instructed using a scripted lesson designed by the researcher. Students participating in the control group received instruction through a traditional teacher presentation with a text-based reading along with an accompanying diagram. Students in treatment 1 (T_1) received a traditional teacher presentation with the text-based reading which was followed by watching and discussing the four computer animations in a classroom setting. The order was switched for students in treatment 2 (T_2), the traditional presentation was followed by the animations after which the students read the text-based account. The students took the post-test the day after the instruction occurred, and again one month after the instruction, to test for retention of knowledge. In some cases the rotating scheduled required the post-test to occur two days after the instruction took place. The Repeated Measure Factorial Design tested for significant differences between and among the groups (Figure 2).

Figure 2. *Hypothesis testing using Repeated Measure Factorial Design.*

ANOVA Repeated Measure Factorial Design		
Question 1	Control vs. Treatment	H_o: $\mu_c = \mu_T$
Question 2	Treatment 1 vs. Treatment 2	H_o: $\mu_{T1} = \mu_{T2}$
Question 3	Level A vs. Level B	$H_{o:}$ $\mu_A = \mu_B$
Question 4	Post Test 1vs. Post Test 2	$H_{o:}$ $\mu_{pt1} = \mu_{pt2}$

Participants

Informed Consent

An expedited review process was submitted to the Institutional Review Board on Human Subjects (IRB) at the University of Rhode Island and approved prior to the beginning of this study. A waiver was requested for the informed consent forms due to the nature of the study; the research is of minimal risk and includes no procedures that would normally require written consent outside of the research context. All participants were provided with an informed consent form, only those who returned the signed form would not participate (Appendix C). No participants chose to opt out of this study.

Nature of Participants

Two hundred ninety-one students enrolled in the ninth grade Earth and Space Science classes from a suburban New England high school participated in the study. Students in the ninth grade are generally 14 or 15 years old. At this age children are bridging the gap between concrete and abstract thought, often gaining the ability to grasp abstract content over the course of the year (Piaget, 1964). It is for this reason that this age group has been picked to participate in the study.

Students in ninth grade science classes are divided into two pathways; the A-pathway (college prep level) represents the largest percentage of the ninth grade population. The B-pathway classes include students with learning disabilities and lower cognitive abilities who are placed in the class based upon teacher recommendation. There is no difference in the curriculum offered to students at the two levels as the curriculum is aligned to the state Science Grade Span Expectations;

however the pacing is slower in the B-pathway. There are 13 A-pathway classes and 3 B-pathway classes meeting during the year of the study. The three B-pathway classes are taught in a collaborative setting with a science teacher and a special education teacher.

Six teachers participated in the study. Each one teaches at least one class of ninth grade Earth and Space Science, up to a maximum of four classes. All of the teachers have a general science certification which is required to teach the Earth and Space Science course, however, only one teacher actually has a background in earth science. The six teachers meet during common planning time, one hour per week, to work on curriculum and assessment. All students in the ninth grade Earth and Space Science class take a common end of the year performance assessment that counts toward 50 % of the final exam grade. The six teachers were given a thank you gift from the researcher for participating in the study.

Setting

The study was conducted at Granville High School (pseudonym), a suburban school located in a northeastern state. The student population of about 1,150 is mainly white middle to upper-middle class mixed with a minority population that represents about 13 percent of students. Twelve percent of students qualify for free and reduced lunch.

Ninth grade students take Earth and Space Science in a traditional (non-laboratory) classroom setting. All science classrooms have at least one computer while six classrooms have up to seven computers available for student use. Seven science classrooms have permanent LCD overhead projectors attached to the ceiling;

the other classrooms share several mobile LCD overhead projectors. A computer and Smart Board™ are available in a rolling cart, as well as a mobile laptop cart.

Instrumentation

The instrument used to measure student achievement of the learning goal is called the Retrograde Motion Assessment. The assessment (Appendix B) includes eight multiple choice questions and one constructed-response question; all addressing the varying components of the concept of planetary motion. Retrograde motion is a complex type of planetary motion which refers to the apparent motion between two or more moving bodies in space based upon a viewer's position. In order to understand the concept of planetary motion students must first learn about the heliocentric model of the solar system, the sun-centered model, developed by Nicolai Copernicus and Kepler's three laws of planetary motion.

The assessment format is based upon the questioning protocol used in the New England Common Assessment Program (NECAP) for science (RIDE, 2006). The multiple choice questions test the student's ability to read and comprehend the text at a cognitive level of recall and beyond. The constructed-response question requires students to interpret and explain the concept in their own words at a higher cognitive level than the multiple choice questions. The questions are based on a reading taken from Namowitz and Spaulding's (1994) textbook, *Earth Science* (Figure 3) and prior instruction on planetary motion. Four of the eight multiple choice questions specifically test the students' understanding of the concept of retrograde motion, the other 4 multiple choice questions were included to minimize the learning occurring as a result of a singular focus on retrograde motion. Only the four questions relevant to retrograde motion were evaluated statistically. A maximum of 16 points may be earned with 12 points for the constructed-response and four points for the multiple-choice questions.

Figure 3: *Reading on Retrograde Motion with diagram from the text.*

Retrograde Motion

Most of the time the planets move eastward in front of the background of constellations, but they periodically make westward loops called **retrograde motion.** These loops occur because each planet travels around the sun at a different speed. Whenever Earth overtakes and passes another planet, that planet appears to move backward, or westward, among the stars. Once the planet has been passed, its eastward motion through the stars continues.

On a single night, a planet will not appear to move in front of the stars. Several days, weeks, or months may be needed to notice a change in the position of a planet. The more distant the planet is from Earth, the more slowly its position changes.

From *Earth Science*, Namowitz and Spaulding, 1994

22.8 Planets move eastward against the background of stars but periodically make westward loops called retrograde motion.

The other materials used in this study were a computer with access to the Internet that is hooked up to an overhead LCD projector; a reading about the construct/concept being tested with a supporting diagram; and the four animations illustrating the concept. The reading is an excerpt from Namowitz and Spaulding's (1994) textbook *Earth Science,* the textbook used in the A-level Earth and Space Science classes. The reading describes the concept of retrograde motion at an age appropriate reading level. The four animations of retrograde motion are:

1. http://www.lasalle.edu/~smithsc/Astronomy/retrograd.html
2. http://web.clas.ufl.edu/users/rhatch/pages/03-Sci-Rev/SCI-REV-Home/resource-ref-read/chief-systems/08-0retro-1.htm
3. http://mars.jpl.nasa.gov/allabout/nightsky/nightsky04-2003animation.html
4. http://www.astro.utoronto.ca/~zhu/ast210/helicentric.html

The researcher and another trained scorer graded the assessments following a procedure that prevents the grader from identifying the condition group of the test-taker. Assessments from each category (i.e., pre-test, post-test one and post-test two) were pre-coded using the school's scheduling section number (Ex. 11401-A1) and then mixed prior to grading. This method ensures that the scorers are unaware of the groups (C, T_1, and T2) while grading the assessments. The constructed-response questions were graded using a rubric (Appendix B). Benchmark answers were used by the researcher while grading the assessments. The researcher also randomly selected 15 percent of the tests using a random number table matched to the student ID number. These tests were graded by a second trained rater to determine inter-rater reliability and lower the probability of rater-drift, the tendency to develop a pattern of higher or lower scores as a result of the earlier tests graded (Wheeler, Haertel & Scriven, 1992). The inter-rater reliability was .954.

Procedure

The study took place in the spring semester of 2009. Four class periods were required to complete the study. Students took the pre-test one month prior to the instruction after which teachers participated in after-school professional development to review the protocol of the experiment. The instruction and posttest1 took two days to complete and approximately one month later, the students were give posttest2.

Each teacher was presented with a scripted lesson plan depending upon which group(s) she would be teaching (Appendix C). The lesson plans (one control and two treatments) were designed by the researcher to model the instruction used during the experiment and established common instructional approaches in the study classrooms. The researcher facilitated the professional development with the teachers and answered questions during the course of the experiment. The teachers (control and treatment groups) were also provided with instruction concerning the necessary prior learning (i.e., heliocentric model of solar system, revolution, rotation and Kepler's three laws of planetary motion) required to teach the target concept of planetary retrograde motion. The treatment requires teachers to guide students as they view four different animations depicting planetary retrograde motion. The researcher instructed the teachers in a specific procedure to assure that the treatment groups received the same approach. The script included a set of directions including prompts for teachers to use and the order in which students' viewed the animations. The treatment required one class period, followed by the first post-test the following day. The teachers in the control group were given instructions to teach the concept using traditional teaching methods, without the use of computer animations. One month later students from 15 of the 16 classes took the second post test; one of the B-pathway classes was not able to complete the second post test due to scheduling conflicts. All students were ultimately exposed to the treatment (viewing the computer animations) at the end of the study since the content is part of the Northeast state's Earth and Space Science expectations that are connected to the statewide science assessment.

Data Analysis

Five questions were tested in the experiment to determine if the stated hypothesis is supported by the analysis of the data; viewing four computer animations is an effective method of instruction to teach retrograde motion to ninth grade earth science students as compared to lecture and text-based only instruction.

- Question one: Is the control (text and diagram) less effective than either of the two treatments: read/animation (T_1) or animation/read (T_2)?
- Question two: Which treatment is most effective, T_1 or T_2?
- Question three: Are there differences in the effectiveness of each approach based upon the aptitude of the students?
- Question four: Do the different instructional approaches result in different levels of long-term retention?
- Question five: Are there specific patterns of error evident in the student's understanding of the concept based upon an item analysis of the multiple choice questions?

The data was analyzed with a 3 x 3 x 2 Repeated Measure Factorial ANOVA to test the first four questions: one within-subject factor, testtime (pretest, posttest1 and posttest2), and two between-subject factors, instruction (control, treatment 1 and treatment 2) and pathway (A and B) based upon cognitive ability.

This study tests the prediction that there will be a difference between the pre and post-test results as well as a difference between the control and treatment groups. The researcher predicts that the treatment groups will show a statistically higher score on the assessment than the control groups after instruction, indicating that the traditional instruction (control) is not as effective as the treatment, instruction including computer animations. The prediction for question two is that there will be a significant difference in the achievement results between the two treatments, which measures the order of instruction. The prediction for question three is that there will be a significant difference in achievement between the two pathways of student groupings (A and B). Not only will there be a difference between the pathways, the B pathway group will demonstrate a relatively greater improvement than the A pathway group due to the treatment. The fourth question tests the retention of knowledge which is predicted to show no difference between the treatment groups, indicating students will retain their knowledge after one month when computer simulations are included in the instruction. The fifth question investigates whether there are patterns of error evident in the student's understanding of the concept of retrograde motion by conducting an in depth item analysis of the multiple choice questions. The researcher predicts that students may have certain misconceptions regarding the concept which will become evident through an analysis of the data.

The outcome of the initial results from ANOVA was analyzed to determine which post-hoc tests were needed, if any. Post-hoc tests are used after a significant F-test value has been determined through analysis of the data in ANOVA. The first two questions posed in this study look for a difference in the dependent variable (achievement) based upon a variation in the independent variable (instruction). The post hoc tests determine the direction of the difference in outcomes on the dependent variable: achievement. For example, if there is a significant difference in achievement (dependent variable) between the control and treatment groups (independent variable), then a post-hoc test determines which of the three groups shows the higher level of achievement.

CHAPTER 4: RESULTS

Overview

This chapter presents an overview of the results from the Retrograde Motion Assessment based upon the five research questions. Each question is described in detail, including a review of the hypothesis tested, and an explanation of the results garnered from the statistical analysis of the data. The data derived from the Retrograde Motion Assessment was analyzed in two different ways. The null hypothesis was tested for 4 of the 5 questions posed by analyzing the student's scores on the assessment using the General Linear Model in SPSS. A total of 291 students enrolled in the 9th grade Earth Science classes participated in the study. However, the total number of students participating in the study (291) decreased to 265 due to absences over the course of the experiment. Using listwise selection for missing data, the overall ANOVA model includes 201 students who completed all three sessions of the test (pretest $n = 265$, posttest1 $n = 254$ and posttest2 $n = 201$). Therefore, the results are based upon a total of 201 students. The assumption of equal covariance is met based upon Box's Test of Equality of Covariance ($F = 1.094$) along with the assumption of normality through the P-P Plot, both in SPSS (Appendix D). The data for the last question was derived from the students' answers to the four multiple choice questions posed on the assessment. An item analysis of the students' answers was conducted to determine if there are specific patterns of error evident in the student's understanding of the concept.

Descriptive Data

The descriptive statistics based upon the mean scores from the assessment are presented in Tables 2 and 3. There are two independent variables: group and pathway. The independent variable group has three levels (control, treatment1 and treatment2). The independent variable pathway has two levels (A pathway and B pathway), and the dependent variable testtime is repeated three times (pretest, posttest1 and posttest2). There are only 16 students analyzed from the B pathway data set even though the 50 students who were enrolled all participated in the study. Two reasons account for the low number of students analyzed in the data set, one is that fewer students are enrolled in this pathway compared to the A pathway due to the nature of the students' academic needs, and the second is related to absenteeism which is a problem for this group of students. Students enrolled in the B pathway require a slower pace of instruction in the science classroom than students enrolled in the A pathway course, and often are team-taught with a collaborative special education teacher, as well as the science teacher. Students enrolled in the A pathway (N = 185) represent the larger group of students in the 9^{th} grade class, though it is not possible to say that the pathway is truly heterogeneous, due to the presence of the B pathway course. There are no data available for treatment2 from the B pathway population due to the small number of students enrolled.

A maximum of 16 points may be earned on the Retrograde Motion Assessment with 12 points for the constructed-response and four points for the multiple-choice questions, each question is worth one point. Table 2 shows the variation in the mean score data as a function of group (control, treatment1 and treatment2) (Figure 4). The difference in mean scores ranges from a low of 4.3 points between the pretest and posttest1 for the control group (text/diagram), to a high of 7.57 points between the pretest and posttest1 for treatment2 (animation/read). The mean score data as a function of pathway (A and B) shows a difference in values ranging from a low of 2.5 points between the pretest and posttest1 for pathway B, to a high of 6.28 points between the pretest and posttest1 for pathway A (see Table 3 and Figure 5).

Figure 4
Graph of the mean score for each group (control, treatment1 and treatement2) as a function of testtime (1 = pretest, 2 = posttest1 and 3 = posttest2).

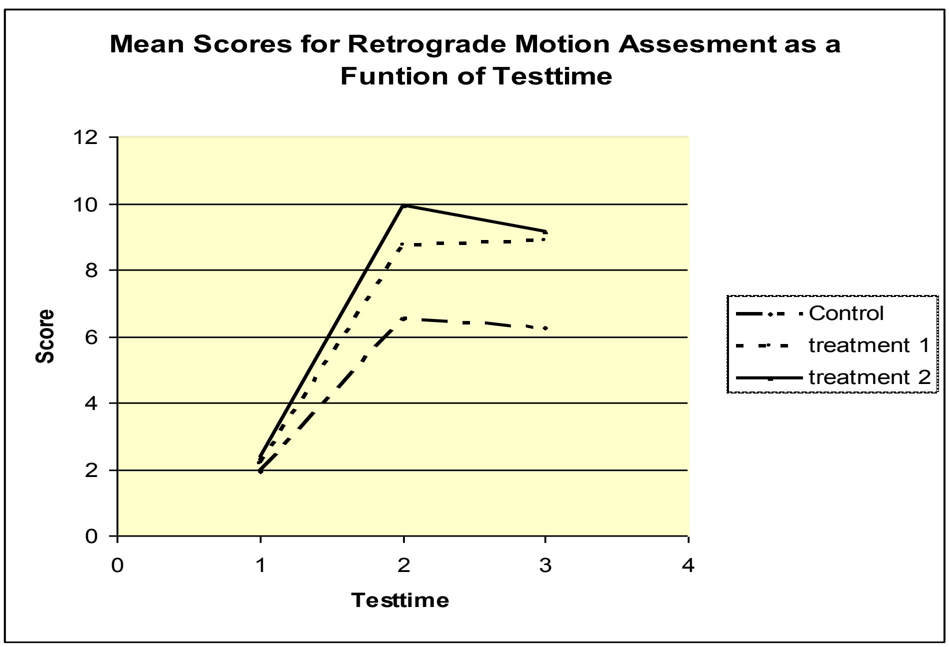


Table 2

Means, Standard Deviations and Number of Students from the Retrograde Motion Assessment as a function of group.

	N	Pretest		Posttest1		Posttest2	
Group		M	SD	M	SD	M	SD
Control	78	1.94	1.166	6.55	3.541	6.24	3.718
Treatment 1	70	2.17[NS]	1.204	8.73*	3.619	8.86*	3.469
Treatment 2	53	2.34[NS]	1.159	9.91*	2.662	9.15*	2.905

Note. [NS] Not a significant difference from the control group.
* Significant difference from the control group at $\alpha = .05$.
Score is based on a maximum of 16 points

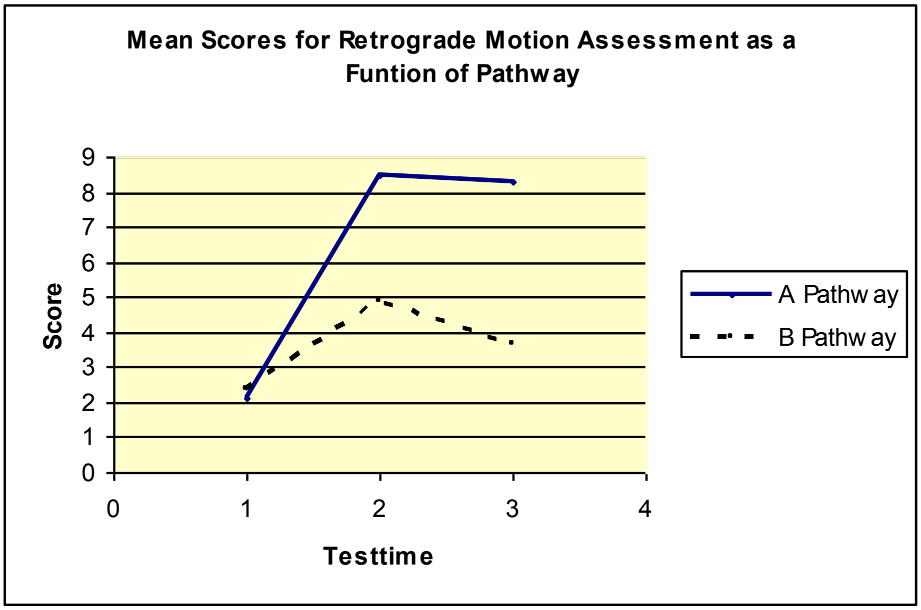
Table 3

Means, Standard Deviations and Number of Students from the Retrograde Motion Assessment as a function of pathway.

	Number	Pretest		Posttest1		Posttest2	
Pathway		M	SD	M	SD	M	SD
A Pathway	185	2.10	1.140	8.48	3.520	8.29	3.528
B Pathway	16	2.38	1.628	4.88*	3.181	3.69*	2.496

Note. Score is based on a maximum of 16 points
* Significant difference from the A pathway at $\alpha = .05$.

Figure 5
Graph of the mean score for each pathway (A pathway and B pathway) as a function of testtime (1 = pretest, 2 = posttest1 and 3 = posttest2).



Analysis of Research Questions

Question one: Control versus Treatment

Question one considers whether the control (text/diagram) is less effective than either of the two treatments: read/animation (T_1) or animation/read (T_2). This question examines if the treatment that requires students to view four computer animations of retrograde motion, along with traditional teaching methods, is an effective instructional technique. And if so, are students able to demonstrate a greater understanding of the concept compared to instruction based upon the traditional method of lecture, reading and viewing a diagram from the text. In order to answer this question the mean scores from the Retrograde Motion Assessment were analyzed to determine if there is a significant difference in student achievement between the three groups; control, treatment1 and treatment2; and if there are any changes across the three testtimes; pretest, posttest1 and posttest2 (see Table 4).

The null hypothesis for question one states that the control (text/diagram) is equal to the treatment (use of computer animation) or H_o: $\mu_C = \mu_T$. An alpha level of .05 was used for all of the statistical tests. The data provides sufficient evidence to conclude that there is a significant difference between the mean score for the control group as compared to the two treatment groups ($F = 13.011$, $p = .000$). Therefore, the null hypothesis is rejected, indicating that there is a difference in student achievement between the control and the two treatment groups. A post hoc test indicates that there is a significant difference in mean scores between the control and treatment groups at both posttest1 and posttest 2 for $\alpha = .05$, but not at the pretest. There was no difference between the control and the two treatment groups at the pretest, before students received instruction as would be expected. However, the mean score for the control group (text/diagram) is significantly less than the mean scores for both treatment groups (use of computer animation) after the students received the instruction including the treatment (see Table 2).

Question Two: Treatment 1 versus Treatment 2

The second question considers which treatment (use of computer animation) is more effective, T_1 or T_2? In this case the null hypothesis H_o: $\mu_{T1} = \mu_{T2}$ assumes that both treatments are equally effective. Students who participated in treatment1 read the text before viewing the four computer animations while students in treatment2 viewed the four computer animations before reading the text. The Tukey HSD Post Hoc Test was used to analyze the between group data. The data provides sufficient evidence to retain the null hypothesis for the pairwise comparison between treatment1 and treatment2 (p = .348). There is no significant difference between the two treatments which suggests that it does not make a difference when the student views the computer animations, only that the student does view it at some point in the instructional sequence.

Table 4

Three-way Analysis of Variance for Achievement Scores based upon the Retrograde Motion Assessment

Source	df	MS	F
	Between subjects		
Level	1	151.198	10.863*
Group	2	181.719	13.011*
Level x group	1	30.476	2.182 .
	Within subjects		
Testtime	2	447.889	101.271 *
Testtime x pathway	2	68.909	15.581 *
Testtime x group	4	23.619	5.340*
Testtime x pathway x group	2	2.347	.531

* p < .05

Question Three: Pathway A versus Pathway B

The third question considers if there is a difference in the effectiveness of each instructional approach (control-text/diagram versus treatment-use of computer animation) based upon the aptitude of the students. This question investigates whether there is a difference in student achievement based upon a student's placement in either of the two pathways (A or B). Students with special learning needs are often placed in the B pathway course. The null hypothesis states that there will be no difference regardless of placement, $H_{o:}\ \mu_A = \mu_{B.}$ In this case, the null hypothesis is rejected ($F= 10.863$, $p = .000$) there is a significant difference in mean scores based upon the student pathway (Table 4). The interaction between the two levels (A pathway and B pathway) and testtime show that the A pathway outperformed the B pathway after the instruction at both testtimes (posttest 1 and posttest2). The mean score for the B pathway population is significantly lower than the mean score for the A pathway population (Table 3).

Question four: PostTest 1 versus PostTest 2

The fourth question asks whether the different instructional approaches result in different levels of retention, in other words, is there a difference in student achievement scores between the three treatment testtimes: pretest, posttest1 and posttest2. The null hypothesis states that there is no difference between mean scores, $H_{o:}\ \mu_{pt} = \mu_{pt1} = \mu_{pt2.}$ The data provides sufficient evidence to conclude that there is not a significant difference between the mean scores at posttest1 versus posttest2 (p = .063). However, the interaction between the three groups (control, treatment 1 and treatment 2) and testtime (posttest1 and posttest2) show that the two treatment groups out perform the control group after the instruction (Table 4 and Figure 4). P,

Question five: Item Analysis of Multiple Choice Data

The fifth question considers whether there are specific patterns of error evident in the students' understanding of the concept of retrograde motion. An item analysis of the multiple choice data was conducted to address this question. Students enrolled in the Earth Science course are taught the same curriculum which is based upon the state science standards, regardless of the pathway (A or B). However, there is evidence in the literature to suggest that separating students by ability grouping may be detrimental to students who are lower achievers (Slavin, 1990). Therefore, the multiple choice data was disaggregated by pathway (A and B) to determine if there were distinct differences in student understanding of the concept depending upon which pathway the student is enrolled. There was no data collected for treatment2 (animation/read) for the B pathway due to the low numbers of students enrolled. The pretest data is not disaggregated by group as it represents all students' knowledge prior to the treatment.

Table 5

Multiple Choice Questions from the Retrograde Motion Assessment.

1. Retrograde motion describes
    a. the blue shift phenomena.
    b. the red shift phenomena.
    c. the relative motion between a planet its moon and the stars.
    d. the relative motion between two planets and the sun.

2. As planets travel around the sun
    a. one planet may travel faster than another.
    b. all planets travel at the same speed.
    c. they are always moving away from the sun.
    d. their speed is steadily increasing.

3. During retrograde motion
    a. one planet hits another planet when the orbits intersect in space.
    b. one planet passes another in its own orbit, as the two revolve around the sun.
    c. one planet moves backwards in its orbit as it revolves around the sun.
    d. one planet slows down in its orbit, while the other speeds up.

4. A person looking at the night sky from any position on earth observes
    a. the planets remaining in the same location throughout the year.
    b. the planets always moving westward across the night sky.
    c. that occasionally a planet appears to move backwards (westward) for a period of time.
    d. the position of the stars changing faster than the position of the planets.

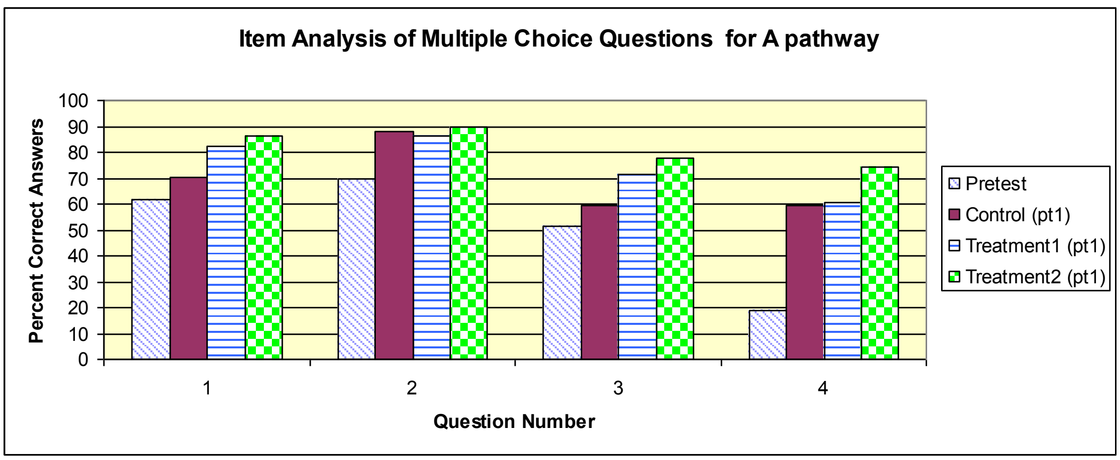
Table 6

Percentage of Correct Responses on Multiple Choice Questions from the Retrograde Motion Assessment for the A pathway group: Pretest and Posttest1

Question	Pretest (%)	Posttest 1 (%)		
		Control	Treatment 1	Treatment 2
1	61.5	70.2	82.2	86.2
2	69.7	88.1	86.3	89.7
3	51.6	59.5	71.5	77.6
4	18.6	59.5	60.3	74.1

Figure 6

Comparison of the Percentage of Correct Answers on Multiple Choice Questions from the Retrograde Motion Assessment for the A pathway group as a function of Testtime (pretest, and posttest1).



A Pathway Analysis

Table 5 shows the four multiple choice questions included in the Retrograde Motion Assessment. Students enrolled in the A pathway showed an increase in the number of correct responses for all four questions between the Pretest and all three Posttest1 groups (Table 6 and Figure 6). The first two questions are posed at a lower depth of knowledge than the last two questions. Question one (see Table 5) asked students to define retrograde motion at the recall level. The percentage of correct answers increased between the pretest and the three posttest1 groups. Most of the gain occurred between the pretest (61.5%) and the two treatment groups (82.2% and 86.2% respectively). The change between the pretest value and the control group was much less at + 8.7%.

Question two (see Table 5) asks another recall question regarding the speed of planets as they orbit the sun. There was an increase in correct answers between the pretest (69.7 %) and the three posttest1 groups (88.1%, 86.3 % and 89.7 % respectively); however the difference between the control group and the two treatment groups was not noticeable.

The third question (see Table 5) asked students to choose an answer which described a planet's motion as it orbits the sun. This question required students to understand the concept at more than the recall level. There was a small positive change between the pretest and control group (+ 7.9 %), however the larger gain occurred between the control and the two treatment groups: 59.5 % (control) to 71.5% (treatment1) and 77.6 % (treatment2).

The largest gain between the pretest and all three posttest groups was noted in question four (see Table 5), the most complex question, which required students to choose an answer which correctly describes the motion of planets in the night sky, a major part of the concept of retrograde motion. The percentage of correct answers increased from 18.6 % at the pretest to 59.5 % control, 60.3 % treatment1 and 74.1%

treatment2. However, the overall score for question four, in all categories, was the lowest of the four questions, most likely due to the higher degree of difficulty.

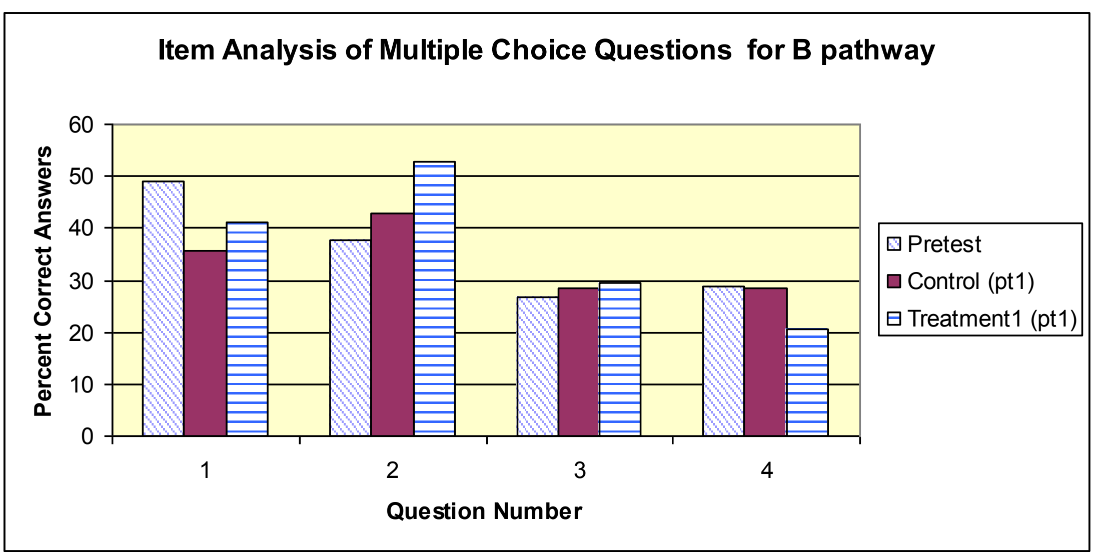
Table 7

Percentage of Correct Responses on Multiple Choice Questions from the Retrograde Motion Assessment for the B pathway group: Pretest and Posttest1

Question	Pretest (%)	Posttest 1 (%)	
		Control	Treatment 1
1	48.9	35.7	41.2
2	37.8	42.9	52.9
3	26.7	28.6	29.4
4	28.9	28.6	20.6

Figure 7

Comparison of the Percentage of Correct Answers on Multiple Choice Questions from the Retrograde Motion Assessment for the B pathway group as a function of Testime (pretest, and posttest1).



B Pathway Analysis

Students in the B pathway group did not show a consistent increase in the percentage of correct responses between the Pretest and the three Posttest1 groups (Table 7 and Figure 7). In fact, there was a decrease in the percent of correct answers for question 1, where 48.9% of students answered correctly in the pretest, while 35.7% answered correctly in the control group and 41.2% in the treatment1 group. There was an increase in correct answers for question two between the pretest and the three posttest1 groups with 37.8 % correct answers for the pretest compared to 42.9% control and 52.9 % treatment1. There was little difference in the percentage of correct answers between the pretest and either the control or the treatment for question three. The only change in question four was a decrease between the pretest, 28.9% and the treatment group 20.6 % however; there was no change between the pretest value and the control group.

A versus B Pathway

There was a noticeable difference in the percentage of correct answers between the A and B pathway groups. The percent of correct answers for the A pathway group was much greater than the B pathway, for questions one, two and three, in both the Pretest and the three Posttest1 groups (Table 6 & 7). However, a greater percentage of the B pathway answered question four correctly, 28. 9% compared to 18.6 % for the A-level on the pretest. The trend did not continue in the three Posttest1 levels where the number of correct answers increased in the A pathway group while the percent correct stayed the same in the control group and decreased in the treatment1 group for the B pathway group.

Distracters

An analysis of the response pattern for each question (Tables 8 & 9) indicates that one specific distracter is dominant regardless of pathway (A or B) and testtime (pretest, posttest1) however; a second and third distracter occurs in some questions, especially in the B pathway data (Table 9). The A pathway data is more consistent than the B pathway data. The frequency of choosing a distracter is similar for all testtimes (pretest, control and treatment) in the A pathway data. The secondary distracter is not present in either question one or two, while it is evident in questions three and four (Table 8). The response pattern for the B pathway data is inconsistent across the two test times and between the control and treatment groups. The pretest data for the B pathway is the most consistent and similar to the A-level data for question one and two with one main distracter evident, questions three and four show multiple distracters and the main one elicited more choices than the correct answer. The secondary distracters are in evidence for all four questions during the posttest1 testtime, including a no response component which was not evident in the A pathway data. A student has a 25 % chance of guessing the correct answer when taking a multiple choice test with four possible answers. The varied response pattern and the low percentage of correct responses, especially for questions three and four suggest that there was more guessing in the B pathway group than the A pathway group.

Table 8

Multiple Choice Distracters Picked by Students in the A Pathway

Question	Correct Answer	A Pathway Distracter(s)	
		Pretest and Posttest1+	
1	D	C	Weak
2	A	B	Weak
3	B	C/D	Equal
4	C	D/B	Equal

Note. + choices were similar at both testtimes
Weak means most students chose the correct answer.
Equal means there is not a significant difference in the number of students who chose either distracter.

Table 9

Multiple Choice Distracters Picked by Students in the B Pathway

Question	Correct Answer	B Pathway Distracter(s)		
		Pretest	Posttest1 Control *	Posttest1 Treatment1 *
1	D	C	C (s)	C
2	A	B	B	B
3	B	C (s)/A/D	A,D	C/D
4	C	D(s)/A/B	D(s)/A	D(s)/A/B

Note. * At least 20% of students left the question blank
(s) Strong distracter, choice is greater than or equal to correct answer

CHAPTER 5: DISCUSSION AND CONCLUSION

Introduction

A cognitive tool "is defined as a computer-available information source or resource presenting focused information specifically tailored for particular learning goals on a particular topic of interest for learning by a particular target audience" (Songer, 2007, p. 476). This study examines the use of four computer animations as a cognitive tool in a 9th grade Earth Science classroom. The results reveal a positive relationship between an instructional approach that uses computer animations and student achievement on the Retrograde Motion Assessment.

This chapter is divided into four sections. The first section is a discussion of the findings from the five research questions with connections to the literature. In the second section the limitations of the study are considered along with the generalizability of the results. The third section makes recommendations for future research and the last section considers the implications of this study.

Discussion of Results

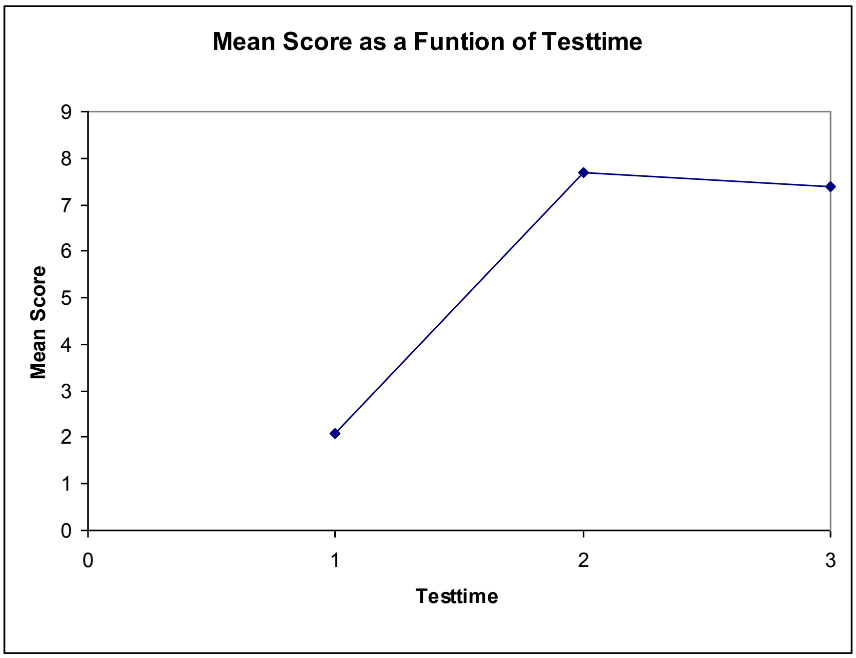
Question One

The first question considers whether the treatment, using computer animations as an instructional tool, is an effective tool to teach 9th grade Earth Science students an abstract concept, as compared to the traditional text-book and lecture method. A pretest was given to all participants to determine the students' baseline of knowledge entering the study. The results from the pretest indicate that the topic, the retrograde motion of Mars relative to Earth, was new to students. The mean score for the pretest ($\mu = 2.08$) is significantly lower than either of the two posttest mean scores ($\mu_{pt1} = 7.70$

and $\mu_{pt2} = 7.40$) (Figure 8). Therefore, the results from posttest1 and posttest2 confirm that students' did learn the concept from the instruction; prior knowledge was not an issue.

Figure 8

Mean Score on the Retrograde Motion Assessment as a Function of Testtime (1- pretest, 2- posttest1 and 3- posttest2).



The findings for question one indicate not only did all students learn the concept from the instruction, but also the students who participated in the two treatment groups (using computer animations) outperformed the control group (text/diagram) at both posttest1 and a month later at posttest2. The null hypothesis was rejected, but the prediction that the treatment groups would outperform the control group was justified. The implication is that the treatment, using an instructional approach which includes computer animations, is effective, and it does aid students in the 9th grade to learn an abstract concept. The increased knowledge is translated into a higher score on an assessment that asks students to explain their understanding of the concept through a constructed response question along with four multiple choice questions.

Marx et al. (2004) reported an improvement in student achievement in science using an inquiry-based and technology-infused curriculum taught to middle school students in the Detroit public school system; however, there was no control group to compare to the treatment participating in the curriculum group. The Marx et al. (2004) study was testing whether students learn science through instruction based upon a particular curriculum, rather than evaluating student achievement gains using that curriculum versus alternatives. This study builds on the findings of Marx et al. (2004) by showing that students both learned the concept through the instruction, and it also confirms that the treatment, using computer animations was an effective instructional tool.

Anderson (2007) begins a conversation about science literacy and research by asking the question, "Why don't students learn what we are trying to teach them?" Others have considered this question as well. Scott et al. (2007) describe a scenario where a student struggles with her conceptual understanding of the concept of energy as it relates to her everyday experiences, as opposed to the scientific meaning of the conservation of energy. The student's lack of understanding originates from her inability to make meaning of the scientific viewpoint. In the present study the question becomes, why does the treatment group outperform the control group, and how exactly does the treatment, viewing computer animations, improve student understanding of an abstract concept to the point where it is translated into improved academic achievement? In order to answer these two questions it is necessary to make a connection to the theory of constructivism, along with the work of Vygotsky, who also questioned how students make sense of the world,

Constructivism is “a theory about learning” (Fosnot, 1996, p. 29), first described by Bruner (1960) in *The Process of Education,* and has been refined by many researchers in the literature since then (Fosnot 1996, Glasersfeld, 1996 and Cobb, 1996). The theory of constructivism views the child at the center of the learning process and the teacher on the outside, subtly guiding the child who is in essence in control of his/her own learning. In a constructivist view of learning, objective reality is not knowable; students create meaning for themselves so that “[w]hat students *know* consists of internally constructed understandings of how their worlds function” (Brooks, J.A. and Brooks, M.G., 1999, p. viii). Fosnot (1996) states that “learning is development”, and it “requires invention and self-organization on the part of the learner” (p. 9), compared to the developmentalists, who view learning as an outcome of development. The question regarding the timing of learning and development has a rich history in the literature. Constructivism also takes it roots in the ideas of Vygotsky (1978) among others, who believed that learning and development are intertwined and cannot be separated. Vygotsky (1978) believed that “[l]earning and development are interrelated from the child’s very first day of life” (p. 84).

The students chosen for this study are between the ages of 14 and 15, at an age when children are cognitively maturing from the ability to think on the concrete to the abstract level (Piaget, 1964). Science curriculum is often abstract in nature challenging students to learn concepts beyond their developmental level. Conceptually, the abstract concept of retrograde motion between two planets is difficult to understand at the ninth grade level, but certainly not impossible. According to Bruner (1960) any topic can be taught to some degree, to students of any age, if prior knowledge is scaffolded properly. In this study, the findings suggest that a concept (retrograde motion between Mars and Earth) not fully understood by most students through traditional text-based instruction (control group) becomes accessible when experienced visually through a computer animation (treatment).

Vygotsky's (1978) theory of social learning and the zone of proximal development (ZPD) help to explain how abstract concepts become accessible to students who might otherwise not be able to construct their own understanding independently. Vygotsky states that "[t]he zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in the embryonic state" (p. 86). The work of Vygotsky (1978) on the ZPD suggests that students can learn concepts that are beyond their own developmental level, or can advance appropriately given the proper teaching aid. In Vygotsky's work the teacher provides the guidance to enhance student learning. In this case, the computer animation enhances the instruction provided by the teacher, serving as a secondary teaching aid, allowing students to explain a concept inside the ZPD which is above their developmental level, or at least beyond their ability to independently understand the information from reading a text. The secondary teaching aid explicitly connects the observed planetary motion with what students already understand about how the earth and other planets orbit the sun. The computer animation improves learning for students, verifying Gordon and Pea's (1995) assertion for the need to incorporate computer visualizations into science education.

Question Two

The second question asks whether one of the two treatments is better than the other, suggesting that the order of the use of the instructional tool might affect the achievement outcome. The findings suggest that there is no difference, students who viewed the animation before reading the text performed as well as students who read the text and then viewed the animation afterwards. The prediction for question two stated that there would be a significant difference in the achievement outcome between the two treatments. In this case the prediction was not correct; the null hypothesis was retained since the achievement difference between the two treatments was not significant. The implication from the findings is that *when* students view the computer animations during the instructional sequence is not important; what is clear is that students *need* to view the animations. The order of instruction within the treatment group does not make a difference in the ability of students to learn the concept and demonstrate their understanding.

Question Three

While most students participating in the study are enrolled in the A pathway (185 students), a few students (16 students) are enrolled in the B pathway. The B pathway allows students who are lower achievers to learn the curriculum at a slower pace and often the class is team taught by both a science teacher and a special educator. There is evidence in the literature however, suggesting that separating students by ability grouping is detrimental to those students who are lower achievers (Slavin, 1990). Question three considers if there is a difference in the effectiveness of each instructional approach (control versus treatment) based upon a student's placement in either of the two pathways (A or B). The prediction for this question is that there would be a significant difference in achievement between the two pathways (A and B). Not only will there be a difference between the pathways, the B pathway group will demonstrate a relatively greater improvement than the A pathway group due to the effect of the treatment. This prediction was partially correct, there was a significant difference in achievement as a function of pathway, however, the A pathway demonstrated the greatest gain, not the B pathway. Therefore, the null hypothesis was rejected, but the direction of the prediction was reversed.

Orion & Ault (2007) suggest that teaching Earth Science requires students to "learn about complex systems on many scales in time and space" (p. 655) which presents obstacles to student understanding. The concept of retrograde motion certainly fits into a description of a system which changes through time and space, most certainly an abstract concept. Montagnero (1996) found a difference in the ability of high school (9th grade) students and middle school (7th grade) students to understand geologic phenomena through "diachronic thinking" where diachronic thinking is defined as the capacity to represent transformations over time. The achievement outcome of the B pathway students showed that the treatment was effective in aiding this group to understand the concept, however the gain between the control group and the treatment group was lower than the respective gain noted by students in the A pathway. The original prediction assumed that the treatment of viewing the animations would overcome the cognitive challenges that students in the B pathway experience. Most students in the B pathway have Individual Learning Plans and are receiving special education services. It may be fair to suggest that the students in the B pathway are functioning at a cognitively lower level than students in the A pathway. As Vygotsky (1978) states,

> When it was first shown that the capability of children with equal levels of mental development to learn under a teacher's guidance varied to a high degree, it became apparent that those children were not mentally the same age and that the subsequent course of their learning would obviously be different. (p. 86)

While the treatment did help the B pathway students' to grasp the concept as compared to the control group, the degree of understanding was not translated as effectively into a demonstration of that understanding on the assessment.

Question Four

Question four considers if the different instructional approaches result in different levels of retention over time, in other words, is there a difference in student achievement scores between the three test times: pretest, posttest1 and posttest2? In this case the null hypothesis was rejected for two of the three comparisons and the prediction that there would not be a difference between the three testtimes was incorrect. The mean score difference between the pretest and both posttests (1 and 2) was expected, as the goal of the pretest was to determine if there was significant prior learning. The null hypothesis is retained for the comparison between posttest1 and posttest2 indicating that there is not a significant difference in the mean scores. The implication is that students did retain their understanding and were able to demonstrate it one month later. This finding is very important because it suggests that students are able to retain information when instruction includes a component of visualization.

Question Five

Analysis of Question Choice

The fifth question considers whether or not there are patterns of error evident in student's understanding of the concept of retrograde motion. The researcher predicts that students may have certain misconceptions regarding the concept that will become evident through an analysis of the multiple choice data. The data are analyzed in two ways. The first looks at the patterns of correct versus incorrect choices within and between the four questions. The second analyzes the distracters that students chose, rather than the correct answer. Both attempt to illustrate the students' strengths and weaknesses at comprehending text through reading multiple choice questions. The process of understanding and constructing one's own individual meaning about the abstract concept was measured through the constructed response question which was posed before the students answered the multiple choice questions.

The results from the item analysis show a distinct difference between the patterns exhibited by the students enrolled in the A pathway as compared to the B pathway, partially verifying the prediction. For example, the percentage of correct answers increased for each question between the pretest and posttest1 regardless of group (control versus treatment) for students in the A pathway (Figure 6). This outcome is not the case for students in the B pathway (Figure 7), where a distinct pattern is not observed between the four questions. More students answered question one and three correctly in the pretest, prior to instruction, than the posttest, an indication that students were guessing rather than using their understanding of the concept to comprehend the questions.

The students in the A pathway also showed an increase in the percentage of correct answers for all four questions after the instruction, indicating that the instruction assisted their ability to comprehend the construct through the question and demonstrate that understanding by choosing the correct answer. However, only question one which asks students to describe retrograde motion and question three, show an increase in the percentage of correct answers in the treatment group as compared to the control. Question three is more complex and requires students to reflect upon the frame of reference problem that occurs during retrograde motion as one planet passes another in orbit. There is no significant difference in the percentage of correct answers between the control and treatment groups for question two. Question two asks about the speed of planets as they orbit the sun, suggesting that both methods provided adequate instruction to understand this question which required recall of information. An unforeseen outcome was noted in question four where the percentage of correct answers for treatment2 was greater than both the control and treatment1 groups. Question four was the most difficult of the four multiple choice questions, requiring a higher degree of critical thinking than the others, building on the frame of reference problem introduced in question three. Now students are asked to choose the correct description of planetary motion as viewed from a position on Earth. The evidence from the analysis of the multiple choice questions suggests that students in treatment2 (view animation/read text) were more successful at answering the multiple choice questions than either of the other two groups, control and treatment1 (read text/view animation). Although the overall mean score results for all questions (multiple choice and constructed response) on the assessment does not mirror this finding. At this point, it is possible to suggest that viewing the animation before reading the text may provide students with better preparation to successfully comprehend the text in the multiple choice questions; however, more research is needed to make a firm conclusion.

Constructed Response

A major part of the Retrograde Motion Assessment is the constructed response question which was worth a maximum of 12 points. The constructed response asked students to respond to the following questions. What is retrograde motion and why does it occur? Use Earth and Mars as an example in your answer. Draw a picture/diagram to explain your answer. Students were asked to answer the constructed response before answering the multiple choice questions. The reason for doing so was to force students to construct their own meaning regarding the concept and not be able to use the wording from the multiple choice questions. Teachers collected the constructed response before handing out the multiple choice questions.

The mean score for the pretest is 2.08 out of a possible 16 points, including points earned from both the multiple choice questions and the constructed response. Most of the points earned on the pretest stem from correct answers to the multiple choice questions, in a few cases up to 3 points were earned on the constructed response. The low mean score on the pretest suggest that students did not have a clear understanding of the concept prior to instruction. The mean score for posttest1 is 7.70, an increase of 5.62 points over the pretest. The range on the posttest1 was 0 to 14 points indicating that in some instances students scored up to 10 points out of the maximum 12 points on the constructed response. There is a significant difference in achievement between the control (text/diagram) $\mu= 6.55$ and the two treatments; treatment1 (animation/text) $\mu= 8.73$ and treatment2 (text/animation) $\mu= 9.91$. The data suggests that students learned about the concept through both the traditional instruction (text/diagram) and the instruction which included the computer animations. However, the evidence indicates that students were able to demonstrate a more complete understanding of the concept through the constructed response after the treatment suggesting that viewing the computer animations provided more meaning for students and an enhanced ability to explain their understanding of retrograde motion. This finding was emphasized in the B pathway where most students guessed on the multiple choice questions indicating that the improvement in the mean score after the treatment is due to the students' ability to answer the constructed response.

Distracter Patterns

The second part of the item analysis investigated the student's choices to each question to determine if there were patterns of misconceptions based upon distracters. The first two questions were both recall questions and in each case there was one main distracter, though both were quite weak in the A pathway as most students answered the question correctly. The distracter for question one was much stronger in the B pathway causing more students to choose that answer than the correct one. The distracter for question one described the concept as the relative motion between a planet, it's moon and the stars, rather than the correct answer, the relative motion between two planets and the sun.

The distracter for question two was again very weak for the A pathway, and stronger for the B pathway. In this case, the correct answer refers back to Kepler's laws of planetary motion, part of the scaffolding required to teach the concept. Most of the students in the A pathway chose the correct answer that one planet may travel faster than another as it orbits the sun, regardless of the group (control vs. treatment) indicating that the scaffolding of information prior to the treatment was beneficial to all students. The distracter, all planets travel at the same speed was more appealing to students in the B pathway who opted for the more concrete of the two answers.

Question three requires a degree of critical thinking, above the recall level; it requires students to demonstrate a correct understanding of the planetary motion described by the concept. The percentage of correct answers decreased in both the A and B pathways as the difficulty of the question increased. There were two distracters picked by students in the A pathway in about equal amounts, both incorrectly describe the motion of the planets as they move through retrograde motion. However, the students in the B pathway picked all four answers for the question which suggests that they were guessing; less than 30 % of students picked the correct answer regardless of group (control vs. treatment).

The last question also asked students to use critical thinking to choose an answer which correctly describes the motion of the planets in the nighttime sky. The students in the A pathway showed the greatest overall gain in correct answers as compared to the other three questions (18% pretest to > 60% posttest1). There were two distracters that both incorrectly described the motion of planets and stars in the night time sky. It is apparent that the instruction regardless of group (control and treatment) successfully prepared many students to answer this question. The situation is quite different in the B pathway where all four answers were again chosen in somewhat equal proportion and the percentage of correct responses in the treatment group was less than the control group, again indicating that students were guessing.

An analysis of the patterns of answers and distracters indicate a distinct difference between students' ability to successfully answer the multiple choice questions as a function of pathway. Most of the students (A pathway) were able to answer the recall questions successfully after the instruction regardless of the treatment and the main distracter was weak. The last two questions required a deeper understanding of the concept, while the percentage of correct answers decreased somewhat as the difficulty increased; students were more successful after the instruction and the treatment.

This was not the case for students in the B pathway; the analysis suggests that the multiple choice questions were a challenge for the students in this group, regardless of the difficulty of the question. The patterns of correct answers and the choice of multiple distracters indicate that students were more likely to guess than read and interpret the question correctly.

Limitations of the Study

There are a number of limitations to this study. The first one is related to the sample. The targeted population for the study is students in the 9^{th} grade, however the accessible population are the students enrolled at a single high school located in a northeastern high school. The sample size is relatively small when compared to the targeted population, and the study is limited to one school and the one age group.

Also the sample is a sample of convenience, meaning it is “a group of individuals who are (conveniently) available for the study” (Fraenkel and Wallen, 2009, p. 98) due to the accessibility of the school to the researcher. Therefore, it might not be possible to draw generalizations beyond the students participating in this study. However, since there have been so few studies of this nature to date the researcher believes the study will be a starting point for other studies of this type.

A second limitation related to the sample is the small number of students enrolled in the B pathway. Fifty students enrolled in the B pathway participated in the study. However, because students in this group are often absent from school, the cumulative absences reduced the number of students in the SPSS data set from 50 to 16, a loss of 68%. According to Fraenkel and Wallen (2009) mortality is one of the more difficult threats to internal validity to control due to the nature of the participants habits. Absences and truancy are an ongoing problem with students in this group. In this study mortality is an internal threat to validity when making conclusions based solely upon the B pathway data, and as such are subject to future research. The conclusions based upon the entire data set are not at risk according to Fraenkel and Wallen (2009) who state “[a]bsence from class on the day of testing, for example, probably would not in most cases favor a particular group, since it would be incidental rather than intentional – unless the day and time of the testing was announced ahead of time” (p. 168). Loss of participants due to maturation is not an issue for the complete data set. Students in the A pathway are not absent on a regular basis. The participation of students in the B pathway needs to be increased and stabilized in a future study in order to remove the limitation of maturation.

Another limitation is the decision to test a single scientific concept taught in a limited time frame, one day of instruction, not including prior scaffolding of the content. Why this concept and not another? Do the results of this study necessarily mean computer animations and visualizations will be effective in teaching other scientific concepts? It is important to define the variables being tested when using an experimental design methodology; otherwise it can be unclear which variable is being measured. This experiment attempts to clearly delineate the variables being measured by limiting the dependent variable (achievement outcome) to the measurement of one single concept, rather than a number of scientific concepts. The concept of retrograde motion is sufficiently abstract to be difficult to represent in text. Also, students in the targeted population are at an age where it is unlikely that they have learned the specifics of retrograde motion in the past. Retrograde motion is one example of a frame of reference problem taught to students in the target population. There are others and certainly many other types of abstract concepts. The motion between the sun and an orbiting planet is another example, though a much simper one. The simplicity of the planet/sun example makes it unacceptable for this study, hence the decision to use the more complex retrograde motion concept. There are in fact two meanings for the term retrograde motion. This study analyzed the concept of retrograde motion as it refers to the motion between two planets orbiting the sun. The term is also used to describe the rotational motion of a planet that spins in the opposite direction than most of the other planets in the solar system. Venus is retrograde because it spins clockwise from the top while Earth spins counterclockwise.

The narrow nature of the experimental design is a strength of the study because both the independent and dependent variables are clearly defined, and the effects of the treatment are clearly linked to the outcome, achievement. However, the narrowness of the study can also be a limitation because the treatment, viewing computer animations, is a teacher-centered instructional method which in some ways is similar to a teacher demonstration. Teacher demonstrations that "provide colorful, surprising, or dramatic effects – such as burning a piece of magnesium ribbon … motivate students but do not necessarily help them develop an understanding of the particular concept being demonstrated" (Treagust, 2007, p. 357). In this study students are viewing computer animations, not manipulating the computer on their own; therefore the study is not investigating the modality of instruction from the student-centered point of view. The computer animation is an instructional tool used by the teacher, not the student. However, the animation is different from a traditional demonstration as defined by Treagust because the treatment, using computer animations, is aiding students to learn the concept through visualization, not to motivate or entertain. Visualization is a way for students to construct individual meaning of the construct.

It may not be possible to generalize the results of this study to all uses of computer animations or interactive simulations as a teaching tool in the science classroom. In order to do so, this study would need to be repeated with the same results, thus eliminating the bias created by a convenient sample (Fraenkel and Wallen, 2009) however; this study is a baseline for future research.

Further Research

The findings from this study suggest that there should be two main directions of research in the future: one aimed at developing professional development for science teachers and the second should further investigate the use of visualization based upon computer animations and its effect on student achievement.

This study shows how an instructional strategy, computer animations, results in positive effects on student learning and understanding of a scientific concept. Therefore, one line of future research should focus on teacher training programs to determine if new teachers entering the practice are being instructed and/or encouraged to use an assortment of instructional strategies, such as computer models and animations. Computer models and animations provide students with a method to construct individual understanding of a concept, a deeper application of the theory of constructivist learning would also include a component of social discourse to develop shared meaning (Fosnot, 2005). Novice teachers need to understand that hands-on learning without a component of minds-on learning is not going to help students construct their own understanding of scientific concepts. Teacher training programs need to teach novice teachers how to effectively include the use of computer animations as a tool to enhance student understanding of the curriculum in a student-centered environment.

Another line of research would be to develop effective professional development models for science teachers who are already in the classroom. Teacher beliefs are very strong and often teachers are the ones who derail the efforts of reformers to initiate curriculum that uses nontraditional instructional strategies.

The second type of research should investigate the use of visualization through computer animations to teach other abstract concepts as a function of student learning and achievement. This line of research should not only investigate using animations to teach other concepts, but also delve into a more student-centered instructional method of using computer animations. The theory of constructivism includes the social construction of learning, not just learning through schemes, structures, and representation (Fosnot, 2005). A study that is designed to test the use of computer animations but also allows students to manipulate the computer on their own while working with others, may prove to be even more effective, especially with those students who do not respond to visualization alone. Hofstein & Lunetta (2004) speak to the value of using "inquiry empowering technologies" (p. 412) in the science classroom and the positive effect that these technologies have on student understanding and learning of scientific principles.

The value of this study may be the clearly defined methodology developed, one that others may employ in the future to test the use of animations in other contexts, such as understanding fault motion when learning about earthquakes. Further studies of this nature may ultimately allow for the outcome of this study to be generalized to other scientific concepts for students of all ages.

Implications for School Practice

A principal goal of science education research is to improve teaching and learning (Abell and Lederman, 2007). The questions asked by researchers must reflect the issues and concerns of all stakeholders including school districts, teachers, parents and students. A major issue for school districts today is determining whether to continue to upgrade and fund technology. Studies which validate the use of technology as an effective learning tool are needed to help school districts make sensible decisions regarding funding that positively affect the education of students.

The value of the findings from science research is actualized when those findings are translated from theory into practice in the science classroom. The main hypothesis of this study considered the use of computer animations to be an effective instructional strategy to teach an abstract concept to students in a 9^{th} grade Earth Science classroom. Demonstrating an understanding of an abstract scientific principal is asked of students on many forms of standardized testing from local assessments, to state (New England Common Assessment Program), national (National Assessment of Educational Progress) and international assessments (Program for International Student Assessment and Trends in International Mathematics and Science Studies). Many researchers have attempted in the past to answer similar questions regarding the types of instruction and curriculum that improves student learning in science (Escalada & Zollman, 1997; Siegle & Foster 2001; Marx et al., 2004; Marbach-Ad et al., 2008).

The findings from this study indicate that instruction which includes visualization of an abstract concept through computer animations improves student learning and achievement. Not only can students demonstrate that understanding immediately following the instruction, they are also able to retain the information for a least one month after the instruction, an important finding considering the frequency of testing that occurs in schools today. The findings from this study suggest that the use of computer animations as an instructional tool in schools is justified when the tool is used correctly to improve student learning.

APPENDIX A

Internal Review Board
Informed Consent Forms

Doctoral Research Project
URI/RIC PhD in Education Program
University of Rhode Island

Parents/Guardians Permission Form

Your child is invited to participate in a research study that examines effective ways to teach science and improve student learning of abstract scientific concepts. The results of this study will not only add to the literature on how students learn science, but will also help guide teachers at [redacted] School to teach science. The [redacted] school department has approved this study.

Goal Of This Research Project?

The goal of this study is to develop a teaching strategy that will improve learning of scientific concepts for all students. By analyzing the information collected in this study, we hope to validate the use of computer animations as a valuable instructional technique in the teaching of science.

Why Is This Research Project Important?

Science for All Americans has outlined the need for all Americans to be science literate yet evidence from multiple testing, NAEPS, TIMSS, PINA show that American students fall behind our neighbors. The need for developing modern methods of teaching science that improves student understanding of scientific concepts is needed. This study addresses the issue of developing teaching strategies that may improve student learning of abstract scientific concepts by using computer animations to enhance instruction.

How Would your Child Contribute To This Study?

Students who have their parents'/guardians' consent and agree to take part in this project will do the following:

1. All students will participate in their regular 9th grade Earth Science classroom instruction that is aligned to the [redacted] Grade Span Expectations for Science. The instructional part of the study only involves one class period.

2. All participating students will receive the same instruction but the order of the instructional approaches will differ in different classes.

3. All participating students will take a pretest and two post tests on a topic in Astronomy. The test has 8 multiple choice questions and one open-ended question. The scores on these assessments will not be used to grade students in science.

4. The classroom teachers will not see the individual results of these assessments.

5. Students who do not participate will be given an alternative science learning activity during the pre and post test.

Students' Rights

Your child's participation, and your consent, is completely voluntary. Your child's participation in the study and the outcome of the assessment will not affect his/her grade in the course of study.

There are no known risks or discomforts involved in this research.

Your child is free to withdraw from the project at any time, without needing to provide an explanation.

All information will be kept confidential. Only the researcher will keep the specific responses of students. No student names will appear on any of the results. No individual information will be disclosed. Only the overall patterns of data will be reported and used to guide new approaches to teaching and learning.

Who is conducting this research project?

This project is directed by Mrs. Kristin E. Klenk, the Proficiency Based Graduation Coordinator (and former science teacher) at [redacted]. Mrs. Klenk is also working on her Ph.D. in Education in the URI-RIC joint Ph.D. Program. She is conducting this research under the supervision of Dr. Betty Young at URI-Kingston (401-874- 4150). Mrs. Klenk's research plan has been approved by the Institutional Review Board for the protection of human subjects at the University of Rhode Island.

If you have any questions or concerns about this study, please feel free to contact me, by phone [redacted], or email [redacted]. You may also contact the office of the URI Vice President for Research, 70 Lower College Road, Suite 2, URI Kingston, RI 02881, phone 874-4328. at URI (401-864-4328).

Sincerely,

Kristin E. Klenk

Please sign and return this sheet to your child's teacher only if you DO NOT want your child to participate in this study.

- -

I ____________________DO NOT give my permission for ___________________to

Your name (please print) Student's name (please print)

participate in this study.

Signature of Parent or Guardian: _________________________Date: _____________

Signature of Researcher: _______________________________Date: _____________

Approved b y the University of Rhode Island Institutional Review Board on 4/23/09

Doctoral Research Project
URI/RIC PhD in Education Program
University of Rhode Island

Student Assent Form

Request for participation

My name is Mrs. Klenk and I am the Proficiency Based Graduation Coordinator here at [redacted] High School. As part of my doctoral research at the University of Rhode Island I am studying ways to improve how we teach science at [redacted].

Why Is This Research Project Important?

Science for All Americans has outlined the need for all Americans to be science literate. There is lots of evidence that American students fall behind our neighbors. The need for developing modern methods of teaching science that improves student understanding of scientific concepts is needed. This study addresses the issue of developing teaching strategies that may improve student learning of abstract scientific concepts by using computer animations to enhance instruction.

What Are The Goals Of This Research Project?

The goal of this study is to develop a teaching strategy that will improve learning of scientific concepts for all students. By analyzing the information collected in this study, we hope to validate the use of computer animations as a valuable instructional technique in the teaching of science.

How Could I Contribute To This Project?

Students who have their parents'/guardians' consent and who agree to participate in this project will do the following:

1. Participate in your regular 9th grade Earth Science class that is aligned to the [redacted] Grade Span Expectations for Science.

2. You will all receive the same instruction but the order of the instructional approaches will differ in different classes.

3. You will take a pretest and two post tests on a topic in Astronomy. The test has 8 multiple choice questions and one open-ended question. The scores on these assessments will not be used to grade you in science.

4. Your teacher will not see the individual results of these assessments.

5. If you do not participate you will be given an alternative science learning activity during the pre and post test.

You and other students will each contribute your own important piece to the big picture of how students learn science. That valuable picture will help guide us toward developing better ways to teach and learn science, first at [redacted] and later at other schools.

Students' Rights

Your participation, and your parents'/guardians' consent, is completely voluntary. Your participation in the study and the outcome of the assessment will not affect your grade in the course of study.

There are no known risks or discomforts involved in this research.

You are free to withdraw from the project at any time, without needing to provide an explanation.

All information will be kept confidential. Only Mrs. Klenk will keep the specific responses of students. No student names will appear on any of the results. No individual information will be disclosed. Only the overall patterns of data will be reported and used to guide new approaches to teaching and learning

Who is conducting this research project?

This project is directed by Mrs. Kristin E. Klenk, the Proficiency Based Graduation Coordinator (and former science teacher) at [redacted]. Mrs. Klenk is also working on her Ph.D. in Education in the URI-RIC joint Ph.D. Program. She is conducting this research under the supervision of Dr. Betty Young at URI-Kingston (401-874- 4150). Mrs. Klenk's research plan has been approved by the Institutional Review Board for the protection of human subjects at the University of Rhode Island.

If you have any questions or concerns about this study, please feel free to contact me, by phone [redacted], or email [redacted]. You may also contact the office of the URI Vice President for Research, 70 Lower College Road, Suite 2, URI Kingston, RI 02881, phone 874-4328. at URI (401-864-4328).

Sincerely,

Kristin E. Klenk

I have read the Assent Form. My questions have been answered. My signature on this form means that I understand the information and I agree to participate in this study.

________________________ ____________________________

Signature of Participant | Signature of Researcher

___________________________ Kristin E. Klenk___________

Printed name | Printed name

______________________________ ______________________________

Date | Date

Approved by the University of Rhode Island Institutional Review Board on 4/23/09

APPENDIX B

Retrograde Motion Assessments and Rubric

Student ID: ___________________________________Course Code: __________

Pre Test Score: __________

Multiple Choice Assessment Instrument

Directions: *Select the correct answer and write the letter on the line.*

1. Which of the following is the most likely reason that ancient observers believed that Earth was the center of the universe?
   a. The Earth seemed to move on its axis.
   b. Earth's motions are only recently known because of high-powered telescopes.
   c. Objects in the sky appear to circle around Earth.
   d. Ancient observers believed the universe was stationary.

2. Retrograde motion describes
   a. the blue shift phenomena.
   b. the red shift phenomena.
   c. the relative motion between a planet its moon and the stars.
   d. the relative motion between two planets and the sun.

3. Which of the following helps explain why the planets remain in motion around the sun?
   a. density   b. gravity   c. inertia   d. both b and c

4. As planets travel around the sun
   a. one planet may travel faster than another.
   b. all planets travel at the same speed.
   c. they are always moving away from the sun.
   d. their speed is steadily increasing.

5. During retrograde motion
a. one planet hits another planet when the orbits intersect in space.
b. one planet passes another in its own orbit, as the two revolve around the sun.
c. one planet moves backwards in its orbit as it revolves around the sun.
d. one planet slows down in its orbit, while the other speeds up.

6. Which characteristic of the inner planets increases with increasing distance from the sun?
   a. equatorial diameter   b. period of rotation
   c. average temperature   d. period of revolution

7. In the formation of our solar system, nearly all of the mass of the solar nebula became
   a. the terrestrial planets
   b. the gas giants
   c. the Sun
   d. the Oort cloud

8. A person looking at the night sky from any position on earth observes
   a. the planets remaining in the same location throughout the year.
   b. the planets always moving westward across the night sky.
   c. that occasionally a planet appears to move backwards (westward) for a period of time.
   d. the position of the stars changing faster than the position of the planets.

Directions: *Answer the question below to the best of your ability. Write in full sentences. Label your diagram.*

What is retrograde motion and why does it occur? Use Earth and Mars as an example in your answer. Draw a picture/diagram to explain your answer.

____

____

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____

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____

Draw your Diagram Here:

Pre-Test Total Score: _____________

Rubric - checklist

10 point answer:
Retrograde motion occurs between two planets as they orbit the sun. Planets generally move eastward across the night sky. Sometimes a planet, such as Mars, forms a loop in the nighttime sky over the course of many weeks, moving westward before resuming its normal eastward motion. Retrograde motion between the Earth and Mars occurs because the Earth is traveling faster in its orbit than Mars. As the Earth passes Mars, Mars appears to stand still and then move backwards (westward) across the nighttime sky.

Each worth 2 points

Retrograde motion occurs between 2 planets as they orbit the sun
Planets move at different speeds (one faster than other)
Earth passes Mars
Mars stands still/ moves backward (westward) - appears to move backwards, it's an illusion
Takes several weeks/months

8 point answer - (missing the time)
Retrograde motion occurs between two planets as they orbit the sun because one planet is traveling faster than the other planet. For example as Earth passes Mars, Mars appears to

stand still and them move backwards (westward) for a time before it moves forward (eastward) again.

6 point answer - missing details on earth and mars
Retrograde motion occurs between two planets as they orbit the sun. One travels faster than the other and when the faster passes the slower planet it appears to stand still and then move backward before moving forward again.

4 point answer – missing orbit sun and missing detail on earth and mars
Retrograde motion is when one planet travels faster than another and one appears to standstill and move backwards for a time.

Drawing 2 points

Loop drawing - correct direction with labels
Or the two planets in orbit with Earth inside and faster

Drawing 1 point
Loop drawing - incorrect direction or no labels
Two planets – no labels

APPENDIX C

Teacher Directions for the Experiment

Control Group -Teacher Directions for Retrograde Motion Experiment

Part 1
The Pre-Test should be given 2 to 3 weeks prior to the first post-test.

Part 2
Prior Instruction:
Instruction on the following topics is a necessary part of the experiment. Please use a traditional lecture/notes format. Do not use any computer simulations during the prior instruction.

1. Rotation and Revolution
2. Kepler's 3 Laws of Planetary Motion
3. Heliocentric Model of the Solar System

Begin the review with an explanation of the Heliocentric Model of the Solar System. Students were introduced to the Geocentric and Heliocentric models in Western Civilization this year. Follow with a review of Kepler's laws, connecting Kepler's description of planetary motion to the model. The three laws describe the motion of planets as they orbit the sun linking motion to Copernicus' Heliocentric Model of the solar system.

Law 1 - The path of the planets about the sun are elliptical in shape, with the center of the sun being located at one focus. (The Law of Ellipses)

Law 2 - An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time. (The Law of Equal Areas)

Law 3 - The ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of their average distances from the sun. (The Law of Harmonies)

An interpretation of law 2 and 3 implies that the planet whose orbit is closer to the sun travels at a faster velocity than one whose orbit is further from the sun. Imbedded in this discussion is the concept that all bodies in the Solar System Rotate, spin on an axis and Revolve, orbit the sun.

Part 3 - Control Group Teacher Instructions

Please instruct the content of Retrograde Motion using a traditional lecture/notes format imbedded within the instruction of rotation, revolution, Kepler's Laws and the Heliocentric Model. Following instruction ask students to read the paragraph and review the picture. However, students in the control group should not view computer simulations or a video of retrograde motion. Instruction may take more than one day. Students should take the Post-Test the day after instruction is concluded, but do not tell the students about the test.

Answer questions as you would in a normal teaching unit. Please write down the types of questions students ask on the paper provided.

Part 4
Second Post-Test
Three weeks later – have students take the Post-Test again

Treatment Group 1 - Teacher Directions for Retrograde Motion Experiment

Part 1
The Pre-Test should be given 2 to 3 weeks prior to the first post-test.

Part 2
Prior Instruction:
Instruction on the following topics is a necessary part of the experiment. Please use a traditional lecture/notes format. Do not use any computer simulations during the prior instruction.

1. Rotation and Revolution
2. Kepler's 3 Laws
3. Heliocentric Model of the Solar System

Begin the review with an explanation of the Heliocentric Model of the Solar System. Students were introduced to the Geocentric and Heliocentric models in Western Civilization this year. Follow with a review of Kepler's laws, connecting Kepler's description of planetary motion to the model. The three laws describe the motion of planets as they orbit the sun linking motion to Copernicus' Heliocentric Model of the solar system.

Law 1 - The path of the planets about the sun are elliptical in shape, with the center of the sun being located at one focus. (The Law of Ellipses)

Law 2 - An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time. (The Law of Equal Areas)

Law 3 - The ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of their average distances from the sun. (The Law of Harmonies)

An interpretation of law 2 and 3 implies that the planet whose orbit is closer to the sun travels at a faster velocity than one whose orbit is further from the sun.

Imbedded in this discussion is the concept that all bodies in the Solar System rotate, spin on an axis and revolve, orbit the sun.

Part 3
Treatment Group One–
Please instruct the concept of Retrograde Motion using a traditional lecture/notes format imbedded within the instruction of rotation, revolution, Kepler's Laws and the Heliocentric Model. Following the instruction ask students to read the paragraph and

review the picture. View the four simulations after reading the paragraph. Instruction may take more than one day. Students should take the Post-Test the day after instruction is concluded, but do not tell the students about the test.

Teachers should answer questions as they would in a normal teaching unit. Please write down the types of questions students ask on the paper provided.

Treatment 1 –

1. Initial instruction
2. Read paragraph
3. View simulations

View the simulations in the following order

1. Apparent Motion against stars - http://www.lasalle.edu/~smithhttp://csep10.phys.utk.edu/astr161/lect/history/kepler.htmlsc/Astronomy/retrograd.html
2. Hatch Retrograde - http://web.clas.ufl.edu/users/rhatch/pages/03-Sci-Rev/SCI-REV-Home/resource-ref-read/chief-systems/08-0retro-1.htm
3. NASA Retrograde - http://mars.jpl.nasa.gov/allabout/nightsky/nightsky04-2003animation.html
4. Heliocentric Model - http://www.astro.utoronto.ca/~zhu/ast210/helicentric.html

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The day after teacher instruction students in treatment group one will take the post-test.

Part 4

Second Post-Test

Three weeks later – have students take the Post-Test again

Treatment Group 2 - Teacher Directions for Retrograde Motion Experiment

Part 1
The Pre-Test should be given 2 to 3 weeks prior to the first post-test.

Part 2
Prior Instruction:
Instruction on the following topics is a necessary part of the experiment. Please use a traditional lecture/notes format. Do not use any computer simulations during the prior instruction.

4. Rotation and Revolution
5. Kepler's 3 Laws
6. Heliocentric Model of the Solar System

Begin the review with an explanation of the Heliocentric Model of the Solar System. Students were introduced to the Geocentric and Heliocentric models in Western Civilization this year. Follow with a review of Kepler's laws, connecting Kepler's description of planetary motion to the model. The three laws describe the motion of planets as they orbit the sun linking motion to Copernicus' Heliocentric Model of the solar system.

Law 1 - The path of the planets about the sun are elliptical in shape, with the center of the sun being located at one focus. (The Law of Ellipses)

Law 2 - An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time. (The Law of Equal Areas)

Law 3 - The ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of their average distances from the sun. (The Law of Harmonies)

An interpretation of law 2 and 3 implies that the planet whose orbit is closer to the sun travels at a faster velocity than one whose orbit is further from the sun.

Imbedded in this discussion is the concept that all bodies in the Solar System Rotate, spin on an axis and Revolve, orbit the sun.

Part 3
Treatment Group Two –
Please instruct the concept of Retrograde Motion using a traditional lecture/notes format imbedded within the instruction of rotation, revolution, Kepler's Laws and the Heliocentric Model. Following the initial instruction view the four computer simulations with the students. After viewing the simulations ask students to read the paragraph and review the picture. Instruction may take more than one day. Students

should take the Post-Test the day after instruction is concluded, but do not tell the students about the test.

Teachers should answer questions as they would in a normal teaching unit. Please write down the types of questions students ask on the paper provided.

Treatment Group 2

1. Initial instruction
2. View simulations
3. Read paragraph

View the simulations in the following order

5. Apparent Motion against stars - http://www.lasalle.edu/~smithsc/Astronomy/retrograd.html
6. Hatch Retrograde - http://web.clas.ufl.edu/users/rhatch/pages/03-Sci-Rev/SCI-REV-Home/resource-ref-read/chief-systems/08-0retro-1.htm
7. NASA Retrograde - http://mars.jpl.nasa.gov/allabout/nightsky/nightsky04-2003animation.html
8. Heliocentric Model - http://www.astro.utoronto.ca/~zhu/ast210/helicentric.html

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The day after teacher instruction students in treatment group two will take the post-test.

Part 4
Second Post-Test
Three weeks later – have students take the Post-Test again

Please write down questions that students ask during instruction of Retrograde Motion.

Teacher Directions for the Pre-Test

1. Please ask each student to carefully write their student ID on the line at the top of each assessment, NOT their name.

2. Give students the Constructed Response Assessment first, collect, and then hand out the Multiple Choice Assessment.

3. Ask students to use capital letters on the multiple choice test and to NOT circle the answers.

4. Please keep the tests from each class separate.

Thanks so much!

Appendix D

PPlot for Normality
and
Box's Test of Equality of Covariance

PPlot – Test for Normality

Case Processing Summary

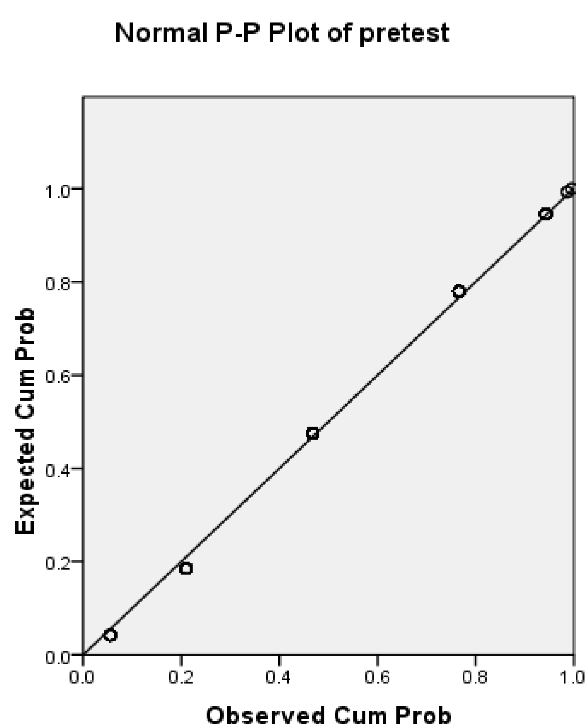
		pretest	postt1	postt2
	Series or Sequence Length	291	291	291
Number of Missing Values in the Plot	User-Missing	0	0	0
	System-Missing	26	37	56

The cases are unweighted.

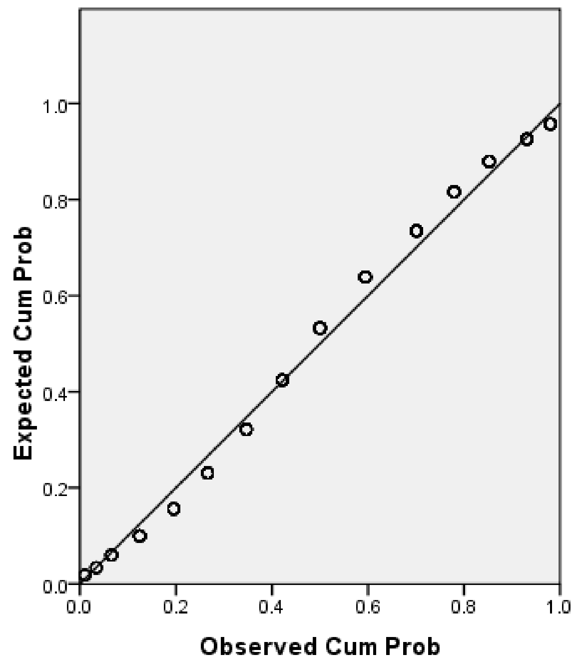
Estimated Distribution Parameters

		pretest	postt1	postt2
Normal Distribution	Location	2.08	7.70	7.48
	Scale	1.201	3.664	3.781

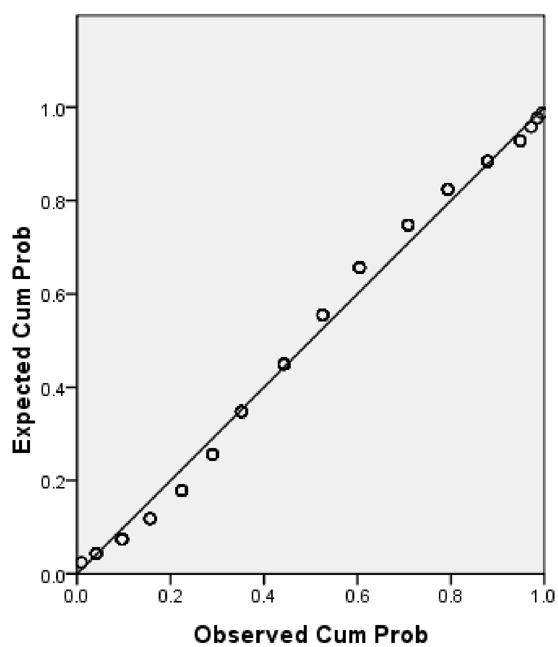
The cases are unweighted.



Normal P-P Plot of postt1



Normal P-P Plot of postt2



Box's Test of Equality of Covariance

Box's M	29.453
F	1.094
df1	24
df2	2022.783
Sig.	.341

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