ABSTRACT

A Study of the Effects of an Experimental Spiral
Physics Curriculum Taught to
Sixth Grade Girls and Boys

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The pilot study compared the effectiveness of using an experimental spiral physics curriculum to a traditional linear physics curriculum for sixth through eighth grades. The study also surveyed students' parents and principals about students' academic history and background as well as identified resilient children's attributes for academic success. The pilot study was used to help validate the testing instrument as well as help refine the complete study.

The purpose of the complete study was to compare the effectiveness of using an experimental spiral physics curriculum and a traditional linear curriculum with sixth graders only; seventh and eighth graders were dropped in the complete study. The study also surveyed students' parents, teachers, and principals about students' academic history and background as well as identified resilient children's attributes for academic success.

Both the experimental spiral physics curriculum and the traditional linear physics curriculum increased physics achievement; however, there was no statistically significant difference in effectiveness of teaching experimental spiral physics curriculum in the

aggregated sixth grade group compared to the traditional linear physics curriculum. It is important to note that the majority of the subgroups studied did show statistically significant differences in effectiveness for the experimental spiral physics curriculum compared to the traditional linear physics curriculum. The Grounded Theory analysis of resilient student characteristics resulted in categories for future studies including the empathy factor ("E" factor), the tenacity factor ("T" factor), the spiritual factor ("S" factor), and the relational factor ("R" factor).

A Study of the Effects of an Experimental Spiral
Physics Curriculum Taught to
Sixth Grade Girls and Boys

by

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A Dissertation

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DEDICATION

To My Savior Jesus the Christ, Abba Father, Holy Spirit, Warren C. Davis Jr., Esther and James Williams, Juliet Shepard, Mable J.Graham, family and friends who helped me achieve this dream with love, prayers, and finances. Thank you for believing in me.

To my anointed son and daughter Joshua Caleb Davis and Jordan Aarone Davis.

CHAPTER ONE

Introduction

Any deficit in science education programs would hinder the progress of the country, yet national and international science achievement data show that the United States of America's students lag behind other nations' students in their understanding of science once they enter high school (National Science Board, 1997). The science curricula in the nation's middle schools have been considered one of the weaker links to the advancement of a scientifically literate society (Forgione, 1999). Science education and scientific literacy are essential to the success of the nation. A scientifically literate nation can help assure a free and democratic society, an economically viable society, and a healthy society. The following review of some of the political influences on science education in the United States shows the importance that recent presidents and government agencies have placed on science education.

Science education standards and science education curriculum are shaped by the political, economic, and sovereign needs of the nation. Scientific progress helps to keep the nation from deteriorating by finding cures for disease that plague mankind, as well as drugs and other medical innovations that help to extend and create a higher quality of life. Scientific progress helps to improve the nation's standard of living by developing new technologies that ultimately increase the number of jobs for American citizens. A scientifically literate society is essential to the nation's security as well as physical and economic health. Scientific progress can help maintain liberties against tyranny by assuring the nation's military has state of the art military weapons and other deterrents (National Science Board, 1998).

The Soviet Union's launching of Sputnik on October 4, 1957 was a political, economic, and military triumph. The Soviet Union's accomplishment in space exploration galvanized the United States resolve to advance in science education and personified the need for scientific literacy for the nation. One of the results was the Woods Hole Conference of 1959 called by Randall Whaley, Director of the Education Office in the National Academy of Science. Whaley gathered together great minds in science education to discuss the question, "How can education in science be improved in our primary and secondary schools?" President Eisenhower, and later President Kennedy, was in full support of these endeavors because the fate of the nation rested in the educational skill base of its youth (Bruner, 1960).

President John F. Kennedy was committed to science education because it would help to produce a scientifically literate nation. Kennedy understood that it would take a scientifically literate nation to develop and maintain the nation's space program. Kennedy, like his predecessor Eisenhower, appointed a strong science advisor and advisory committee to serve the nation's best interests in science education. Kennedy's administration issued a reorganization plan that relieved the National Science Foundation (NSF) from coordinating federal science policy. His administration permanently added the Office of Science and Technology, which his predecessor Eisenhower had created, to the executive office of the President. Kennedy's administration transferred the NSF government-wide evaluation and policymaking functions to this newly formed office. Kennedy addressed the National Academy of Science on its 100th anniversary. He stated that “scientists alone can establish the objectives of their research; but society, in extending support to science, must take account of its own needs” (Woolley & Peters, 2007 ¶ 12).

Like Kennedy, President Lyndon B. Johnson believed that science education has a direct relationship to the creation of a scientifically literate society and the perpetuation of a democratic nation. In 1965, Johnson told his cabinet that it was “very much the concern of the federal government” through funding of basic research to be sure that the nation’s “future… rests upon diversity of inquiry as well as the universality of capability” (Woolley & Peters, 2007, ¶ 4). History shows that Johnson was strategic in the funding of the nation’s science education endeavors through the Elementary and Secondary Education Act (ESEA) of 1965. Johnson made his mark in the creation of a scientifically literate nation over forty years ago through the enactment of ESEA.

Johnson’s vision of a scientifically literate society included the war on poverty, which targeted the areas of health, education, and welfare. Congress passed the funding of these programs in 1964 and 1965. Johnson declared an "unconditional war on poverty" in his 1964 State of the Union address. He referred to federal aid to education as an important part of that war. As a result, Title I of the Elementary and Secondary Education Act of 1965, which included Head Start, had a major impact on the education of children from low income families (Andrew, 1998).

Secretary of Education T.H. Bell continued the quest for scientific literacy of the nation through science education standards and science education. Bell’s report to President Ronald Reagan, *A Nation At Risk, 1983* stated:

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act

> of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament (NCEE, 1983, ¶ 3).

Although Secretary Bell was talking about education in general, the commission recognized the importance of the nation acquiring scientific literacy for the success of the nation.

In his first state of the union speech, President George Herbert Walker Bush showed his support of science education and science research. He proposed $2.2 billion to the NSF for the promotion of basic research and proposed to double its budget by 1993. Bush proposed a permanent tax credit for research and development. He requested that the National Aeronautic and Space Administration (NASA) have its budget increased by $2.4 billion. Bush also established a new program called National Science Scholars (Bush, 1990).

President Bill Clinton also believed in harnessing the powerful forces of science and technology for the nation's welfare. The creation of the nation's Goals 2000 had a major impact on education in general as well as science education (Ravitch, 1995). President George H. W. Bush tapped President Clinton when he was governor of Arkansas to head the nation's gubernatorial initiative for improving education. Clinton was convinced from the experience that the nation needed national education standards.

President George W. Bush, like his father before him, proposed to double the federal commitment to basic scientific research in the physical sciences over the next ten years. He proposed a permanent research and development tax credit which he felt would help fuel scientific research and science education. Bush proposed that children should be encouraged to take more rigorous math and science courses. He also proposed that 70,000 high school teachers be trained to teach Advanced Placement courses in math and science and invited 30,000 math and science professionals to teach and give early help to students who struggled with math and science (Bush, 2006).

In 1990, the Secretary of Labor appointed a commission to determine what skills were needed in America's high performance work organization. The Secretary of Labor's commission was called the Secretary's Commission on Achieving Necessary Skills (SCANS). In 1991, the commission issued its initial report called "What Work Requires of Schools". The skills that were cited were some of the same skills needed for increased scientific literacy such as critical thinking skills (US Department of Labor, 1991).

On November 19, 1998, the National Science Board Strategic Plan Committee confirmed previous concerns about the significance of scientific literacy. The National Science Board stated that the nation's investment in science is considered standard practice around the world. It is universally understood that new knowledge is perhaps the single most important catalyst for economic development. It is also important to note that new scientific knowledge is the most priceless and fully renewable resource available to the world for its advancement. All stakeholders in science education must make sure that the infrastructure is in place to support scientific research and science education in order to assure an inexhaustible supply of scientific knowledge that can address the future needs of the nation and the world. The need for better science curricula must be addressed as one of the fundamental steps towards improving science education in the nation (National Science Board, 1998).

Center for Astrophysics, Space Science and Engineering Research (CASPER) Physics Curriculum Project

Since the year 1999, Baylor University's Center for Astrophysics, Space Science and Engineering Research (CASPER) has conducted a variety of programs and activities designed specifically to introduce students to career paths in science, technology, engineering and math, and to bring students into a research environment that provides for an immediate application of knowledge. In conjunction with its annual Physics Circus for middle and high school students and funding from the National Science Foundation and the U.S. Department of Education, CASPER members have developed curriculum modules in selected science topics for classroom use. The spiral physics curriculum tested in this study was developed in part from the CASPER Physics Circus Classroom Light Curriculum Module (Hyde, 1999).

The CASPER physics curriculum was developed by physicist Dr. Truell Hyde and NSF Research Experience for Teacher Fellows. The curriculum has six stand alone modules; these are light, color, sound, waves, electricity and magnetism. Section one of each module contains the Texas Essential Knowledge and Skills (TEKS) and National Science Education Standards (NSES), teacher study aids on the concepts, lecture notes, "warm-ups" or introduction activities, real life examples, and online links. Section two contains demonstrations and labs. Section three contains overhead transparencies. Section four contains guided practice sheets, closure activities, gifted and talented extensions, alternative assessment ideas and a multiple choice test. The CASPER assessment is a multiple choice test designed by Dr. Hyde.

A modified version of the CASPER light module was the basis for the curriculum implemented in this study. The CASPER light module was compatible for the researcher's experimental spiral physics curriculum. The researcher determined that these concepts could be taught to middle school students in the time frame allowed for the study.

Resilient Children

In addition to teaching the experimental spiral curriculum to middle school students, this study also targeted resilient children. Resilient children are those who manage to not only survive; but, also to thrive in and out of the classroom despite extreme societal hardships. These are the same children labeled as "poor" who do not appear to have a chance for educational success based on where they live or their economic status (Elliott, et al, 2000). As defined by the World Hunger Organization, poor means that the total income of a person's family is less than the threshold appropriate for that family, and that person is considered "poor" together with every member of his or her family (US Census Bureau, 2001). An identifier used in public school of children who are considered poor is their eligibility to receive free or reduced price lunches. For example, ZISD, one of the school districts participating in this study, had 79% of all the youth and 83% of the middle school enrolled youth accepting free or reduced lunches (TEA, 2006).

Resilient Children and Science Education

Several instructional strategies for resilient children were evaluated during development of the spiral curriculum for this study. David Snow's research on instructional strategies for resilient children revealed that adult and peer tutoring was one of the most effective instructional strategies for resilient children (Snow, 2003). Their and Davis' 2002 instructional strategies for resilient students' learning of science combined literacy with guided inquiry. Harold Pratt, President of the National Science Teachers Association, 2001–02, affirmed this approach. Pratt stated that the development of language literacy in the context of inquiry-based, hands on science instruction embraces the richness and utility of language as a relevant part of students' science learning experiences (Their & Davis, 2002).

Katie Frey identified four instructional strategies for teaching resilient children: first, build on students' prior knowledge when developing lesson plans; second, discover what excites students in learning; third, have flexibility in permitting students to learn in their own way; and fourth, learn what students do best (Frey, 1998). Brinton and Master's instructional strategies for resilient children included information management, critical thinking, hands-on activities, data gathering, text analysis and construction (Brinton & Master, 1997). Crystal Kuykendall's strategies for reclaiming resilient children are similar to strategies that are effective for all students. Kuykendall recommended using real world examples and guiding students into thinking like scientists by forming hypotheses, doing experiments, encouraging students to investigate problems, emphasizing hands-on inquiry based science instruction, encouraging students to explore, and dialoguing with other students. Kuykendall's strategies helped to create a safe environment where failure was used as a tool to guide students to a successful understanding of their natural world (Kuykendall, 1991). Many of the strategies promoted by Snow, Their, Davis, Frey, Brinton, Master and Kuykendall are found in the spiral curriculum used in this study.

The Spiral Curriculum

The concept of a spiral curriculum is one in which there is a reiteration of concepts, subjects or themes throughout the course. Each time the concept is repeated, more in-depth knowledge is presented so that each successive encounter of the concept builds on the previous one. This method of learning was first described by Taba in 1962 and popularized by Bruner in 1977 (Taba, 1962 & Bruner, 1977b).

The spiral method of learning information is intuitive and repetitive in nature. Many basic concepts are taught in a spiral method. An example of a spiral curriculum is when a student first learns the alphabet. The student learns that “A” is for apple, the pronunciation “A,” and that “A” is also written “a”. The student continues to revisit the initial concept of “A,” adding to it each time. A process of repetition is established. Another example of spiral curriculum is when a mother teaches her four year old child the parts of the plant. The basic information obtained at this early age was spiraled into a broader knowledge of botany and biology, with recursive visits back to the foundational knowledge of a plant. These examples are spiral in nature because as the student progresses in depth of knowledge, the fundamental points are revisited and new information is attached to the original topic.

A spiral physics curriculum was selected for implementation in this study based on its adaptability for students. Taba demonstrated a spiral curriculum to be effective in her research with various schools. Taba believed that inductive thinking was the way to develop higher order thinking skills (Taba, 1962).

These are features of a spiral curriculum. First, the concepts are revisited. The students revisit the concepts and the subject’s content frequently throughout the academic year. Bruner suggested that such a curriculum would be structured “around the great issues, principles and values that a society deems worthy of the continual concern of its members” (Emling, 1977, p.230). Second, each visitation increases depth of knowledge. The prior concepts and subject content are enriched with new knowledge with each visitation. Each recursive visitation has added knowledge and skills that increase learning opportunities. These drive the student toward mastery of the subject matter. Third, all knowledge and skills are tied back to the foundational basis, the knowledge of the student. New knowledge and skills are linked directly to the learning of previous concepts and subject content of the previous spiral. The learning of previous foundational materials is fundamental to future learning. In 1993, Dowding gave this description of spiral curriculum as the sequencing which provides linkages between the lesson and the student’s learning experience. As new knowledge and skills are introduced too the student subsequent lessons reinforce what is already known and the new knowledge becomes intertwined with previously learned information (Dowding, 1993). Previous knowledge that is learned in earlier visitations of the spiral is linked to future learning in later spiral visitation. The first spiral visitation introduces foundational material—basic knowledge—so that the student is not overwhelmed. Fourth, student’s proficiency is increased. The student’s achievement level increases with each visitation, until finally the concepts and subject content are mastered. The gains in achievement can be tested through standard assessment procedures (Harden & Stamper, 1999). The spiral curriculum is quite different from the traditional linear curriculum usually found in the nation’s classrooms.

Linear Curriculum

A curriculum where the learning of concepts and skills are predicated on the mastery of previous concepts and skills is called a linear curriculum. A linear curriculum is characterized by sequential presentation of concepts. Linear curriculum takes the body of knowledge that is to be taught to the students and builds upon each concept, block by block, each concept interlocking with the next. Mastery of previous concepts is essential before proceeding to the next concept. The overall objective is the mastery of the body of knowledge that is being taught. Some examples of such curriculum are Mastery Learning Methods and Fred Keller's Personalized System of Instruction (PSI) program (Block & Burns, 1976). PSI focuses on a single concept and skill that is taught to mastery level before learning another concept. The spiral curriculum would offer an alternative to the traditional linear curriculum now used in many classrooms.

Statement of the Problem

The pilot study compared the effectiveness of using an experimental spiral physics curriculum to a traditional linear physics curriculum for sixth through eighth grades. The study also surveyed students' parents and principals about students' academic history and background as well as identified resilient children's attributes for academic success. The pilot study was used to help validate the testing instrument as well as help refine procedures for the complete study.

The purpose of the complete study was to compare the effectiveness of as experimental spiral physics curriculum and a traditional linear curriculum with sixth graders. Seventh and eighth graders were dropped from the complete study. The study also surveyed students' parents, teachers, and principals about students' academic history and background as well as identified resilient children's attributes for academic success.

Hypothesis

It was hypothesized that the experimental spiral physics curriculum taught to sixth grade girls and boys would produce significantly higher achievement in science compared to sixth grade girls and boys who received the traditional linear science curriculum instruction. The following are the research questions which were derived from the hypothesis.

Research Questions

The questions guiding the study were:

1) Were there significant differences in physics achievement scores for female students who received instruction using an experimental spiral physics curriculum as compared to female students who received the traditional linear physics curriculum?

2) Were there significant differences in physics achievement scores for male students who received instruction using an experimental spiral physics curriculum as compared to male students who received the traditional linear physics curriculum?

3) Were there significant differences in physics achievement scores for minority students who received instructions using an experimental spiral physics curriculum as compared to minority students who received the traditional linear physics curriculum?

4) Were there significant differences in physics achievement scores for resilient students who received instructions using an experimental spiral physics curriculum as compared to resilient students who received the traditional linear physics curriculum?

5) Were there significant differences in physics achievement scores for students from the BMS, CMS, CSI, GMS and WMS schools who received instructions using an experimental spiral physics curriculum as compared to students from the BMS, CMS, CSI, GMS and WMS who received the traditional linear physics curriculum?

The research questions derived from the hypothesis comprised the foundation of the study. The following paragraphs explain the significance of answering such questions to the educational and scientific community.

Significance of the Problem

First, the study compared the effectiveness of an experimental spiral physics curriculum with sixth graders who were taught using a traditional linear physics curriculum. Second, the study contributed to the literature on science achievement as related to curriculum development. Third, the study provided new insights into the learning and achievement of resilient children. The following paragraphs give the organization of how the study was implemented.

Participants

The population of the pilot consisted of students from BMS, CMS and GMS in ZISD which represented the urban African American, Latino, and Anglo populations. The students from CMS represented the Latino population and students from GMS represented the urban African American and Latino population.

In the case of the complete study, the participants represented urban, rural and suburban schools. The CSI School represented the rural and suburban Anglo population. The CMS represented the urban Latino population. The GMS represented the urban

African American population. The WMS represented the urban/suburban Anglo population. The participants were sixth graders from CMS, CSI, GMS and WMS.

Different quantitative and qualitative techniques were used to evaluate the participants including the Grounded Theory method and random purposeful sampling stratified strategy. The Grounded Theory method demands a rich data base which influenced the data collection phase of the study. The random purposeful sampling stratified strategy was used to ensure credibility and to illustrate subgroups and facilitated comparisons as well as criterion sampling in the case of the resilient children (Gay & Airasian, 2003). The random purposeful sampling strategy was achieved by sampling the various social and economic strata that exist in Central Texas.

Instruments

Prior to and during the pilot study, the researcher designed and validated a written, multiple choice test for the physics content taught during the two week period. The validated test was named the Physics Evaluation Test (PET) and is found in appendix (see Appendix A).   The researcher adapted the CASPER physics test to create the PET. The content of the PET was validated by the pilot study. The study's reliability was increased with the elimination of the test questions that all students answered correctly as well as all questions students answered incorrectly prior to the test being administered to the experimental groups in the complete study in 2006. The test was validated by the Cronbach alpha reliability method with an alpha of 0.799.

Observation

The researcher used the participatory observation method which entailed the naturalistic approach, due to the fact that the researcher was highly immersed in the experimental environment as the teacher of the curriculum. Participatory observations required the process of reflexivity, a meta-cognitive process of critical thinking on a higher level. The researcher was required to deconstruct her actions throughout the qualitative research study, which entailed the qualitative research design, data collection, and analysis (Gay & Airasian, 2003).

Interviews, Surveys, Observations and Video Recording

The researcher used surveys, semi-structured interviews, observations, and video recording in the study. These qualitative methods were used in the assessment of the observations. Observations of the study were the reflections of the researcher during implementation of the study. The use of observations and video recording also helped with ensuring validity and the reduction of bias. Video recording enabled the researcher to clarify any questions that may come up during analysis (Gay & Airasian, 2003).

Ensuring Credibility in the Study

To ensure credibility of the study, the following steps were taken: triangulation and corroboration to help ensure valid observations. The circumstances of the observation were also examined, the data was checked for reliability, the motivations were assessed, and the biases were addressed. The triangulation involved comparison of interviews, surveys, observations, and video tapes after the implementation of the study (Gay & Airasian, 2003).

Definition of Terms

Grounded Theory: Grounded theory holds a dual role in qualitative research because as a theory it enables the researcher to approach the data in an inductive manner, but also while analyzing and comparing the data, the researcher looks for relationships until a theory emerges. As a methodology, this guides the researcher with methods of coding, memoing, grouping, fracturing, and synthesizing the data so that an emerging theory is revealed.

Spiral Curriculum: The concept of a spiral curriculum is one in which there is an iterative revisiting of concepts, subjects or themes throughout the course. A spiral curriculum is not simply the repetition of a concepts taught, but a deeper understanding of a concept with each successive encounter building on the previous encounter.

Linear Curriculum: The concept of a linear curriculum is characterized by sequential alignment of concept subjects or themes throughout the course.

Resilient children: Resilient children manage to not only survive, but also thrive in spite of extreme societal hardships. These are the same children labeled as "poor" who do not appear to have a chance of success based on their geographical location or economic status (Elliott, et al, 2000).

Summary

The importance of science education is suggested by the review of the literature and recent political events. National and international data on science achievement data showed that the United States of America's students lag behind other nations' students in their understanding of science once they enter high school (TIMSS, 2007). Studies have indicated that attitude, beliefs, teachers' effectiveness, parental involvement, and curriculum may have an impact on this phenomenon (Ware, 1992).

The purpose of this study was to focus on the curriculum aspect of teaching physics to students at the pre-high school age. The ultimate qualifier of an effective physics education curriculum is the increase of physics achievement in the students receiving the curriculum. This study compared the effectiveness of an experimental spiral physics curriculum as compared to a traditional linear physics curriculum. This study also identified the resilient children through a grounded theory methodology in order to discover the secret of their academic success.

Education is fundamental to the health of the nation, the states, the communities, the families and the individual. The education of a nation's people in reading, math, and science is imperative if a society is to continue to progress. Science education will help American society retain the most distinctive feature of the nation, its democracy, by educating the American people to think critically. The scientific progress produced by a scientifically literate nation creates the solutions to the many needs of the nation.

CHAPTER TWO

Literature Review

Introduction

The purpose of the study was to investigate the effectiveness of teaching physics using an experimental spiral physics curriculum in the sixth grade. Effectiveness was determined by comparing science achievement test scores of the experimental population versus the controlled population. This chapter will give an overview of the political influences on science education in the United States. A review of the literature of spiral curricula, studies on resilient children and related areas are also included.

An Overview of Political Influences on Science Education

Three major events in the second half of the twentieth century influenced education in the United States (U.S.). President Franklin Roosevelt was concerned with the scientific advances made during World War II and transference of these advances to the public sector for the good of the country. In a letter dated November 17, 1944, President Roosevelt requested that the director of the Office of Scientific Research and Development, Mr. Vannevar Bush, respond to the following questions regarding science in the U.S.: First, how could the government assure that scientific advancements against diseases made during the war are available to the general public? Second, how could the government help to create an environment that nurtures and perpetuates scientific research activities in the public and private sectors? And lastly, could the government help foster science education in the nation that would assure the continued discovery and development of the nation's youth, assuring a large and dynamic pool of scientific talent (Bush, 1945)? In response to Roosevelt's concerns, Bush appointed a commission to evaluate the state of America's scientific literacy. The commission produced the report, "The Endless Frontier," which sounded an alarm for scientific literacy and offered recommendations in response to the alarm. In one response, the report suggested the creation of the teacher education and curriculum development sector of the National Science Foundation (Bush, 1945).

Bush also helped to create national policies, which guaranteed that discoveries in science served national goals to promote economic development, improve the people's quality of life, and guarantee national safety. Bush, by building a consensus among the institutions such as the National Science Foundation, the National Institute of Health with Congress, and the President's Office, helped to create their policies. The foundation of these national science policies were reported in "The Endless Frontier" which was the seminal work for Bush (National Science Board, 1998).

After World War II

After World War II, American society was transformed from a pre-industrial economy where capital accumulation was low, to an industrial economy closely intertwined with technological innovation, such as the development of large-scale energy production operations. As the nation's economic base changed so did the nation's demographics. The changes in technology, economics and demographics increased the public's expectations of its educational institutions.

An increase in births was one of the first demographic changes. Then, as American cities' industrialized urban sectors grew, there was an increase in foreign immigrants seeking jobs. Further, the northern cities experienced mass migrations of minorities from the south seeking better lives for themselves and their children (Cremin, 1975). The nation's curricula needed to provide a stronger instruction in science for the constantly growing and diverse student population.

The need for a stronger science curriculum was confirmed by the events of 1957 (Cremin, 1975). America was shocked on October 4, 1957 when the Soviet Union successfully launched the world's first artificial satellite, Sputnik. The Soviet Union's victory in space exploration galvanized the United States' concern about its educational system, especially in the area of science. There were two major events that followed the Soviet's triumph. First, the National Aeronautic Space Administration (NASA) was established and has generated many great scientific and technological feats in air and space since its inception in 1958 (National Science Board, 1997). The second major event, the Woods Hole Conference, profoundly changed the educational process.

Woods Hole Conference

Recognizing the Soviet Union's great advances in science, America's psychologists, physicists, mathematicians, and other educated professionals all met to produce recommendations that educational leaders would consider when designing science and mathematical education programs for the nation. Randall Whaley, Director of the Education Office in the National Academy of Sciences, chaired the Woods Hole conference of 1959. Whaley invited great minds in science and education such as Bruner, Begie, Blum, Finlay, Fischer, Friedman, Gagne, Glass, Page, Rosenbloom, Steinbach, Vaughn, Skinner, and Schuman. The group gathered together to discuss the question, "How can education in science be improved in our primary and secondary schools" (Bruner, 1960).

The 1959 Woods Hole conference recommended that the nation look at five major areas of change in the educational process. First, students must be taught to understand the complex structure of knowledge. Once the student truly understands the structure of a subject, the student can relate the concepts to other subjects. Bruner, one of the more notable conference attendees, gave the example of the tropism in biology. The understanding of the structure of the tropism in biology enables the student to comprehend other phenomena. In the case of tropism, the effect of temperature on swarming locust and how it relates to other concepts is explained below.

> The swarming of locusts where temperature determines the swarm density in which locusts are forced to travel, the species maintenance of insects at different altitudes on the side of a mountain where cross breeding is prevented by the tendency of each species to travel in its preferred oxygen zone, and many other phenomena in biology can be understood in the light of tropisms (Bruner, 1960, p. 7).

Bruner suggested that in the case of the curriculum, this structure concept would enable the teacher to design the best fit of instructional practices that meet the students learning style. The more fundamental the idea, the more powerful is the applicability of the idea to other subjects. The critical factor that makes the match between the teaching and the learning process is that that the knowledge being taught is structured in such a way that the learner perceives the knowledge as worth knowing and usable beyond his or her classroom experience. Bruner believed that "the teaching and learning of structure, rather than simply the mastery of facts and techniques, was at the center of the classic problem of transfer". Particularly in the area of science, being able to solve problems as well as ask the right questions is essential (Bruner, 1960, p.12).

Participants of the Woods Hole Conference, which gathered together some of the top minds in the field of education, concurred with Taba and Bruner. The consensus was that the emphasizing of structure was very valuable not only for the gifted students, but for the less able students as well. It was understood that the less able student was most easily "thrown off the track" by poor teaching (Bruner, 1960, p.9).

The second recommendation of the Woods Hole Conference was that young students must be prepared with readiness activities. Bruner stated, "Nothing is intrinsically difficult if we "wait until the proper point of view and corresponding language for presenting it is revealed" (Bruner, 1960, p. 33). Bruner and others suggested that one can assist children in their progress of learning through the practice of linking new knowledge with the child language and perspective and that any subject could be taught. This concept is supported by the work of Professor Inhelder of Geneva who showed that, if this philosophy was practiced, physics and mathematics could be taught to seven and ten-year olds (Bruner,1960, p.40 & Matherne, 1999). Bruner also believed that children at the age of seven and ten years old could be taught concepts in physics as long as the concepts were studied by the children through material that the child felt comfortable using by themselves. The members of the conference agreed that the foundations of any subject may be taught to anybody at any age in some form. The "curriculum, as it was developed, should revisit these basic ideas by repeatedly building upon these basic and powerful ideas until the student has grasped the full formal apparatus that goes with them " (Bruner, 1960,p.13). Hilda Taba's "spiral curriculum" that turns back on itself at higher levels was cited as one of the possible solutions (Taba, 1967).

The third recommendation of the Woods Hole Conference was that students needed to be taught how to do intuitive thinking and trained in following “hunches”, which was a much-neglected and essential attribute of critical thinking, not only in academic life but also in everyday life. The astute guess, the productive hypothesis, and the daring leap to a tentative conclusion become the most valuable assets of the thinker at work regardless of the line of work. Can students be guided to master this gift? If the teacher did not demonstrate this skill in the classroom and did not have the confidence to let his or her hunch be tested under analytical examination, students would not develop the self-confidence to do this as well. People who make intuitive guesses are very knowledgeable about the subject. Bruner introduced the nation to discovery learning, which correlates to intuitive thinking and which in turn helps to increase critical thinking (Bruner, 1960).

The fourth recommendation of the Woods Hole Conference was that teachers needed to stimulate the learning of students. Ideally, interest in the material to be learned is the best stimulus to learning, rather than such external goals like grades or competitive advantage. However, this is not very realistic because many things are in competition for the minds and the attention of children such as television advertisers, music industry, and gangs. The educational system can reclaim the minds and attention of the nation’s children through the mentoring of teachers, more professional development for teachers, more criterion based school examinations, and the improved quality of a curriculum (Bruner, 1960).

The fifth recommendation of the Woods Hole Conference was that all participants agreed that teachers, not teaching devices, were the principal agents of instruction. Two points of view were voiced at the conference:

> 1) The teacher must be the sole and final arbiter of how to present a given subject and what devices to use; and 2) The teacher should be the explicator and commentator for prepared materials made available through film, television, teaching machines, and the like. The conclusion was that every effort should be made to educate the teacher to a deep knowledge of his or her subject so that he or she may do as good a job as possible with it, and at the same time the best materials should be made available for the teacher to choose from in constructing a course that meets the requirements of the syllabus (Bruner, 1960, p 81-92).

A critical point that emerged from the Woods Hole conference, that is still important today, is that the teacher understands the type of learners that he or she has and in turn translates that knowledge into the medium that would best be received by the students. A teacher has a diverse student population and a multitude of devices must be used in order to ensure that all students are kept engaged in the learning process (Bruner, 1960).

Bruner believed that the goal of educators and the leadership of the nation should be to make sure that the knowledge, skills, values, and life lessons imparted to the nation's children are made important in their thinking thru out their lives. Unfortunately, the ideas concerning structure, readiness for learning, intuitive thinking, motives for learning, and aids to teaching were slow to be implemented in the nation's schools and once again the nation found itself not prepared for the next challenge (Bruner, 1960).

A Nation at Risk

The Honorable T. H. Bell, Secretary of Education in the newly formed United States Department of Education, reported to President Ronald Reagan that the USA was

“A Nation at Risk”. James Baker and others played a strategic role in getting the report before President Reagan. James Baker, Ronald Reagan's Chief of Staff, and Mike Deaver, Reagan's close advisor, defeated Attorney General Ed Meese in a skirmish of White House insiders over the acceptance of the report. Baker and Deaver outmaneuvered Meese and convinced President Reagan to accept A Nation At Risk: The Imperative for Educational Reform, reported by the National Commission on Excellence in Education (Bell, 1988).

Bell’s report educated the nation’s leadership that the United States’ school system was at risk of not preparing the nation’s students for their future. The recommendations of “A Nation At Risk” were that the nation needed more focused education in science, mathematics, computer science, and foreign language along with increased homework, more rigorous courses, more time spent on-task, additional days in the school year with more hours training, and more money for teachers (Kraft, 1984).

The strategic efforts of Bell, Baker, and others were successful in securing national media interest in the report. Public attention was the catalyst for renewed federal involvement in science education. Coalitions of schools, communities, and industry were established and a call for help was issued to all stakeholders. The nation’s industrial leaders were concerned with the scientific literacy of their present and future employees. Business and industry offered assistance by providing needed human and capital resources (Johnston & Packer, 1987). The assistance from the private sector, along with governmental committees such as the National Science Board Strategic Plan Committee, played important roles in the promotion of science education reforms (Bell, 1988).

The Quest for Scientific Literacy

The National Science Board played its role in attaining scientific literacy for the nation's children. The role of the National Science Board is as follows:

> The National Science Board, established by Congress in 1950, has two important roles. It provides oversight for, and establishes the policies of, the National Science Foundation within the framework of applicable national policies set forth by the President and the Congress. It also serves as an independent body of advisors to both the President and Congress on broad national policy issues related to science and engineering research and education (National Science Board, 2007, ¶ 2.).

On November 19, 1998, the National Science Board Strategic Plan Committee corroborated the concerns of their predecessors regarding the significance of scientific literacy in a report to the President and Congress. The National Science Board stated that significant investment in science education was considered standard practice by most countries because new knowledge was perhaps the single most important catalyst for economic development. It was also important to note that new scientific knowledge was the most priceless and fully renewable resource available to the world for its advancement. All stakeholders such as government officials entrusted with oversight of the nation's educational systems, the nation's businesses that benefit from the nation's schools, the nation's communities which participate in the development of the nation's children, the nation's schools that have the responsibility of educating the students, and the nation's families whose future hopes and dreams rest in their children should all ensure that the infrastructure is in place to support research so that an inexhaustible supply of scientific knowledge addressing the nation's and the world's future needs is assured (National Science Board, 1998).

Science Education Standards

The historical events described above helped to produce the National Science Education Standards that are in place today. The committee of Science Education Standards and Assessment (SESA) developed the standards for science education in 1992. The SESA committee believed that science should have a spiral approach because of the structure of science and the fact that science lends itself well in interdisciplinary units (AAAS, 1993). The *Benchmarks for Science Literacy*, the seminal work of the American Association for the Advancement of Science's Project 2061, was the foundation for the content sector of the standards.

The objectives of the standards were to ensure scientific literacy for all children. The National Science Education Standards (NSES) achieved these objectives by establishing what students needed to know, understand, and perform in order to be scientifically literate. The standards were not just about accruing skills or performing the science processes such as inquiring, observing, inferring, and experimenting. But, it was also about the quality of the content.

The central tenant of inquiry involves the student describing the phenomena, asking questions, constructing explanations, testing those explanations, and communicating their findings. Students use their critical thinking skills to differentiate the assumptions from generalizations, which in turn can become theories. This is the path students take in order to become scientists. The students deepen their understanding of science by combining critical thinking skills with scientific knowledge, reasoning, and thinking skills (NSES, 1996).

The SESA, NSES, and Project 2061 each played a strategic role in the development of the science standards. The standards act as guidelines to be used by stakeholders on the local, state, and national levels to assess whether their educational aims, goals, and objectives met the objective of scientific literacy for the nation. The NSES committee delegated the SESA to develop the standards and the NSES committee for the content portion of the science standards adopted the work specifically on science content by the science project 2061. The following are NSES science standards categories:

Standards for science teaching
Standards for professional development for teachers of science
Standards for assessment in science education
Standards for science content
Standards for science education programs
Standards for science education systems

Each category of the NSES science standards is discussed below. The science teaching standard outlines the content knowledge and skills that are needed by science educators. The standard is partitioned into six areas: 1) the creation of lesson plans with inquiry based programs; 2) the steps needed in order to enhance students' abilities to learn science; 3) the type of assessments needed to evaluate teaching and the learning of science by students; 4) guidance on how to create an environment for the learning of science; 5) assistance on building the community infrastructure to support the learning of science by its children; and 6) insight on how to develop effective science programs.

The professional development standard gives guidance regarding the type of science knowledge and skills science teachers should acquire. The professional development standard addresses four areas: 1) inquiry based learning of science; 2) the integration of science knowledge, pedagogy and students' learning styles; 3) the ability to create a thirst for learning science within students that will last a lifetime; 4) and the creation of an integrated and coherent professional development program that will best serve the teachers' needs (NSES, 1996).

The assessment standard identifies the criteria by which assessment practices are judged. The assessment standard looks at five areas: 1) the decisions that need to be addressed; 2) tools that evaluate achievement and the opportunity to learn science; 3) the quality of the technical data regarding the action taken by decision makers; 4) fairness for all; and finally, 5) assessments that assure the inferences that are made concerning students' achievement and opportunity to learn science are credible (NSES, 1996).

The science content standard describes the expectation of students' understanding of science, students' knowledge of science content, and students' scientific skills that enable them to perform scientific research from kindergarten to twelfth grade. The science content standard addresses eight sections which deal with the integration of learning of science concepts and science process: 1) the use of science inquiry methodology; 2) the integration of the learning of science concepts and science process; 3) the use of science inquiry methodology; 4) the inclusion of physical science and life science; 5) the inclusion of earth and space science; 6) the integration of science and technology in all grades; 7) the personalization and socialization of science; and 8) the inclusion of the history and the nature of science in the nation's classroom (NSES, 1996).

The science education program standard gives the criterion for a quality science program. The science education program looks at six areas: 1) the consistency of all grades' standards with the science program standard; 2) the content standard should be developmentally appropriate, relevant to students' lives, and engaging; 3) inquiry based and integrates other school subjects for all grades; 4) the integration of science and math programs in the nations' classrooms; 5) the fair disbursement of science resources to all students; and 6) the creation of a community infrastructure that supports, sustains, and encourages teachers (NSES, 1996).

The science education system standard sets the criteria by which all science education programs are evaluated. The science education system considers seven sectors: 1) the alignment of policies with science content; 2) the professional development of teachers and the consistency with science program standards; 3) the synchronization of science education policies within the infrastructure that supports its agencies, institutions, and organizations; 4) the science education policies that are congruent over time compare to the availability of the resources needed to sustain science education policies; 5) the assurance of an equitable science education policy; 6) the assessment of unanticipated effects of other policies' impact on science education; and, 7) the assessment of accountability that is required by individuals who are responsible for carrying out the science education standards (NSES, 1996).

Current Composition and Practices in United States' Science Education

The following paragraphs look at the impact of the standards on the nation's science education. The source for info discussed here is the national composite included schools in Central Texas where the study is a part of the national sample set. The fact that Central Texas was a part of the national study gives significant relevance to educational stakeholders of Central Texas (Smith & Banilower, 2002).

The following is a review of the relative impact of these standards on current practices at the time of the 2000 national study commissioned by the National Science

Foundation on elementary and middle schools. Four major sectors of current practices as of the publishing of this report were reviewed: the teacher, the student, the curriculum and the instruction development. The National Science Foundation (NSF) in 1976 commissioned three major studies to get the status of science education in the United States. The studies included 1) a review of the science education research literature, coordinated by Stanley Helgeson at The Ohio State University; 2) a national survey of teachers, principals, district, and state personnel, directed by Iris Weiss, and 3) case studies in 11 districts, coordinated by Robert Stake and Jack Easley at the University of Illinois. The results of these studies are collectively known as "the NSF needs assessment. The NSF needs assessment was followed up with national surveys of science education in 1985–86, 1993, and 2000 (Smith & Banilower, 2002).

On average, fifth through eighth grade science teachers in the United States are educational veterans. The average years of teaching experience for fifth through eighth grade science teachers range from eleven to twenty years. It is important to note that this is the targeted group in this study (Smith & Banilower, 2002).

The average educational level of the elementary and middle school teacher increased in educational levels typically beyond the four year undergraduate degree when the 1993 survey was compared to the 2000 survey. The National Center for Education Statistics of 1999 data revealed that middle school science teachers had two semesters or less of coursework in physics or physical science which is equivalent to 74 percent, 68 percent in chemistry courses, and 55 percent in earth or space science courses. The NSF 2000 study found that 40 percent of grade five through eight students were enrolled in physical science and 29 percent enrolled in biology/life science nationally were taught by teachers who lacked either a major, minor, or certification in the subject (McMillen, et al, 2002). The percentage of America's fifth through eighth grade science teachers having knowledge obtained from college courses of life science, earth science, space science, physical science, environmental science, natural science, and science education courses was 63 percent (Weiss, et al, 2001). The primary disciplinary major for most fifth through eighth grade science teachers continues to be biology. The amount of content knowledge of various science topics for fifth through eighth grade science teachers' has not changed since the National Science Foundation 2000 study (Smith & Banilower, 2002).

The NSF auditors learned that the science education standards for science teachers in the nation and Central Texas have not fully been implemented in the areas of content knowledge of physical sciences, earth, and space science. Life science is still the dominant area of content knowledge for national and Central Texas science teachers, which was reflected by the higher scores in life science in the Third International Math and Science Study. The general experience level and pedagogical understanding of science teachers was in alignment with the standard (Smith & Banilower, 2002).

As of 2000, one quarter of the nation's fifth through eighth grade science teachers spend 35 hours in subject-specific professional development. The fifth through eighth grade teacher in-service hours for science education is 16 to 35 hours, which is an increase of nine-tenths of one percent over the 2000 NSF study development. There is no change in nonsubject-specific professional development (Smith & Banilower, 2002).

The majority of the nation's fifth through eighth grade science teachers are not familiar with the National Science Education Standards, and the majority either does not agree or has no opinion about the overall vision of science education described by the National Science Education Standards. These findings correspond to the fact that the National Science Education Standards have little impact on the nation's fifth through eighth grade students. The study also reported that the fifth through eighth grade science classroom continues to be heterogeneous, with a mixture of gifted and talented, above average, average, and special education students (Smith & Banilower, 2002).

The science education standards face serious challenges in the nation and Central Texas due to the changing demographics and special education needs. The fifth through eighth grade science classes have minority students whose first language is not English. The impact of the growing Latino population significantly impacts the nation's elementary and middle schools. What may have the greatest impact is that the nation is moving towards a more inclusive classroom development. As a result, the science classroom is also experiencing an escalation in the number of students who were formally classified as learning disabled, limited English proficient (LEP), mentally handicapped, or physically handicapped. The science classrooms are not equipped to meet the special needs of the more inclusive classroom (Smith & Banilower, 2002).

Science Education Standards' Impact on Students

The science education standards' impact on the nation's students, and more specifically the students of Central Texas, is limited at best since 2000. The goal of an equitable science education for all students faces serious obstacles. The Latinization of America will need to be addressed in the implementation of the science standards. The growing population of disabled students and the requirements for labs and field trips is a challenge for the integration of the science education standards and will need to be addressed in the nation's classroom. The overall requirement of appropriate resources for science education for all students will also need to be addressed if the science education standards are to be met (Smith & Banilower, 2002).

The United States' science curricula direct impact on the children's ability to learn depends on whether the content is at the student's developmental level and the child's interests and experiences (Glickman, 1991). Teaching is a deliberate and intensely intellectual practice. The planning of units, lessons, activities, demonstrations, labs and field trips involve meticulous instructional decisions involving the compatibility of the content to the students' cognitive abilities, learning styles, and interests. In order to increase the success of the students' learning, all of these objectives must be achieved. Carl Glickman, author *of Pretending Not To Know What We Know*, believed that effective teaching is not a set of generic practices, but instead is a set of context driven decision effective teachers that reflect about their work, observe whether students are learning, and then adjust their practice as a result (Glickman, 1991).

The nations' fifth through eighth grade science teachers are highly dependent on the commercially published textbooks and programs in teaching their students. The following are the publishers of primary textbooks used in the nation's science classroom: Prentice Hall. Inc., McGraw-Hill and Merrill Co., Addison-Wesley Longman, Inc., Scott Foresman, Silver Burdett Ginn, Holt, Rinehart, and Winston, Inc., Harcourt Brace and Harcourt, Brace and Jovanovich, Houghton Mifflin Company, McDougal Littell and D.C. Heath, Scholastic, Inc., Globe Fearon, Inc. and Cambridge, Carolina Biological Supply Co., Kendall Hunt Publishing, and Lawrence Hall of Science. The amount of science content covered in 2000 commercial textbook has dropped by about 16 percent when compared to commercial textbooks in 1993. The amount of time spent preparing students for state exams may have had some impact on this decrease in coverage of material (Smith & Banilower, 2002).

The fifth through eighth grade science teacher believes that the quality of the commercial textbooks has degraded from very good to good when the 1993 survey was compared to the 2000 survey. Errors in the science textbooks are not uncommon. The fact that there are fewer publishers of science textbooks in the 2000 study when compared to the 1993 study may also impact the quality of the science textbooks. The fifth through eighth grade science teachers have less control over the curriculum due to the increased demands made by state standardized testing (Smith & Banilower, 2002).

Science Education Standard Impact on Curriculum

The science education standards recommend inquiry based curriculum. However, the directive of inquiry based science curriculum is still not met in the science education curriculum of the nation or in the case of this study, Central Texas. The integration of math and other subjects is also an area of opportunity recommended by the standards. The directive of creating an environment for the learning of science and creating a desire to become a lifelong science learner is a hard pressed objective to achieve in this present environment of high stakes testing. The goal of the integration of the science standards with other standards also faces obstacles of implementation (Smith & Banilower, 2002).

Over half of the nation's fifth through eighth grade classrooms are self contained. The rest are non-contained and have departmentalized instruction. The primary teaching strategies are lectures and discussions. The lectures in the fifth through eighth grade science classroom emphasize the learning of terms and facts versus the understanding of science concepts and the process of scientific investigation. The 2000 NSF study revealed that the amount of time spent on science, while greater than in the 1977 NSF study, was the same as in the 1993 NSF study (Smith & Banilower, 2002).

The nation's class size continues to be large with over 20 students per class. The large class size can make it prohibitive for the teacher to give students the necessary time to learn and retain science concepts. The fifth through eighth grade science student spends the least amount of time learning science when compared to the earlier and later grades. The Third International Math and Science Study, which sees the middle school science curriculum as a major factor in the low performance in science of the nation's youth, corroborate this finding. The fifth through eighth grade science classrooms are becoming more diverse and are not ability grouped (Smith & Banilower, 2002).

The nation's science teacher must be able to meet the educational needs of students whose first language is not English, as well as various learning styles of students. The teacher must also be able to meet the special needs of the increasing number of children with disabilities who are being mainstreamed into the science classrooms. The nation's fifth through eighth grade science students take just a few field trips per year. The teachers will primarily depend on audiovisual aids and demonstrations to teach students. In the fifth through eighth grade classroom, the use of computers for science simulation exercises and the collection of data via probes are very rare (Smith & Banilower, 2002).

Students in Singapore spend 4.6 hours per day on homework. The international average for homework is 2.4 hours per day, which is corroborated by the International Association for the Evaluation of Educational Achievement (IEA). U.S. eighth graders average 2.3 hours per day on homework. On average, the amount of science homework assigned to U.S. fifth through eighth grade students is about 30 minutes a week (Haynes & Chalker, 1997).

The primary methods of assessing the students' understanding of the science concepts taught are observation once or twice a week, review of homework, and the embedding of some activities to see if the students truly understand the concepts. One of the most important tools used by scientists is the lab or field notebook that is reviewed once or twice a month. Pre-assessment to learn students' previous knowledge base prior to entering class is done a few times a year. Simulation exercises to evaluate students' understanding and the ability of students to perform the scientific process are rarely used (Smith & Banilower, 2002).

The science education standards face serious challenges to their implementation in science classrooms in the nation and Central Texas. The current instructional practices are not in alignment with the directive of an inquiry based science education classroom since the lecture format is more in line with the traditional educational practices of the past. Furthermore, the classroom size, students whose first language is not English, and the fact that very few field trips and labs are integrated into instructional practices are all detrimental factors to science classrooms meeting the science education standards. The amount of time allocated to the science class is generally 40 to 50 minutes per day. This is also not conducive to inquiry based science experiments. Authentic assessments by reviewing the field notes are not a common practice in the national and Central Texas science education classrooms. The implementation of the science education standards is limited at best (Smith & Banilower, 2002).

Science Achievement

International, national, state, regional, and local science achievement data showed that some United States' students had a deficit in their understanding of science once they entered high school, primarily when compared to some nations in the Pacific Rim. National science achievement data corroborated this finding (TIMSS, 1999). Researchers indicated that attitude, beliefs, teachers' effectiveness, parental involvement, and curriculum may have had an impact on the ability of students to learn science. The research of the 1980's and 1990's added to the knowledge of the areas for focus while teaching science to the nation's children by identifying key attributes to academic achievement, one of which was the curriculum (Gardner, 1991; Ware, 1992). The following paragraphs discuss the NAEP, TIMSS, and PISA measurements of science achievement in the nation's children.

National Assessment of Educational Progress (NAEP)

Congress responded to "*A Nation at Risk*" with the 1988 National Assessment of Educational Progress Improvement Act (NAEP) legislation that created the National Assessment Governing Board (NAGB). The legislation directed the board to identify suitable achievement goals for each subject area that the NAEP measured. Although the NAEP achieved this directive, the USA's quest for scientific literary has not been achieved. Dr. George D. Nelson, director of the American Association for the Advancement of Science Project 2061, best summed up the USA's progress in his statement after the release of the 2000 NAEP Science Assessment results. He stated that the 2000 NAEP science assessment results revealed that the nation's children are not prepared for the challenges that they face in a world that is becoming increasingly more scientifically and technologically driven.

The relationship of educational achievement in the sciences impacts the U.S. citizen as consumers in the areas of work, politics, and parenting. Science education of the nation's children is understood to have a direct relationship to the qualities prized by the American people such as prosperity, security, and health which are dependent on the attainment of scientific literacy. Dr. Nelson also agreed with his earlier predecessors that scientific literacy and the knowledge and skills that are acquired in the quest for scientific literacy are essential to American citizens. The NAEP average scores showed no progress over the past four years and a decline in the average scores of twelfth graders. The data showed that 81 percent of twelfth graders performed below proficient levels (AAAS, 2001).

The NAEP science achievement gaps among ethnic groups were pronounced. The average gap in scores between Anglo and African American twelfth graders were 31 points three percent of African Americans were considered to be proficient whereas 23 % of Anglos were proficient in science. The narrowing of the gaps between ethnic groups was due to the decline in the science achievement of the Anglo students by five points and the African American students by one point (NAGB, 2000). As stated so eloquently by Kimberly Oliver, National Teacher of the Year 2006-2007, equity in the nation's educational systems is imperative if the nation is to achieve scientific literacy for all (AAAS, 2001; Oliver, 2007).

Although both the American Association for the Advancement of Science and the National Research Council have developed science literacy goals that have been carefully crafted with the nation's science communities; to date, these goals have generally been poorly translated into state and local standards. Most state standards still envision science education as the accumulation of almost random facts rather than the development and application of concepts and skills (AAAS, 2001).

Dr. Nelson's first recommendation was that the curriculum materials and assessments be in aligned with learning goals. His second recommendation was that the local curricula be well designed in that the K-12 curriculum lessons and labs are integrated and linked to preceding grades. The third recommendation was that teachers should recognize and use effective educational strategies. Dr. Nelson's fourth recommendation was that states, school districts, and communities be committed to long term reform because there was no quick fix to the ills of the educational sector (AAAS, 2001).

Dr. Nelson suggested that improving science literacy in American educational institutions could result in improved science achievement scores, but these improvements could not be done overnight. History confirms that the results of the implementation of a new curriculum could take five years or more. Training of U.S. teachers in the use of the new curriculum, as well as true commitment by state and local stakeholders to coherent long-term reform programs, is also necessary. Nelson also said "unless immediate actions are taken to remedy all of these shortcomings in science education, the prospects for improved science learning and resultant increase in NAEP scores will remain grim for the foreseeable future" (AAAS, 2001, ¶ 4). Nelson expounded on whether or not the achievement gaps have narrowed between majority and minority students:

> Evidence so far suggests not. For instance, the black-white gap in reading test scores for 9-, 13- and 17-year-olds actually narrowed throughout the 1970s and

> until the mid-1980s, a time when the nation's schools, according to *A Nation At Risk*, were deemed to be on the brink of calamity. And yet, from about 1988 to the present, a period marked by rapid growth of testing and new rules for holding schools accountable, those achievement gaps have again started to rise. Has achievement overall improved? As it happens, savvy school bosses operating in high-stakes environments have installed intensive test-preparation programs narrowly focused on drilling for specific exams, thereby pumping up test scores in a matter of weeks or months. But we find those steroid-induced gains don't transfer into real and lasting learning, because the improvements on the targeted test typically cannot be detected in other tests of achievement. In a recent study of eighteen states with high-stakes testing programs, David Berliner and Audrey Amrein of Arizona State University concluded, Analyses of these data reveal that if the intended goal of high-stakes testing policy is to increase student learning, then that policy is not working (AAAS, 2001, ¶ 4).

Project 2061— The Stakeholders

The American Association for the Advancement of Science (AAAS) founded Project 2061 in 1985 to help all Americans become literate in science, mathematics, and technology. The publication “Science for All Americans” set out recommendations for what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school. “Science for All Americans” laid the groundwork for the nationwide science standards movement of the 1990s. Another publication in 1993, “Benchmarks for Science Literacy”, translated the science literacy goals in “Science for All Americans” into learning goals or benchmarks for grades K–12. Many of today's state and national standards documents have drawn their content from “Benchmarks for Science Literacy” (AAAS, 1993 ¶ 1).

It became clear to the stakeholders of the United States’ corporations, educational systems, governments, and communities that the deficit in students’ science knowledge and the achievement gaps found between majority and minority students could not be sustained if the USA was to continue to lead the world in scientific research. Dr. Nelson, director of the American Association for the Advancement of Science Project 2061, stated that future generations of scientists should reflect the nation's growing diversity. Nelson further stated, “What is more, the nation’s citizens must understand the importance of science in sustaining and improving the nation’s quality of life. This will not be possible unless we make significant improvements in science education for every student” (AAAS, 2001, ¶ 4). Another issue that Dr. Nelson addressed was how swiftly science literacy could be achieved and how rapidly goals could be attained. Nelson stated that the 2000 NAEP results indicated, “the vast majority of the nation’s students today are learning very little science. They are taught to memorize some facts and vocabulary, but almost never to connect the knowledge into a coherent picture of how the world works and how we have come to know it” (AAAS, 2001, ¶ 4). Nelson said that USA’s students do not understand science or the scientific process.

Third International Math and Science Study

The Trends in International Mathematics and Science Study (TIMSS) was developed by the International Association for the Evaluation of Educational Achievement (IEA) to assess trends in students' mathematics and science achievement. TIMSS provides countries with data on students' progress in mathematics and science achievement. The United States has gained data on the mathematics and science achievement of the nation’s students compared to that of students in other countries. Started in 1995, TIMSS has collected new data every four years. TIMSS data has been collected in 1995, 1999, 2003 and 2007 (TIMSS, 2007, ¶ 2).

The TIMSS revealed that U.S. fourth-graders performed poorly, middle school students performed worse, and high school students performed badly when compared to their peers in other industrialized countries. The criteria used in the TIMSS study indicated that the USA students were "average" in elementary school and American high school students were "near the bottom". High school students that enter higher education or the labor force are doing so badly in science that they are considerably weaker than their peers from other countries. The U.S. idea of "advanced" is clearly below international standards (Forgione, 1999).

The Third International Math and Science Study (TIMSS) had a tectonic effect on the U.S. educational system. The TIMSS, like Vannevar Bush's report to President Franklin Roosevelt, *"The Endless Frontier,"* and T. H. Bell's report, *"A Nation At Risk,"* had major repercussions for education, particularly in the area of science.

Dr. Pascal D. Forgione, a former U.S. Commissioner of Education Statistics, reported that science offered a common basis for comparing American schools to the rest of the world because other subjects vary from one country to another. The TIMSS was a study that involved a half-million students in 41 countries. The world's leading experts on comparative studies and educational systems as well as experts in assessment design and statistical analysis held oversight responsibility of the study. Commissioner Forgione gave a synopsis of the TIMSS results in his answer to the question, "Were the TIMSS comparisons fair?"

> The comparisons are fair traditionally; the most common criticism of international studies is that it is unfair to compare US results to other countries because their national scores are based on a highly selective population. While this may have been true in the past, it is simply not valid in the case of TIMSS. Using several different methods of measuring enrollment, the data indicated that the enrollment rate in the United States is closer to the international average than to the desirable upper extreme. Even the theory that higher secondary enrollment rates hurt a country's overall achievement did not hold true. Students in countries with higher enrollment rates tended to score significantly higher on both the math and science general knowledge assessments. Higher

> secondary enrollment rates are associated with higher levels of performance, rather than the reverse. The range of scores, from high to low, is no greater in the United States than in the higher-scoring countries (Forgione, 1999, ¶ 3).

Considering the superior resources of the United States and the level of educational spending that far exceeds its competitors, the United States should out-perform nearly everyone. This is not the case. Dr. William Schmidt, the overseer of the research effort into the TIMSS results, said the real cause for the failures was the weak science curricula in U.S. middle schools (Forgione, 1999):

The biggest deficits in the curricula were found at the middle school level. In middle school, most countries shift curricula from basic arithmetic and elementary science to the direction of chemistry, physics, algebra and geometry. Even poor countries generally teach a half-year of algebra and a half-year of geometry to every eighth-grader. However, in U.S. middle schools, most students continue to review arithmetic and are more likely to study earth science and life science as apposed to physics or chemistry (Forgione, 1999, ¶ 10).

In the October 2006 issue of *Phi Delta Kappan, the 16th Bracey Report on: The Condition of Public Education,* by Gerald Bracey, reported that the "slip" of science scores between 1995 and 2003 as cited by Friedman in *The World is Flat* was "making much to do about very, very little" (Bracey, 2006, p.155) Bracey stated that only three nations achieved top rankings in science based on TIMSS-R: England, Singapore and Hong Kong. However, it was Hong Kong that had a 34-point gain in science. Bracey stated that U.S. eighth graders had a 15-point gain in science (Bracey, 2006, p. 156).

Bracey gave a different picture of science achievement than Dr. Forgione, Jr. (Bracey, 2006). All science achievement assessments were correct. The perceived differences were due to the facts that the data was analyzed at different times and/or was interpreted differently. The true question that needed to be asked was, "Did science performance of U.S. fourth and eighth graders change between 1995 and 2003" (Bracey, 2006, p.156)? There was no measurable difference for U.S. fourth graders in average science achievement.

Program for International Student Assessment (PISA)

The United States also participated and collaborated in another international assessment called the Program for International Student Assessment (PISA). The Organization for Economic Co-operation and Development (OECD) developed the program in 1997. The purpose of the PISA study was to compare the academic achievement of 15-year old students across nations with the intention of improving educational practices for all. The PISA assessments were given every three years and allowed approximately one year to analyze the data (IEA, 2004).

The first PISA was administered in 2000 and over 265, 000 students from 32 countries participated in the PISA study. The focus of the 2000 study was science literacy. Another PISA was administered in 2003 and over 275, 000 students from 41 countries participated in the PISA study. The focus of the 2000 study was science. The results of the PISA test often contradict the Trends in International Mathematics and Science Study (TIMSS) administered by the International Association for Evaluation of Education Achievement (IEA). The PISA study focused on an international assessment that dealt with real-life problems and life-long learning (IEA, 2004).

PISA test students were aged between 15 years to 16 years. Students in schools were tested, not home-schoolers. Students took a two-hour handwritten test. The test was a combination of multiple-choice and essay. In total, there were six and one-half hours of assessment material, but each student is not tested on all the parts (IEA, 2004).

The PISA 2003 study found that Finland, Japan, Hong Kong, and Korea had roughly equal scores in science. Finland placed first in literacy, followed by Korea in second place and Canada in third. Indonesia placed last. In problem-solving, South Korea came first, with Finland and Hong Kong tied second.

Jouni Välijärvi, the administrator of the Finnish PISA study, believed that the high Finnish scores were due to outstanding Finnish teachers and to Finland's 1990s LUMA curriculum. The curriculum was specifically designed to improve student’s skills in mathematics and natural sciences. It was also important to note that the Finnish school system taught the same curriculum to all students. All Finnish schools had similar scores and individual Finnish students' scores were also similar. Pauli Siljander of Finland attributed the outstanding results to the many socio-political decisions that Finland has made. Finland’s position on education was that education is important to the Finnish welfare state and cannot be considered separate from the socio-political issues of the country (Siljander, 2005).

Comparing the PISA, NAEP and TIMSS

The Program for International Student Assessment (PISA), the NAEP or Nations’ Report Card, and the TIMSS are important assessments of the nation’s scientific literacy; however, it is important to understand the differences as well as the similarities of the studies when making the comparisons (IEA, 2004). The National Center for Education Statistics (NCES) provided information to assist educational stakeholders such as policymakers, researchers, educators, and the public to obtain a comprehensive picture of the U.S. students' performance in the arena of science. NCES performed a comparison of NAEP, TIMSS, and PISA in science so as to understand the similarities and differences in those science results and to identify and understand the contribution of each assessment to the overall knowledge base of student performance in these three studies (Neidorf, Binkley, & Stephens, forthcoming).

The NAEP findings contradicted the Third International Mathematic and Science Study (TIMSS) by reporting that U.S. fourth graders are performing well. The NAEP findings showed that 71 percent of fourth graders scored below proficient achievement levels. The NAEP data does show that some states performed better than others for various reasons; but on the whole, the nation did not perform well (Neidorf, Binkley, & Stephens, forthcoming).

Each assessment had a different design and perspective of students' science achievement. The three assessments were conducted periodically, each with different time tables to allow the monitoring of student achievement over time. The similarities of these studies were age, grade, and content of areas studied. The differences were in the assessment designs that served different purposes. For example, the NAEP targeted students in the fourth, eighth, and twelfth grades, and the results reflected the performance in these grades. The TIMSS targeted all students in grades that contained the largest number of nine-year olds, which is typically fourth graders, and all students in grades that contained the largest number of 13-year olds, which is typically eighth graders. PISA targeted students from ages 15-years to 16-years, which are typically 10th and 11th graders (Neidorf, Binkley, & Stephens, forthcoming).

The NAEP sources for information on science achievement test questions are adapted from U.S. curricula. The National Assessment Governing Board (NAGB) uses the U.S. science curricula as external benchmarks of performance. The nationally used benchmarks are defined as basic, proficient, and advanced. The TIMSS and PISA assessments are based on participant's science curricula. The U.S. international source of comparative information on science achievement in the primary and middle grades is the TIMSS (Neidorf, Binkley, & Stephens, forthcoming).

The 2003 TIMSS science results for fourth graders in the United States showed an average score that was higher than the international average score. The U.S. fourth graders placed fourth after the Pacific Rim countries Chinese Taipei, Japan, and Singapore (Neidorf, Binkley, & Stephens, forthcoming).

The 2003 TIMSS science results for U.S. eighth graders showed a score was above the international average score. The seven countries that performed better than the USA were Singapore, Chinese Taipei, Hong Kong, Japan, Hungary, and the Netherlands; most countries that performed better than the USA were located in the Pacific Rim, with the exception of Estonia and the Netherlands (National Center for Education Statistics, 1996, 1998).

Although the increase in the nation's eighth grade science results was good news for U.S. eighth graders, there appeared to be a global decline in science scores. The International Association for the Evaluation of Educational Achievement (IEA) report called "*A Splintered Vision,*" published in 1997, collaborated with NAEP and documented that the U.S. science education programs are incoherent and fragmented. When a topic is introduced in one year, with intended instruction for one or more years, and then is excluded from the curriculum, it causes fragmentation. The TIMSS report recommended a more focused and coherent curriculum. A curriculum that covers topics that correspond to the students' developmental level and also increases gradually with each higher developmental level would be considered a focused and coherent curriculum. The spiral curriculum has these characteristics (National Center for Education Statistics, 1996, 1998).

Another example of a coherent curriculum is one in which topics are introduced in a logical sequence. Different topics 'fit' as part of an integrated, systematic whole, both within a developmental level and from year to year. The coherent curriculum starts with simple concepts at first, and then introduces more complex concepts. The simple concepts are developed more fully by gradually moving to more complex concepts. The spiral curriculum meets these criteria (National Center for Education Statistics, 1996, 1998).

In 2002, President George W. Bush signed into law the No Child Left Behind (NCLB) Act to focus the nation's schools system on assessment and accountability. The NCLB Act, which enforces assessments such as the Texas Assessments of Knowledge and Skills test, also agrees with the NAEP national study, the TIMSS international study, and the national assessment of the current practices in the nation's science classrooms that the nation's children have a deficit in science (National Center for Education Statistics, 1996, 1998).

No Child Left Behind and Texas Assessment of Knowledge and Skills™

President Bush's education proposal believed that attention to the nation's science instruction was needed and worthy of attention. NCLB provides a blueprint to accomplish this goal. NCLB is a blueprint that should guide the upcoming reauthorization of the Elementary and Secondary Education Act (Bush, 2006.). NCLB was the USA's national response to its educational issues, while the Texas Assessment of Knowledge and Skills™ (TAKS) was Texas' response to its state's educational issues.

Implemented at the beginning of spring 2003, TAKS is the evaluation and assessment phase of Texas' statewide curriculum. The Texas Essential Knowledge and Skills (TEKS) that are found in the statewide curriculum are the criteria that are assessed. The Texas Education Agency (TEA) is the agency that has oversight responsibility in the administering of the TAKS testing program. In 1998, TEA started requiring science to be added to the TEKS and began the process of having the science TEKS assessed by the TAKS (Bush, 2006, TEA, 2006). The following are the results of the 2003 to 2006 science TAKS results for Education Service Center Region 12 (Region 12), the 12th district that is located in Central Texas. ZISD and CISD are included in Region 12.

TAKS Results

The 2006 TAKS science results from Region 12 (see Table 2.1) showed that 75% of all fifth grade students met the minimum standard in science, compared to 62% in 2005, 58% in 2004, and 38% in 2003. Eighth grade science results from the 2006 TAKS science results for Region 12 showed that 54% of all students met the minimum standard. The 2006 TAKS science results for tenth graders from Region 12 showed that 61% met the minimum standard, compared to 53% in 2005, 50% in 2004, and 38% in 2003. The 2006 TAKS science results for 11^{th} grade students from Region 12 showed that 73% of the students met the minimum standard, compared to 79% in 2005, 61% in 2004, and 41% in 2003. The 11^{th} grade science results from July 2005 showed that 59% met minimum standard in 2003, 70% in 2004, 59 % in 2005. The 11th grade science results from spring 2005 showed that 80% met minimum standard (see Table 2.1). It is important to note that the WMS has no TAKS scores because they are a private institution.

Table 2.1

TAKS Science Scores for Region 12Percentage that Met Minimum Standard

Grade	TAKS 2003	TAKS 2004	TAKS 2005	TAKS 2006
5th grade	38%	55%	62%	75%
8th grade	NA	NA	NA	54%
10th grade	38%	50%	53%	61%
11th grade	41%	61%	79%	73%

The 2006 TAKS science results for ZISD (see Table 2.2) indicated that 59% of the fifth grade students met the minimum standard, compared to 44% in 2005, 58% in 2004, and 62% in 2003. The 2006 eighth grade TAKS science results for ZISD showed that 37% of the students met the minimum standard. The 2006 TAKS science results for ZISD tenth graders showed that 39% of the students met the minimum standard, compared to 35% in 2005, 45% in 2004, and 42% in 2003. The 2006 TAKS science results for ZISD indicated that 55% of the 11th grade students met the minimum standard, compared to 59% in 2005, 70% in 2004, and 59% in 2003 (see Table 2.2).

The 2006 fifth grade TAKS science results for CISD indicated that 92% of the students met the minimum standard, compared to 81% in 2005, 87% in 2004, and 76% in 2003. Eighth grade science TAKS results for CISD indicated that 65% of the students met the minimum standard in 2006. That same year, 81% of the tenth grade students in CISD met the minimum standard, compared to 67% in 2005, 76% in 2004, and 80% in 2003. The 2006 TAKS science results for CISD indicated that 87% of the 11th grade students met the minimum standard, compared to 92% in 2005, 92% in 2004, and 82% in 2003 (see Table 2.2).

Table 2.2

TAKS Science Scores for ZISD and CISD Percentage that Met Minimum Standard

School/Grade	TAKS 2003	TAKS 2004	TAKS 2005	TAKS 2006
ZISD 5th grade	62%	58%	44%	59%
CISD 5th grade	76%	87%	81%	92%
ZISD 8th grade	NA	NA	NA	37%
CISD 8th grade	NA	NA	NA	65%
ZISD 10th grade	42%	45%	35%	39%
CISD 10th grade	80%	76%	67%	81%
ZISD 11th grade	59%	70%	59%	55%
CISD 11th grade	82%	92%	92%	87%

It is important to note that ZISD and CISD had significantly different science scores each time TAKS science test was administered. ZISD science scores were consistently below CISD science scores.

Theories of Learning (Epistemology)

The teaching and the learning of science has a fundamental foundation based on the work of many researchers whose objective was to understand how children learn and how can teachers teach effectively so that children can be effective learners. The following highlights some of the work done by researchers over the decades to answer these questions and thereby help improve the teaching and the learning of science.

The Epistemology or theory of knowledge evaluates “What is knowledge?”, “How is knowledge acquired?”, and “What do students know?”. The educational systems are primarily based on positivist or objectivist epistemology where the information in the teacher’s brain is transferred to the brain of the student, similar to the analogy of radio wave transmitters and receivers (Roth, 1993). An alternative epistemology would be constructivism, where the student knowledge is derived from individual experiences and beliefs. The learners adapt by converging past knowledge with new knowledge and conceptual understanding of concepts are modified in the student (von Glasersfeld, 1987).

Other scientific research performed by Piaget and others in the 1970s hypothesized that children show various levels of cognition of knowledge and skills at various developmental levels. Scientific research performed by Walsh in 1991 showed that the findings given by Piaget and others in the 1970’s were not indicative of the cognitive abilities of the children studied, but were artifacts of the research tasks given to the children (Walsh, 1991).

In 1962, the western world discovered Lev Vygotsky’s pioneering work, which revealed that learning also took place in a social context. In the 1970s and 1980s, Vygotsky's work began to be more widely known in the United States. Vygotsky added the dimension of the social context of how knowledge was acquired during the 1970s and 1980s. Vygotsky's research promoted a view of learning based on both individual and social construction and showed the importance of social functions in supporting and extending learning. Language, tools, and social interactions all assisted children in acquiring skills and concepts. For example, a problem that seemed beyond the capabilities of a child working alone with paper and pencil can often be solved when appropriate manipulatives were available (Walsh, 1991).

When children interact with each other or with adults, their learning potential, or per Vygotsky, "the zone of proximal development," is extended, increasing both the types of tasks that can be accomplished and the amount of learning that takes place. The child is able to extend and increase both the level of tasks that he or she was able to perform as well as the level of learning he or she was able to acquire. This concept enabled the child to use aids such as manipulatives or guidance from an adult to help him or her proceed to the next level of learning of a new concept or skill. Early learning appears to be greatly enhanced by ongoing interactions between children and their world, including adults in that world. Talking about ideas, with informal error corrections by adults and peers, is often as important as thinking about ideas. Conversations can gradually become internal dialogues that guide the child's progress through a problem. Vygotsky's research on learning in social and individualized constructs gives deeper insight into how children learn concepts and skills. Vygotsky's research shows the relationship of extension and retention of knowledge and skills. The educational and scientific academies agreed that language, tools, and social interactions were all essential to children's acquisition of concepts and skills (Walsh, 1991).

The body of research on early childhood learning showed that interaction between peers and adults greatly facilitated the cognitive abilities of young children. The child's verbalization of ideas, along with the creation of an environment where the child felt safe to make mistakes and receive correction, was essential to increasing the child's cognitive abilities. The research revealed a later phase of cognitive abilities where the child would have internal dialogues that assisted the child in problem solving (Walsh, 1991).

The way that people evolve over time is considered "human development". Development of the human race is no longer restricted to "child development"; it is now understood that humans continue to develop intellectually, emotionally, socially, and morally throughout their lives. Research on the role of formal classroom instruction in the context of culture and language on human development and learning is explored in the following paragraphs (Thomas & Loxley, 2001).

The universal theory of development based on Western European and North American values, as well as methods of raising children, is no longer an absolute standard because development is based on culture and the socialization of children (Greenfield & Cocking, 1994; Tharp & Gallimore, 1988; Vygotsky, 1978). Research has shown that all cultures have their own goals for their children, which in turn effects how the people of that culture learn and think. This phenomenon helps explain why children learn skills and behaviors differently. Research results reveal that culture plays a vital role in human behavior. Jensen stated in his 1998 research that all learning is contextual (Jensen, 1998). The learner makes connections between personal understandings and cultural perspective; therefore, if information in the classroom is not presented from that child's cultural perspective, then there may be a disconnection in his or her understanding of the classroom information the teacher is trying to impart. The students that learn are able to make a connection between their personal experiences and the curriculum material that is being taught. Students construct their own meanings to the acquisition of knowledge regardless if it is through direct observation of an expert, which is the apprenticeship model, or through direct instructions, which is a traditional approach to learning (Brooks & Brooks, 1999; Cobb, 1994; Perkins, 1999; von Glasserfeld, 1995). A paradigm shift occurs because now the learner plays an active role in learning and the teacher now has the responsibility of learning the student's perspective and prior knowledge in order to create an effective learning environment (Brooks & Brooks, 1999; Gardner, 1991).

Prior to the 1980s, understanding the methods of how children obtained knowledge was limited. The status quo considered young children's interface with their world to be passive. Starkey and Cooper (1980), Strauss and Curtis (1981), and others, changed the paradigm of what was known about how children learn and interface with their world. The researchers' findings also showed that young children were aware of a number of differences between objects.

Starkey, Cooper and Curtis found that young children were not passive but were capable of encoding a great deal of knowledge at a rapid rate. A prime example of this was the ability of young children to learn languages. It was also discovered that the opening to the neurological pathways in children's brains for the absorption of large amounts of information at a rapid rate starts to decrease as the child gets older. The older child's brain soon mimicked the adult's brain in the learning of concepts at a slower rate. Certain supposed constraints on what and when children could learn (Walsh, 1991).

Researchers' pioneering works have been expanded in recent years, such as Karen Wynn's 1992 research, which showed the crucial importance of early childhood experiences in the building of cognitive abilities. One paradigm shift was that young children were not passive learners, but acknowledging differences in what they observe. Wynn did work in 1992, the "Evidence Against Empiricist Accounts of the Origins Numerical Knowledge," that explained the direct relationship to early childhood experience and cognitive abilities (Wynn, 1992).

Investigations into problem solving showed that an important step in solving a problem is choosing a model or representation for the problem situation (Polya, 1948, 1962; Lesh, Post, & Behr, 1987; Schoenfeld, 1987; Janvier, 1987). Researchers and theorists stress the importance of natural language, concrete models, physical or mental visual images (including pictures, graphs, and diagrams), and symbols in representing mathematical ideas (Bruner, 1964a, 1964b; Lesh, Post, & Behr, 1987; Silver, 1987; Hiebert, 1988). The aptitude of multiple representations, especially the ability to translate among representations, is found to be important in problem solving.

Researchers also noted that the symbolic manipulations that students carry out in school were often disconnected from reality and common sense (Hiebert, 1984, 1988; Barody & Ginsburg, 1986; Van Lehn, 1986; Silver, 1986; Resnick, 1987b; Kaput, 1987, Romberg and Tufte, 1987). As a result, students unwittingly produced nonsense. Research also showed that if symbolism was closely related to actions and familiar to young students, then they were able to deal effectively with the symbolism (Hiebert, 1984, 1988; Carpenter, Fennema, & Franke, 1994). Calls for increased tool use in schools were common before 1990. Both research findings and theoretical considerations supported the increased use of tools or manipulatives in school (Bruner, 1964a, 1964b; Hiebert, 1984, 1988; Suydam, 1984, 1986 Lesh, Post, & Behr, 1987; Resnick, 1987b).

Concept Transfer

German psychologist Hermann Ebbinghaus, based on his work of 1885 on memory, discovered that correct spacing of concepts taught to children increased their cognitive ability to learn and retain the concepts. Researchers continue to confirm Ebbinghaus' findings (Caple, 1996). The long term retention is more effective when concepts are spaced over time. The child's ability to transfer concepts and skills is also more effective when the concepts and skills are learned over time versus a large amount of concepts and skills "crammed" into the child's brain over a short period of time. Most of this information goes into short term memory, never to be encoded into long term memory, and therefore forgotten soon after it is taught. The proper spacing of the concepts and skills also help with the recall of the material long after it is taught. The spiral curriculum has many of the characteristics of proper spacing of information that ensures long term retention and good recall of what is learned (Anderson, Reder, & Simon, 1997).

In 1917, Dewey argued that the disciplines' presentation as an isolated body of knowledge can undermine students' motivation to learn that discipline because it does not relate to the students' life experiences. Dewey promoted the presentation of concepts in the context that relates to the learner's life experiences. Dewey argued that the isolated nature of the disciplines undermined the potential in a student, since a particular subject may not have interest to a student. Dewey thought that if the concepts were presented in a context familiar to the learner, the act of learning would be realistic, purposeful, and more effective (Dewey, 1917). The spiral curriculum meets this concept for the learning of science.

Researchers' recognition of cognitive constructivism as a basis for pedagogical theory lends itself well to integration or spiraling of science. Roth believed that the problems of schooling had a direct correlation between educational practices in school and real life problems experienced by the students. Roth believed that the curriculum should incorporate real-world problems with school subject and support student's labors in creating meaningful knowledge (Roth, 1993).

Research has revealed that choosing the proper models of representation is critical to children's abilities to solve problems (Polya, 1948, 1962; Lesh, Post, & Behr, 1987; Schoenfeld, 1987; Janvier, 1987). The ability of children to use language, visualization, concrete models, symbolism and translation, especially in representing mathematical concepts, is also critical to problem solving (Bruner, 1964a, 1964b; Lesh, Post, & Behr, 1987; Silver, 1987; Hiebert, 1988).

It is important to note that the symbols used must relate to the children's life experience in order to solve problems in the real world (Hiebert, 1984; 1988, Baroody & Ginsburg, 1986; Van Lehn, 1986; Silver, 1986; Resnick, 1987; Kaput, 1987; Romberg & Tufte, 1987). If symbols do not relate to the real world, then children will produce results that have no connection to the real world (Hiebert, 1984, 1988, Carpenter & Fennema, 1992). Since 1990, researchers and theorists have concurred that the use of manipulatives and symbolism in schools does help children make connections to concepts and the real world. Both research findings (Suydam, 1984, 1986) and theoretical considerations (Bruner, 1964a, 1964b; Hiebert, 1984, 1988; Lesh, Post, & Behr, 1987; Resnick, 1987) support increased use of manipulatives in school.

Research reveals that learning is no longer based on individual effort or intelligence, but a social process. Learning involves the social process of interfacing with parents, family members, peers, and teachers (Gutiérrez, Baquedano-Lopez, & Tejeda, 1999; Perkins, 1999; Vygotsky, 1978). People learn in a social context and from personal life experiences. Darling-Hammond's 1997 research revealed that social learning lends to the process of constructing meaning from the knowledge. The process of interactions with peers provide an audience for trying out ideas, thinking out loud, and getting feedback (Darling-Hammond, 1997)

Powerful learning outcomes are created when teaching and grouping strategies expose students to academic tasks such as observation, verbalization, interaction, and peer learning (Palincsar & Brown, 1984; Anderson & Pavan, 1993; Cohen, 1994; Oakes & Lipton, 1999; Slavin, 1995). Cognitive and social developments are nurtured in environments of collaborative and cooperative group instruction. A new construct must be formed where intelligence is a continual development of expertise and never static (Sternberg, 1998).

The past two decades of research have revealed how students learn. The fields of research that have embarked on this study of how students learn are cognitive psychology; developmental psychology; cultural psychology; biology and neuroscience, cultural anthropology, sociolinguistics, and sociology. These fields of research have looked at the educators, the students, the families, and the communities (Palincsar &

Brown, 1984; Anderson & Pavan, 1993; Cohen, 1994; Oakes & Lipton, 1999; Slavin, 1995).

The body of research describes two significant and integral points; intelligence is pliable and is molded by the expectation of subjects' culture, experiences, and opportunity (Brislin, 1993; Feuerstein, 1980; Resnick & Resnick, 1989). This is good news for the nation's educational systems because they can impact a student's intelligence. Gardner and others' research have proven that intelligence takes many forms; however, schools tend to draw upon only a fraction of students' intelligence (Armstrong, 1994; Gardner, 1988; Sternberg, 1997). In order to teach all of the nation's children, schools must use various instructional practices in order to impact children's cognitive development. Cognitive development is not limited to just academic pursuits, but also sociocultural pursuits that emphasize human development. In order to teach children in this new millennium, the educator must consider the language, values, perceptions, motivations, emotions, and interpersonal interactions (Greenfield, 1994; Heath, 1983; Lustig & Koester, 1999; Wilkinson, 1990).

Learning is multifaceted and involves psychological processes and social processes that impact the student both directly and indirectly (Vygotsky, 1978; Wertsch, 1991). The understanding of the student's values, the student's interface with his or her family, and the student's cultural values are important in the quest to teach the child. The social context of the home and the school is important to the understanding of how students learn and impacts how educators teach. The understanding of the sociocultural context of home and school will impact how the educators organize knowledge and deliver instruction to meet the ever growing needs of this culturally and linguistically diverse generation (Greeno, et al., 1996, Sylwester, 1993, Wozniak & Fischer, 1993, Zeichner & Hoeft, 1996).

Bruner and Ausubel looked at how concepts are presented to the students in order to motivate students to pursue science instruction beyond the standard requirements in school. Bruner and Ausubel identified how properly organized knowledge plays a key role in the motivation of students to understand and pursue further learning of science. Bruner is the promoter of the spiral curriculum and Ausubel is the promoter of the advanced organizer and meaningful learning (Ausubel, 1960). Bruner's research in public school education examined the nature of learning, knowledge, and instruction. Bruner's assessments identified a number of fundamentals of instruction that should motivate the learner. One of the fundamentals identified was that the focus should be on the student's understanding of the fundamental concepts, instead of just learning skills or facts. In spiral curriculum, attention to the connections among concepts and the use of the instructional method of inquiry could help motivate students in science (Bruner, 1977b; Raizen, 1982; Jacobs & Borland, 1986; Childress, 1994).

The traditional theoretical framework is the oldest and most used framework in the educational system; the following is an overview of the traditional theoretical framework.

Theoretical Framework for Learning

The U.S. educational system responded in 1890-1920 to the new demands made on it by moving from traditional theoretical perspectives of curriculum to an experiential theoretical perspective. The traditional theoretical perspective of curriculum believed that the most important question was "What are the most important aspects of our cultural heritage that should be preserved?" The traditionalist perspective of science was a learning environment consisting primarily of textbook and lectures, with pencil and paper assessment. The apprenticeship model, which was learning from experts, was an example of the traditionalist perspective and was the dominant practice in education. The apprenticeship model served the nation well in the pre-industrial age of agricultural societies and still has some validity today based on the research of Lave and Wenger (Lave, 1988; Lave & Wenger, 1991; Posner & Rudnitsky, 1994).

Due to the new demands placed on the growing U.S. economy and governing systems, the next theoretical framework in education to evolve was the experiential. The driving question of the experiential perspective of curriculum was "What experiences will lead to the healthy growth of the individual?" The Deweyian broad-based curriculum was used in the U.S. model in the Gary, Indiana school system since most experiences led to the growth and development of the student. The creation of field trips, community-based learning, hands-on learning, the exercising of students' minds and bodies, and students moving from class to class with teachers staying in one room were all by-products of the experiential-progressive movement (Posner & Rudnitsky, 1994). The experimental perspective impact on the science curriculum was the beginning of the child centered, inquiry mode of learning and teaching with field trips.

The next educational theoretical perspective to evolve out of the necessity of the nation's educational conditions was the behaviorist theoretical perspective (Posner & Rudnitsky, 1994). The industrial age placed new demands on the nation's educational system; hence, the factory model of education was introduced. The factory model of education forced all students to fit one mold, which rendered tremendous cost savings to the nation. The factory model of education matched the behaviorist approach to learning.

During the 1950s and 1960s, behaviorist theories of human learning dominated educational practices. Behavioral psychologists John Watson and B. F. Skinner were considered the leading experts; they based their model of human learning on an external reward and reinforcement system. The behaviorist placed little to no value on the internal cognitive processes of learning and the research work on the concept to the mind. The behaviorist perspective fit well with the training or factory model of education found in the industrial age.

The behaviorist approach emphasis is the learning of skills and not concepts. The behaviorist impact on science education was the refinement of the science lab and the establishment of the laboratory notebook and field notes. The complex acquisition of the language is due to environmental responses. Other research contradicts the behaviorist perspective and views. For example, the acquisition of language is thought to have a biological and environmental interface along with input, which results in the internal construct that organizes components of language. This opposes the behaviorist's view of learning (Posner & Rudnitsky, 1994).

The information age gave the educational and the scientific academies access to a vast amount of information and knowledge. The manner in which to pass that information and knowledge on to the next generation was then answered by the Structure of the Discipline theoretical perspective (Posner & Rudnitsky, 1994). The structure of the disciplines' driving question was "What is the structure of the disciplines knowledge?" A science educator who practiced the structure of the discipline methodology was Jerrold Zacharias (1905-1986), developer of radar systems at MIT and nuclear weapons at Los Alamos, had deep concerns about science education in the USA and initiated the Physical Sciences Study Committee (PSSC) (Posner & Rudnitsky, 1994). Other notables of the structure of the disciplines perspective were Hilda Taba (1902-1967), who created the spiral curriculum in the 1950s and later became a constructivist, and Jerome Bruner, who later popularized the spiral curriculum in the 1960s. Other by-products of this time were the creation of new math in 1955; the development of the process writing created in 1980; the National Science Foundation's emphasis on "modes of inquiry"; and the acceptance of the curriculum practitioners in the planning of curriculum. These were all responses to the "knowledge explosion" influenced by the launching of Sputnik. All of these programs greatly impacted the present standards for science education.

The constructivist theoretical perspective is the latest of the educational theoretical perspectives. The constructivist objectives are to create live long learners in the most authentic educational environment that educators can create. The constructivist view believes that only through authentic practices can one tap the intellectual and creative potential of each child (Posner & Rudnitsky, 1994).

Research on the Teaching and Learning of Science

A review of the literature revealed that there is not an extensive amount of research in print on the teaching and learning of science for middle school students. There are a smaller number of studies on science curricula that directly impact students' achievement with comparison groups, and even fewer studies on science for subgroups by sex, minority status, and urban status. However, the findings strongly suggest that science curricula are more effective when it is inquiry-based. The following is a summary of some of the research found in the literature.

The National Science Teachers Association featured an article, by Grumbine and Alden, titled "Teaching Science to Students with Learning Disabilities" that was published in *The Science Teacher* on March 2006, p. 26-31. The article revealed the need to address the fact that most science teachers had little to no training in identifying and meeting the needs of students with disabilities; this need, with the growing inclusion practices in American, must be addressed in the nation's science classrooms. The article recognized that between five and ten percent of all K through 12th grade children were identified as having a learning disability (U. S. Department of Education, 2002; Kavale & Forness, 1995). Research showed that children with learning disabilities perform one standard deviation lower on science achievement tests than those students without disabilities. The article also reviewed a science teacher education program called *Biology Success* that was funded by the National Science Foundation. The program was designed to give science teachers ideas, tools, and inspiration for teaching the diverse learners. The study revealed that it has yet to be proven that the principles discovered meet the requirements of good pedagogy for all science students; however, it has proven to be effective with the learning disabled student. The following are the principles that were revealed in the study: 1) Learning is enhanced when teachers recognize and teach to diverse learning styles and strengths; 2) Content learning is supported by explicit instruction in skills and strategies; 3) Learning is facilitated when instruction and assessment are clearly organized; 4) Learning is maximized when instruction and assessment are based on explicit objectives; 5) Learning is improved when teachers provide consistent feedback; and, 6) Learning is sustained when students develop self-knowledge (Norman, Casea, & Stefanich, 1998; Anderman, 1994; Grumbine & Brigham Alden, 2006).

In "Common Sense Clarified: The Role of Intuitive Knowledge in Physics Problem Solving" Sherin and Fuson (2005) reviewed the literature and discovered that in the last two decades, a significant body of research had been accrued on the nature of intuitive physics knowledge, or in other words, the knowledge of the world that students bring to the learning of formal physics. However, there was very little research on the role of intuitive physics knowledge in expert physics practice. Sherin's research addressed three questions: 1) What role, if any, does intuitive knowledge play in physics problem solving?; 2) How does intuitive physics knowledge change in ordered to play that role, if at all?; and, 3) When and how do these changes typically occur? The finding of the research revealed that intuitive knowledge does play a role in physics problem solving, especially in the weighting and priority setting for the sequencing of problem solving (Sherin & Fuson, 2005).

The GE foundation requested a review of the evaluation studies of mathematics and science curricula in addition to the professional development models. Clewell, Campbell, Deterding, Manes, Tsui, Rao, Branting, Hoey, and Carson reviewed the literature in search of middle schools' science curricula that effectively increased students' science achievement. The researchers discovered that most middle schools' science curricula did not have studies focusing on the effectiveness of students' science achievement by subgroups such as sex, minority status, and urban status. The finding of the researchers were that science curricula were more effective when it is inquiry based (Clewell, et al, 2004).

Anderson discussed reforming science teaching in the *Journal of Science Teacher Education (2002)*. Anderson's article was titled "Reforming Science Teaching: What Research says about Inquiry". Anderson's research revealed that there was some merit in the studies on inquiry based science education; however, an operational definition of inquiry was not found at present. Anderson specifically looked at the studies discussed by the National Science Education Standards (NSES) committees and discovered that the uses of inquiry in the NSES were three fold: 1) There was Scientific Inquiry which referred to the ways scientists study the natural world; 2) There was Inquiry Learning which referred to the learning process in which students participate in the learning of science; and, 3) There was Inquiry Teaching which referred to a variety of ways science teachers teach science using the inquiry methodology. The science teaching inquiry methodology entailed authentic questions generated by students, process oriented inquiry teaching, and inquiry learning activities.

Shymansky, Kyle and Alport's findings were that inquiry based science education means many things to many people. The researcher revealed that the research suggested that inquiry science education teaching does have a positive effect on increasing science achievement based on the meta-analysis done in 1983. The researchers also revealed that the findings were primarily based on empirical research however; no specific criterion measures were found for the basis for success in increasing science achievement. Nor does the research provide the science teacher with suggestion for how to use inquiry based science teaching in the classroom (Anderson, 2002).

The National Science Foundation commissioned a study on students' science achievement. Researcher Banilower presented to the National Science Foundation a report titled "Results of the 2001-2002 Study of the Impact of the Local Systemic Change Initiative on Student Achievement in Science". The study looked at longitudinal data that pre-tested and post-tested students on their prior knowledge of science content. The study used a hierarchical linear model (HLM) to test the relationships among the independent variables measured at the student and teacher levels and the outcomes measured on the assessment instruments. The model included science achievement gains on each of five sub-scales which were earth science, electricity and magnetism, life science, nature of science, and physical science. The results of the study revealed that the Local Systemic Change (LSC) program had a positive impact on student achievement in science. The overall results showed a positive and direct correlation between increased in student's scores and teacher participation in the LSC professional development program (Banilower, 2002).

Hilda Taba, the Developer of the Spiral Curriculum

Hilda Taba was a nationally recognized authority on curriculum development and design. Hilda Taba's 1962 book, *Curriculum Development: Theory and Practice*, addressed the questions educational policy makers are asking today such as: How should fact be identified for mastery? What knowledge is the most lasting? How is content to be effectively used for maximum application? And, how can student achievement be assessed? Taba addressed the problem of too much data and obsolescence of facts by suggesting that many sets of facts can support the next level of knowledge, ideas, and principles. Taba's findings were that the most powerful ideas and principles "must have scientific validity, must be learnable at the age level at which they are offered, and must have utility in our current culture" (Costa & Loveall, 2002, p. 58).

Taba influenced the design of the spiral curriculum in her book *Curriculum Development: Theory and Practice*. Taba set the foundation of the hierarchy for instruction based on multiple intelligence and knowledge facts which were created to help show how these similar concepts are scaffold to produce higher order thinking. The characteristics of Taba's curricula were inductive teaching strategies that fostered critical thinking skills, multiple objectives, organizing information such as content sampling, the sequencing of learning activities, and the use of inductive teaching strategies (Durkin, 1993; Davis & Clery, 1994; Fraenkel, 1994; Ngozimba, 2001).

Hilda Taba's spiral curriculum is two-pronged with a horizontal integration of learning and vertical integration of learning. Taba's spiral curriculum is organized around concepts, skills, or values, with these factors as the underpinning of the horizontal integration of learning. An example of the horizontal integration of learning is a concept of physics: in elementary school, children could study and understand gravity and its impact on their everyday lives; while at the same time, gravity could be studied by elementary students in reading (Durkin, 1993).

The domain of curriculum development will forever be impacted by the work of Hilda Taba. Taba's "spiral" curriculum use of repetition for key concepts and skills throughout the academic year is important to the educational academy. Both the cognitive and the affective domains are impacted by her inductive instructional strategies, which help to enable students to learn concepts, identify values, and analyze value conflicts and ultimately apply generalizations. Taba's organization activities around concepts and ideas and the sequencing of learning activities require the integration of students' previous knowledge. Taba still influenced many in the educational and scientific academies and helped to reform the curricula of the 1960s and 1970s as well as still impacts curricula today (Parry, 2000).

Spiral Curriculum Research

The literature review revealed that very few studies are in print on increasing science achievement using a spiral curriculum. In 1995, "Effects of spiral testing and review on retention and mathematical achievement for below-average eighth- and ninth-grade students" was published in the peer reviewed journal *International Journal of Mathematical Education in Science*. This study observed two groups of eighth and ninth graders who were tested using traditional testing methods and a spiral testing method. The ninth graders who were tested using the spiral method scored significantly higher than the control group in a pre-algebra class on both a mid-semester test, as well as a semester test. The eighth graders who were tested using the spiral method scored significantly higher than the control group in a basic mathematics course on a mid-semester test (Wineland & Stephens, 1995).

In another study by researchers DiBiasio, Clark, Comparini and O'Connor in 1999 evaluated an innovative first year spiral chemical engineering curriculum. The open-ended project emphasized learning through engagement. The curriculum was spiraled because it revisited concepts periodically with increasing difficulty throughout the curriculum. The purpose of the curriculum was to increase technical proficiency, communication and teamwork skills, as well as help with the identification of chemical engineering majors. The project base was a spiral curriculum where students learned and applied chemical engineering principles by completing a progression of open-ended design projects beginning their sophomore year. This was contrary to the traditional method of solving problems in their textbook. The spiral curriculum reinforced students' understanding of the basic concepts and highlighted the concepts' interrelationships. The spiral curriculum reinforced the concepts by revisiting the concepts in different contexts with ever increasing erudition. This differs from the traditional curriculum's strategy of teaching related but compartmentalized subjects in a lecture based course sequence. The curriculum was evaluated in part by comparing the experimental curriculum with a "traditional" method of courses that were taught concurrently. The traditional course sequence was taught using the instructional method of lecture with some emphasis on project work.

DiBiasio, et al (1999) study all second-year chemical engineering students were randomly assigned to either the experimental or the traditional group and remained in those sections throughout the year. The second year chemical engineering majors' experimental group had 14 students. The remaining 40 students were assigned to the traditional class. The random selection was repeated in the second year of the experiment with half of the total student population in each section. There were 16 students in the experimental section and 18 in the traditional sequence. The result attained by the comparison of students from experimental and traditional course method showed that the students in the experimental class gave more favorable ratings for each of the criteria than students in the traditional class. In addition, qualitative research was conducted where the students from the experimental class were interviewed and surveyed periodically throughout the year. The results of these measures indicated a progression from less favorable towards more favorable ratings of the spiral curriculum. The experimental groups' interest and motivation for pursuing chemical engineering as a career was positively affected by the spiral curriculum. Finally, teamwork and communication skills were more developed in the students from the experimental class. In addition, the results from the design competition suggested that newly developed team work skills actually enhanced students' technical proficiency on "real world" projects (DiBiasio, Clark, Dixon, Comparini & O'Connor, 1999).

In September 2004, the NSF sponsored a collaborative project involving engineering and education faculty members at Virginia Tech (VT). The purpose of the study launched was to undertake department-level reform (DLR) of freshman engineering also called General Engineering (GE) within the Department of Engineering Education (EngE) and the bioprocess engineering option within the Biological Systems Engineering (BSE) program using a theme based spiral curriculum approach. The goal of BSEVT was to initiate long lasting collaborative relationships among VT engineering and education faculty, K through 12 educators, corporations, and policy/decision makers throughout Virginia. The DLR project represented an initial success of the collaborative. The curriculum consisted of the principles of design, ethics, and a systems approach and crosscutting skills of communication, teamwork, life-long learning, research experience, and new laboratory experience. Results of a successful project-based spiral curriculum design, implementation, and evaluation in chemical engineering at Worcester Polytechnic Institute were presented in a series of papers (Lohani, V. K., et al., 2004).

Jerold Touger researched a spiral curriculum design for college students involving the wave phenomena. Touger's results were published in the *American Journal of Physics* in September 1981. The researcher described a single introductory course for non-science and physics majors, emphasizing wave aspects of selected physics phenomena rather than traditional Newtonian mechanics. Modes of presentation, consistent with the notion of a spiral syllabus, were explained with reference to the cognitive and educational theories of Bruner and Piaget. The results were non-conclusive (Touger, 1981).

Norman Wallen's published work, *The Taba Curriculum Development Project in Social Studies: Development of a Comprehensive Curriculum Model for Social Studies for Grades One Through Eight in 1969* . Focused on the revision of existing curriculum guides for grades one through six (the Contra Costa Social Studies Guides) and the development of guides for grades seven and eight. The emphasis was organization of learning activities under significant generalizations of main concepts that included sequential treatment, inductive process emphasis, and specific teaching strategies to promote cognitive and affective objectives, statement of behavioral objectives, and the inclusion of evaluation materials in the guides. An open ended generic curriculum development model was described and applied to different curricular areas. An in-service training program, with the dual purpose of learning as well as teaching, with an emphasis on teacher feedback was described and evaluated as the major dissemination tool. Two types of tests to measure thinking skills were included: fixed response and free response to provide a means for ongoing evaluation. Test reliability and validity data, procedures for scoring, and a coding system were presented (Wallen, 1969).

Jenny Armstrong published "The Relative Effects of Two Forms of Spiral Curriculum Organization and Two Modes of Presentation on Mathematical Learning" in 1968. The researcher analyzed the relative effects of two forms of spiral organization (area or topical) and two instructional modes of presentation (inductive or deductive) on the mathematical learning of sixth graders. The learning was assessed at each of six cognitive levels, within three areas, on four topics, over a three month time period. The results indicated that the form of spiral organization and mode of presentation differentially facilitated various types of learning when adjustments were made for the pupils' mathematical aptitude, prior mathematical learning, and global intelligence. The interaction of curriculum and instruction variables was not found to significantly affect mathematical learning (Armstrong, 1968).

Inquiry Based Science Curriculum Research

The National Science Foundation (NSF) primarily funded inquiry-based science curricula research; few independent reviews of inquiry based research have been funded by other agencies. Evaluations of the effectiveness of inquiry based science curricula reported in the literature were limited. The National Science Foundation (NSF) sponsored some evaluations of the inquiry based science curricula. The first wave of the inquiry based science curricula was introduced in the nations' classrooms in the sixties. Meta-analyses examined the effect on student achievement results from these types of curricula. The experimental design was that the treatment group received the inquiry-based curricula and the control group received the traditional textbook based curricula; the students' achievements in the treatment group were compared with students' achievement in the traditional, textbook based science curricula. The evidence provided by meta-analyses and evaluations of individual curricula confirmed that inquiry based science curricula produced larger effects on student achievement than did the more "traditional" science curricula. The largest studies of this kind were Shymansky, Kyle, and Alton in 1983 and Shymansky, Hedges, and Woodworth in 1990. They reanalyzed results of 81 studies which revealed that inquiry-based science programs had the greatest impact on student achievement and process skill development in the primary grades. Significant differences in effect sizes were found in the fourth through sixth grades, but the meta-analysis only evaluated students' attitudes and perceptions (Shymansky, Kyle, & Alton 1983; Shymansky, Hedges, and Woodworth, 1990).

The National Research Council (NRC) held a meeting in May, 2004 that evaluated inquiry-based science curricula. The effectiveness of inquiry-based science curricula on student achievement was positive. These earlier meta-analyses used the terms "new" and "innovative" to describe inquiry-based science curricula. "New" curricula were defined as curricula that were developed after 1955 and promoted nature, structure, and processes of science and the essential use of lab activities, as well as prioritizing higher cognitive skills. "Traditional" curricula were defined as curricula that had been developed before 1955 and prioritized the knowledge of scientific facts, laws, theories, and applications and implemented the secondary usages of lab activities (NRC, 2004).

The NRC (2004) analyzed the following curricula: 1) the physical science courses in middle school (Designs/Designs II); 2) the foundational approaches in science teaching (FAST) is a comprehensive, laboratory-based program in which students in grade seven construct their own knowledge through experiential, hands-on learning; 3) the Center for Learning Technologies in Urban Schools called LeTUS, where curriculum materials supported the development of integrated science understanding for middle school students in urban schools; 4) the National Science Curriculum for High Ability Learners, which was a supplemental program for average to gifted students in grades two through eight employing problem-based method; 5) the Physics Resources and Instructional Strategies for Motivating called PRISMS, which was a program to promote understanding of physics principles in the context of experiences relating to the real world of high school students; and 6) the World Watcher/LATE environmental science curricula which was an inquiry base curriculum for high school students. No finding on the effect of these science curricula on different subgroups of students such as girls, minority group members, and urban students was available (NRC, 2004). The curriculum called LeTUS reported data by sex and showed greater gains in achievement for female students. And another curriculum called CIPS showed no difference by sex and the curriculum Designs/Designs II showed larger gains for boys. A large meta-analysis of NSF-funded inquiry-based science curricula had a significant positive effect on males but not on females; nevertheless, analytic skills of females improved significantly in the treatment group which was resynthesized in 1990 (Shymansky, Hedges, and Woodworth, 1990).

Full Option Science System (FOSS) Curriculum and of Expeditionary Learning Outward Bound (ELOB) Results

The 1990 meta-analysis reported that FOSS and ELOB inquiry-based curricula had positive results for the fourth and sixth grade classes where English was the secondary language for the student. The results of this study demonstrated a positive correlation between years in the science program and standardized test scores results for the fourth and sixth grade classes where English was the secondary language for the student. The meta-analysis evaluation of Expeditionary Learning Outward Bound (ELOB) results showed consistent gains in all science subjects for five years. It is important to note that one school had 22 percent immigrant students whose primary language was not English, as well as a high percentage of economically disadvantaged students as defined by students on the free or reduced lunch program (Shymansky, Hedges, & Woodworth, 1990).

The 1990 large meta-analysis found that the inquiry based programs, while having a greater effect on all students versus the traditional programs, showed a greater effect on achievement scores for urban students versus suburban and rural area. World Watcher/ Learning about the Environment (LATE) reported higher gains for urban students than for suburban students. None of the studies that provided disaggregated data on urban students showed separate outcomes by race/ethnicity (Shymansky, Hedges, & Woodworth, 1990).

The re-analysis of the large 1983 meta-analysis of inquiry-based science curricula by Shymansky, Hedges, and Woodworth in 1990 revealed a large effect size for the student whose teachers had inquiry based courses through their professional development through a program called Project Inquiry. Students of teachers who did not have inquiry based courses also outperformed students in traditional textbook courses. The Project Inquiry curriculum results found that teachers who received professional development regarding implementation of inquiry based science programs performed significantly higher on two science assessments (Rose-Baele, 2003).

Hands-On Science Research

Research by Saunders and Shepardson compared the science achievement and cognitive development of sixth grade science students. The treatment group (N=57) received instruction with an emphasis on hands-on instruction, discovery, invention, and exploration for forty-five minutes a day for nine months. The control group (N=58) received formal instruction and was not involved in experimentation and did not use laboratory equipment. The results showed a positive statistical significance for the treatment group in both science achievement and cognitive development. The study suggested that hands-on approach to instruction may be superior to traditional instructional methods of lecture and demonstration (Saunders & Shepardson, 1984).

Glasson's (1989) research measured the science achievement and problem-solving abilities of ninth grade science students and determined if reasoning ability and prior knowledge were predictors of the dependent variables. The treatment group (N=27) received hands-on experimentation for the three weeks and the control group (N=25) received demonstrations on the same science content. The results showed no significant statistical difference in the science achievement of the two groups. However, in the case of problem-solving ability, there was a statistical significance in favor of the treatment group. Prior knowledge and reasoning ability were significant predictors of problem-solving ability. The teaching of science has proven to be very effective in a small group setting (Glasson, 1989; Childress, 1994).

Jester conducted a study in 1966 on the achievement of eighth grade students in language arts and in social studies using team teaching. There were 197 students in the treatment group and 262 students in the control group. The treatment group was taught by team teaching and the control received traditional instruction by individual teachers. Significant differences were found in favor of team teaching for language arts, but no statistical significance was found for social studies. The results implied that team teaching may positively affect students' achievement (Jester, 1966).

Resilient Children

The literature search revealed over thirty years of research on at-risk and resilient students. The body of research ranged from empirical studies to true experimental studies. True experimental studies were rare. The literature revealed the formidable challenges for educators that included educational, community, and family problems facing students in urban cities. The research revealed an increasing number of at-risk middle school students. At- risk, in this context, was defined as those middle school students who were in danger of dropping out of school because of academic failure or other societal ills. At-risk students demonstrated persistent patterns of under-achievement and behavioral problems in the classroom, which in turn would lead to the middle school students failing high school (Waxman, Gray, & Padrón, 2002).

Most researchers define resiliency similarly; however, there are some distinctions. Synonymous terms used interchangeably in describing resilient individuals are invulnerable, invincible, and hardy. The research approach or the social context in which it is used often explains the differences among the definitions of resilience. The term "high-risk" often refers to people who live in poverty or are victims of abuse. In 1993, Wolin and Wolin explained that the term "resilient" was adopted instead of terms such as invulnerable, invincible, and hardy (Wolin & Wolin, 1993). Understanding the construct in which the resilient individual is being observed will influence the definition of resiliency. It is important to note that generalizing the resilient concept to larger educational resilience spheres is highly dependent on the context in which the resilient individual is being studied. Each approach contributes to the whole of the understanding of resilience. Researchers need a better understanding of the phenomenon of resiliency before the transfer of these attributes into the nation's schools (Liddle, 1994).

Differentiating resilient from non-resilient may be whether the students dropped out of school. The national dropout rate averages about 10.9 percent (NCES, 2000); for minorities the dropout rate is higher, with an average of 40.9 percent of students leaving school before they graduate (NCES, 2000). It is important to note that these numbers do not include youth that are incarcerated for crimes. In Texas, the dropout rate for African Americans is 44.5 percent, while the Latino's dropout rate is 47.2 percent (TEA, 2006). Additionally, students in urban schools have much higher dropout rates than those in other areas; in Boston, Chicago, Los Angeles, Detroit, and other major cities, dropout rates range from 40 percent to 60 percent of the total school population (NCES, 2000).

While success is an educational variable that researchers often investigate and measure through cognitive, affective, and behavioral outcomes, the phenomenon of adversity is often not operationally defined. An at-risk school environment could be considered an adverse condition; however, other risk factors such as poverty, drug abuse, coming from a single-parent home, having a sibling who has dropped out of school, or being home alone after school three or more hours a day, could also be considered adverse conditions. The measurement of resiliency should be evaluated. Scoring in the top quartile on standardized tests, receiving a National Merit Scholarship, or graduating with honors from a top school are some of the criteria considered in the determination of academic success. A child in an "at risk" environment achieving these objectives should be considered educationally resilient. A similar issue regarding the measurement of resiliency applies to different identification procedures for distinguishing resilient students from non-resilient students (Waxman, Gray, & Padrón, 2002).

Many resiliency studies have used academic achievement, such as grades and standardized achievement tests, as the criterion for identifying resilient students. This approach has often been criticized because of the potential limitations of measuring academic achievement, such as validity or reliability concerns. These studies often identify resilient students based on one achievement test, which may not in fact represent students' overall academic achievement. Other resiliency studies have used teacher nomination as the criterion for determining resilient students. Not surprisingly, the dramatic differences found in most of these studies between resilient and non-resilient students may be consistent with teachers' expectations and attitudes toward the students (Waxman, Gray, & Padrón, 2002).

Other studies have researched the relationship between resilience and non resilience as well as academics skills and opportunities to learn. Most of the research on resilient and non-resilient students has focused on comparing family and individual characteristics and important classroom processes that may foster resiliency (Hahn, 1987; Storer, Cychosz, & Licklider, 1995). Some researchers' findings show that significant differences between resilient and non-resilient students are found in individual characteristics such as future aspirations and motivation.

The use of teacher nomination to identify resilient students could be considered a limitation of the current research in the field because there is the danger that having teachers identify or classify students as non-resilient could ultimately impact their success. At the same time, the teacher nomination approach may be one of the most valid identification procedures because teachers' decisions are typically based on a variety of indicators that are exhibited throughout the school year (Storer, Cychosz, & Licklider, 1995; Waxman, Gray, & Padrón, 2002).

The concept of resilience has been used to describe three major categories of phenomena in the psychological literature. The first category includes studies of individual differences in recovery from trauma. The second category is comprised of people from high-risk groups who obtained better outcomes than would typically be expected of these individuals. The third major category of the resilience literature refers to the ability to adapt despite stressful experiences. The following studies have been identified as the pioneering work in identifying the resilience concept and represent all three categories of the resilience phenomena (Masten, Best, & Garmezy, 1990; Waxman, Gray, & Padrón, 2002).

Rutter conducted an epidemiological study in 1979 that reflected the first category of resilience, recovery from trauma. Over a 10-year period, he studied children on the Isle of Wight and inner city London whose parents had been diagnosed with a mental illness. Through intensive interviews, he found that these children had escaped relatively unharmed. They did not become mentally ill themselves, nor did they exhibit maladaptive behavior. Rutter began to question why so many of these children showed no signs of the adverse conditions that they had to deal with on a regular basis. He found that both individual characteristics and the children's school environment were important protective factors. Rutter suggested that genetic factors do play a significant role in determining individual differences in personality characteristics and intelligence. He also found that the school environment contains important protective factors, such as fostering a sense of achievement in children, enhancing their personal growth, and increasing their social contacts (Rutter, 1979).

In 1977, Werner and Smith reported longitudinal study that reflected the second category of the resilience phenomena. The focus of this longitudinal study was on a high-risk group of children born in 1955 on Kauai, Hawaii. One third of this cohort (n = 201) was designated as high-risk because they were born into poverty and lived in a family environment troubled by a number of factors including biological and prenatal stress, family instability and discord, parental psychopathology, or other poor child-rearing conditions. One third of these high-risk children (n = 72) grew up to be competent, confident, and caring adults. Several differences were found when these children were contrasted with the at-risk children who did develop serious problems. These results were separated into three types of protective attributes that supported resilience: dispositional attributes of the individual, affectional ties with the family, and external support systems in the environment (Werner & Smith, 1977).

Werner and Smith found that in early childhood, resilient children at high-risk experienced fewer illnesses and were perceived as active, affectionate, and socially responsive by their parents. Resilient children displayed additional traits, such as self-help skills, sensorimotor acquisition, and language development. In early adolescence, resilient children displayed good problem-solving skills, communication skills, and perceptual motor development. In their late teens, resilient individuals possessed high internal focus of control, an achievement-oriented attitude, and positive self-esteem (Werner & Smith, 1977).

The Center for Research on the Education of Students Placed At Risk (CRESPAR) reported on several studies on educational resiliency. In 1991, the study on resilient students, "Education and Urban Society" by Lee, Winfield, and Wilson, used 1983-84 reading assessment scores from the National Assessment of Educational Progress (NAEP) data to compare 661 African American eighth graders who were high academic achievers to 1,894 African American eighth grade students. High-achieving students who were low academic achievers were defined as those who scored above the overall population mean on reading performance, while low achieving students were defined as those who scored below the population mean. Characteristics such as being of a higher social class, being of a younger age, and having a working mother were found among the high-achieving students and not among low-achieving students. In terms of school differences, researchers found that high-achieving African American students were attending Catholic schools where the student received more exposure to the curriculum, teachers had higher student commitment, and fewer students were in remedial reading, as opposed to schools attended by low-achieving African American students. High-achieving African American students read more per week, did more homework, and had higher grades than low-achieving African American students (Waxman, Gray, & Padrón, 2002).

The US Department of Education National Research Centers, the Center for Education in the Inner Cities (CEIC), and the Center for Research on Education, Diversity & Excellence (CREDE), and Waxman, et al conducted several research studies on differences between resilient and non-resilient elementary and middle school students. The participants were from several urban cities with a high concentration of students whose first language was not English, as well as students identified as economically disadvantaged. Waxman and Huang conducted the first study in 1996. The initial study examined the classroom learning environment and the motivation of 75 resilient students compared to 75 non-resilient sixth, seventh, and eighth grade students found in an urban middle school located in the south central region of the United States. Educationally resilient students were defined as students in the ninetieth percentile of standardized mathematics achievement tests for two years. Non-resilient students were defined as students who scored at the tenth percentile or lower on standardized mathematics achievement tests for two years. The findings revealed that resilient students had a significantly higher involvement in class activities and were more task orientated than non-resilient students. Resilient students also reported having significantly higher self-esteem and higher academic success rates than non-resilient students. It is important to note that there were no significant differences between the resilient and non-resilient students on factors such as homework, parental involvement, and teacher support. The research revealed that the resilient and non-resilient students both felt that there was little teacher support, which may explain the above finding. One explanation for why no differences were found on the teacher support variable was that both resilient and non-resilient students had low perceptions of their teachers' support. Also, there was significant variability within the group's responses. Another factor for parental involvement not showing significant differences between the groups of resilient and non-resilient students was that unlike the teacher support response, the response rate was high and there was very little variability within groups (Waxman, Gray, & Padrón, 2002).

In 1999, Waxman and colleagues interviewed several fourth and fifth grade teachers about how they defined resilient and non-resilient students. The teachers indicated that the resilience construct used to identify resilient versus non-resilient students looked for certain behavioral attributes and work products. The study revealed behavior characteristics that teachers believed distinguished resilient students from non-resilient students. The lack of parental involvement, low self esteem and lack of motivation was the main factors teachers used to identify non-resilient students. Parental involvement, high self esteem and motivation were the factors use to identify resilient students. It is important to note that teachers did not identify school programs or classroom environment as an indicator of academic success for resilient students or academic failure for non-resilient children. The teachers also did not reveal any instructional strategies that could impact resilient students. However, teachers did recommend some instructional strategies that could impact non-resilient students (Waxman, Gray, & Padrón, 2002).

Academic Environment and Resiliency

In April of 2003, Kimberly Rouse presented "The Academic Environment's Impact on Motivation in Resilient and Non-Resilient Middle [Schoolers]" at the biennial meeting of the Society for Research in Child Development. The study focused on the academic achievement and the motivations of resilient and non-resilient high school students. These were the same motivations found in middle school students. The participants were six resilient and 43 non-resilient students from four mid-western urban middle schools. Participants' values concerning their academic environment and their motivation were measured using the Assessment of Academic Self-Concept and

Motivation instrument (AASCM). The findings were that the resilient students had more positive values regarding their academic environment than non-resilient students. The instrument stratified the academic environment into cognitive, social, extracurricular, and personal areas. No statistical significance was found in the individual areas; when the total academic environment was taken into account, the t-test showed statistical significance. It is important to note that the assessment of resilient students' motivation, which was based on the Motivational System Theory, was more positive than the non-resilient students (Rouse, 2003).

Morrison and Masten (1991) reported on a study that examined increased poverty among single-parent homes, and the increase in violent crimes, particularly murder. The study targets the African American male middle school students may be the nation's best hope at saving the African American male so that they can be positive contributors to the society hence. The study examined conditions that are catalysts to academic success over adverse conditions that are precursors to academic failure (Morrison & Masten, 1991).

In one academic achievement example, the October 1992 Christopher McCormick and Emory Gerard published study on "The resilient African American child: Parents', teachers', and students' perceptions of factors that influence resilience" examined the perspectives of four parents, four teachers, and four resilient African American students concerning the attributes that impacted high academic achievement in the resilient students. In-depth, semi-structured interviews were used with the parents, teachers, and resilient African American students. The following were the interview questions:

> (1) How do African American students, their parents, and their teachers perceive the influence of individual agency on the students' resiliency?

(2) How do African American students, their parents, and their teachers perceive the influence of parents on the students' resiliency?

(3) How do African American students, their parents, and their teachers perceive the influence of teachers on the students' resiliency?

The results suggested that resilient students can have academic success regardless of their ethnicity, family status and economic status. This study supported past research that revealed that leadership skills were a common characteristic of resilient African American students. The parents of the resilient African American students were highly involved and committed to their children. The teachers of resilient students invested time and energy (Waxman, Gray, & Padrón, 2002)

McCormick and Gerard's 2003 study challenges current resilience literature in that resilient African American students' demonstrate effective communication skills in regards to their parents, teachers, and peers. The resilient African American student's ability to communicate some of the barriers to their potential success may have endeared them to their teacher, causing a more nurturing and academically sustaining environment. The information provided by the resilient student would enable the teachers to adapt to the resilient students learning style and need, thereby making the teacher more effective. The resilient students were quite adept in eliciting help from adult mentors, administrators, and teachers. The study also added to the body of literature concerning the strong value systems that all four parents exhibited concerning academic achievement. The values exhibited by the parents were the beliefs that education would give their child freedom and power in their lives, as well as the material possessions that were found in households of those with a higher socioeconomic status. A spiritual factor was also revealed to be evident in all of the resilient students' mothers. The spiritual factor had never been considered in previous studies. Also, the resilient students had resilient mothers as demonstrated by the fact that the mothers were survivors who raised their children in adverse conditions. The resilient mothers passed on these survival skills to their children through modeling. The resilient students then adapted these survival skills to their academic environment. In other words, attributes of resilience may be transferred generationally and across other domains of life (Waxman, Gray, & Padrón, 2002).

Constance Jackson published her dissertation, *Factors that foster academic resilience in African American male middle school students from low socioeconomic, single-parent homes,* in the 2000 edition of the *Abstracts International Section A: Humanities and Social Sciences.* The qualitative study attempted to identify factors common to resilient middle school African American male students from low socioeconomic, single-parent homes in Birmingham, Alabama who attended public schools in inner city schools. The study defined resilience as scoring at or above the 80th percentile on the SAT-9.

Jackson's 2000 study chose depth versus breadth of knowledge on the resilient population. The study used a purposeful random sample procedure to create two sample groups composed of six clusters of three respondents—a student, a parent/ guardian, and a teacher. A total of 36 interviews were conducted. Structured interviews were used to collect data on the participants. A secondary data source was obtained by doing an extensive review of the literature that was comprised of journals, books, and peer reviewed publications. The inductive analytical methodology revealed that the resilient students had strong parent/family connections, were leaders rather than followers, were not controlled by the peer group, invested trust in a significant other adult in their lives, were healthy children with pleasant temperaments, received positive rather than negative reinforcement, spent time with their parents engaged in educational pursuits, had parents whose educational levels ranged from 2nd year of college to Master's degree, and/or and had parents who were supportive of schools and spent time at their children's school. Several variables were identified in this study as protective factors that contribute to resilience. The following sources of protective factors were noted such as personal factors, family factors, peer factors, school factors, and community factors (Jackson, 2000).

Summary

Clewell, et al (2004) study reviewed the literature in search of middle schools' science curricula that effectively increased students science achievement. They reported that most middle schools' science curricula did not have studies focusing on the effectiveness of students' science achievement by subgroups such as sex, minority status, and urban status. This researcher's literature review also revealed that very few studies are in print on increasing science achievement using a spiral curriculum. The body of literature on quantitative and qualitative research of spiral curriculum is sparse at best. The1995, article on the "Effects of spiral testing and review on retention and mathematical achievement for below-average eighth- and ninth-grade students" showed a statistical significant increase in science achievement once applying the treatment of the spiral curriculum in both eighth and ninth graders (Wineland & Stephens, 1995).

The majority of the most current National Science Foundation funded research has been on the college level and in schools of engineering and mathematics. A study revised in June of 2001, "Research-Based Curriculum: The Research Basis of the

UCSMP Everyday Mathematics Curriculum", by Andrew Isaacs, William Carroll, and Max Bell criticized what they call a "flat spiral" found in textbooks (Flanders, 1987). The "flat spiral" is defined as the annual repetition cycle of disconnected texts topics. It is important to note that these findings do not imply that all spiral curricula are necessarily flawed, only that the traditional US curricula are flawed. Indeed, Thomas Romberg, the general editor of the National Council of Teachers of Math (NCTM) Standards, determined that the first characteristic of curriculum for engineering was that the main schemata (i.e. measurement, mappings, proportionality) that could be develop in school children must be identified in a spiral curriculum built around those main concepts (Romberg & Tufte, 1987). The flat spiral is not the same as the spiral developed by Hilda Taba.

This chapter revealed the scarcity of educational and scientific research on the effectiveness of a spiral science curriculum targeted to middle school research. The literature review also revealed that it is the middle school science curriculum that is considered the weak link in educating the nation's youth in science. In the case of the quantitative research on the spiral curriculum for elementary and middle school students, very little research has been done in this area; therefore, the study described in the remaining chapters will contribute to the body of knowledge by addressing these issues. Furthermore, the study will contribute to the literature by the examining the effects of increasing science achievement in sixth through eighth grade students by teaching a spiral physics curriculum.

The literature review also revealed over thirty years of research that was both quantitative and qualitative in nature on at-risk and resilient children. In regards to academic resilience, several grounded theory research studies have been performed. In both cases more research is needed. In the case of the grounded theory using Becker's inductive method, the researcher is the instrument; consequently, each researcher can add some new dimension to the understanding of the attributes of academically resilient children and the possible transfer of these attributes to non-resilient children. These attributes may be used to increase academic achievement in students; therefore, the study will contribute to the literature by examining the attributes of academically resilient children.

CHAPTER THREE

Methodology

The rationale for the study, the purpose of the study, and the questions that guided the development of the research methods used in the study are reviewed in this chapter. The subjects/participants and the research design are described, followed by a description of the instruments used in the study. The procedures are also outlined, as well as the methods of data collection. Finally, limitations of the study are discussed. The methodology of the pilot study is explained as a means of contextualizing the complete spiral physics curriculum (SPC) study, and an explanation of the methodology used in the final study is provided. Dr. Roger Kirk, Dr. Jack Tubbs and doctoral candidate Terry Martin guided the researcher in identifying statistical procedures and in the analysis of the statistics.

Purpose of the Study

The purpose of the experimental complete SPC study was to compare the effectiveness of an experimental spiral physics curriculum and a traditional linear physics curriculum with a selected group of sixth grade students. A pilot study was conducted prior to the complete experimental study. The purpose of the pilot study was to validate the written, multiple choice test for the physics content taught during the two week period, as well as to refine the final procedures for the complete study.

Hypothesis

The hypothesis was that the experimental spiral physics curriculum taught to sixth grade girls and boys would produce significantly higher achievement in physics compared to sixth grade girls and boys who received instruction using a traditional linear physics curriculum.

Research Questions

Here are the questions that guided the study:

1) Were there significant differences in physics achievement scores for female students who received instruction using an experimental spiral physics curriculum as compared to female students who received the traditional linear physics curriculum?
2) Were there significant differences in physics achievement scores for male students who received instruction using an experimental spiral physics curriculum as compared to male students who received the traditional linear physics curriculum?
3) Were there significant differences in physics achievement scores for minority students who received instruction using an experimental spiral physics curriculum as compared to minority students who received the traditional linear physics curriculum?
4) Were there significant differences in physics achievement scores for resilient students who received instruction using an experimental spiral physics curriculum as compared to resilient students who received the traditional linear physics curriculum?
5) Were there significant differences in physics achievement scores for students from the ZISD, CISD, and WMS who received instruction using an experimental spiral physics curriculum as compared to students from the ZISD, CISD, and WMS who received the traditional linear physics curriculum?

The research questions that were derived out of the hypothesis comprised the foundation of the study. The following paragraphs explain the significance of answering such questions to the educational and scientific community.

The Pilot Study

The first phase of the pilot study was to establish the methods for testing of the experimental spiral physics curriculum in order to refine the subject matter content and validate the testing instrument. The second phase of the pilot was to implement the lessons and measure student learning. The third phase of the pilot was to survey and perform semi-structured interviews with the school principals in order to gather socio-economic information about the school and information about the school's science curriculum. The final phase was for the principals and instructor/researcher to identify resilient students and for the researcher to proceed to interview the resilient students as an observer. The pilot study occurred from June 20, 2005 to July 1, 2005.

Pilot Study Methodology

Phase One—Participants in the Pilot Study

The Grounded Theory method demands a rich data base, which influenced the sampling phase of the study. First, the scope of the pilot was restricted due to economic concerns; therefore, the selection of schools for the pilot was restricted to the urban schools located in ZISD. The ZISD is located in an urban area of McLennan County Central Texas with a general population of 120,465 as of 2005. The economy is base on manufacturing, agribusiness and education. The ethnicity of the ZISD community is Anglos 61%, African American 23%, Latino and others 14%, Asian 1%, and American

Indian 1%. The ZISD school district has 20 elementary schools, seven middle schools, four high schools, and three colleges (Local Information Data Server [idcide], 2007). ZISD's communities' median household income is $26,264 (U.S. Census, 1999).

The school district serves a small section of McLennan County and has a total enrollment of 15, 591 students as of the 2004 ZISD annual report. Pre K students represent 13.7% of the total enrollment, the elementary students represent 39.2 %, middle school students represent 21.4%, and high school students represent 25.7%. The ethnicity of the school district indicates that Latino students represent 45.7 % of the district population, African American students represent 37% of the district population, Anglos represent 16.8% of the district population, economically disadvantage 80.8% of the district population, and Limited English 11.6% of the district population. The average class size in the district ranges from 20 to 24 students (ZISD 2004 Annual Report, 2004).

The researcher purposefully selected the urban schools. In identifying the schools, the random purposeful sampling stratified strategy was used to ensure credibility and to include ethnic subgroups, as well as to facilitate comparisons. There were 63 student participants in the sixth through eighth grades in the pilot. All participants were urban middle school youth from BMS, CMS, and GMS. All three schools are located in ZISD district. The pilot was conducted during the summer session, which meant that the majority of the participating students had either failed a class the previous semester or had failed to attend the required number of school days. Principals identified students who were required to attend summer school, as well as some gifted and talented students to participate in the pilot. The principals used the ZISD's criterion for the identification of the gifted and talented students. The principals of each participating school also took part in the pilot study by answering the survey.

In the pilot study, the students were randomly assigned to one of the four groups in the Solomon Four group design. The numbers one, two, three, and four were written on equal size pieces of paper and placed in a box. The students randomly selected a number from the box identifying their assigned group for the pilot study. The researcher recorded the randomly selected number next to the students' name on the class attendance rosters. Groups one and two received experimental spiral physics curriculum. Groups three and four received the traditional linear curriculum. Groups one and three were pre-tested. Groups two and four were not pre-tested. In addition, the principals and researcher identified resilient students who participated in the two week instructional period.

Permissions in the Pilot Study

Written consent was obtained from the ZISD superintendent, principals of the piloted schools, parents of the participating students, and the participating students prior to the beginning of the pilot study. The requisite legal approval for use of the CASPER Physics Light Module and Physics test for the pilot was obtained through Dr. Truell Hyde and Baylor University's legal department. Dr. Matthew Stanford, chairman of the Baylor University Institutional Review Board (IRB), was notified that the pilot study would begin by the end of June 2005.

The procedure for acquiring permissions from the parents of the participating students required that the principals give the researcher the list of student participants. The timing of the receipt of the list of participants meant that the researcher was required to make visits to the students' homes in order to obtain parental consent for the students to participate in the pilot study. As a result, the researcher was able to perform visual observation of the students' neighborhood, home life, and school environment. The principals also signed consent forms.

Phase Two—Implementation of the Pilot Study

The pilot study was conducted on each of the school campuses. The school campuses were chosen by the researcher in order to have suitable access to the pilot study's population. Initially, the participants were going to be bused to the Baylor campus. However, due to the expense and the inconvenience to the students, it was decided that the researcher would go to the students' schools. The researcher taught three sessions for ten days: 8:30 am to 10:00 am at BMS; 11:30 am to 1:00 pm at CMS; and 2:00 pm to 3:30 pm at GMS. The pilot session was held from June 20-July 1, 2005. The researcher taught both the experimental spiral physics curriculum and the traditional linear physics curriculum to the selected student participants during separate sessions. Again groups one and two received the experimental spiral physics curriculum and groups three and four received the traditional linear physics curriculum. Groups one and three were pre-tested, while groups two and four were not pre-tested. All four groups were post-tested.

The researcher conducted the instructional sessions. The first half of the spiral and linear instructional sessions were a combination of lecture, demonstrations, discussion, and computer research; the remaining fifty percent was laboratory experiments. The instructional session was two hours each day for ten days. The instructions were given and a physics evaluation pre-test was administered to two groups.

Groups one and three were given the pre-test. Groups two and four were not given the pre-test. The post-test was administered at the end of the ten day instructional sequence. Each group completed the post-test. The data was collected at the end.

Data collection for the pilot consisted of pre-tests, post-tests, and participatory observations, video tapes of the students, and surveys and interviews from the principals. The researcher designed the surveys and the semi-structured interviews. The pre-test and post-test were developed by selecting items from the CASPER multiple choice test for the light instructional module designed by physicist Dr. Truell Hyde and NSF RET fellows. These items were supplemented by additional questions developed by the researcher.

Phase Three—Observations, Surveys, Interviews, and Videotapes in the Pilot Study

The researcher used the participant observation method, which entailed the naturalistic approach. The participant observation method is where the researcher is the instrument in the qualitative portion of the study and is totally immersed in the study. The researcher is required to use the higher metacognitive ability of reflexivity. The term reflexivity is the concept where the qualitative researcher understands the impact of ones views and perspectives have on a study (Patton, 2002).

Observations of the students helped the researcher to refine the curriculum and instructions for the sample population. The observations were participatory due to the high immersion of the researcher as the teacher of the curriculum. The purpose of the observations was to increase reliability and protect the quality of pilot study. Observation can also help ensure the validity of the study as well as reduce bias. The observations were comprised of the researcher's reflections while implementing the study. Forms used to record observations can be found in appendix (B).

The researcher administered the surveys and interviews of the principals in order to obtain information about the economic environments of the participants, ethnic characteristics of students, teachers and administration, as well as information about the students' science curriculum. Another purpose of the survey was to gather socio-economic information about the participants' schools and provide an opportunity for principals to state concerns about the study and physics instruction on their campus. The survey was a combination of quantitative and qualitative questions and can be found in appendix (C).

The researcher used video taping to assist with observations. The video taping increases reliability, validity, and reduces bias by helping to clear up questions that may arise during the pilot study's analysis. Each campus class instructions were video taped. The form used to record information for the video taping protocol can be found in appendix (D).

Phase Four–Resilient Students in the Pilot Study

The researcher performed separate interviews of the identified resilient students throughout the study. The resilient students were selected by the researcher/teacher and principals based on the student population, the observation, survey, and interview results, as well as the researcher/teacher's insight and experience with the student. The informal interviews occurred during home visits, class set ups, and after class instructions. The interview protocol can be found in appendix (E).

Curriculum–Design Components of the Pilot Study

The experimental spiral physics curriculum lesson plans were designed specifically for this study by the researcher after reviewing the CASPER light modules and the content of several high school physics textbooks. The experimental spiral physics curriculum had several components, including direct instruction of content, the critical think tank center and critical thinking center.

The purpose of the critical think tank center was to enable the students to deepen their knowledge of concepts taught during instruction and lab sessions. The critical think tank center permitted the students to practice team problem solving techniques. The researcher also established a critical thinking center for individual problem solving. The critical think tank center and critical thinking center were offered as a reward mechanism for critical thinking. All student participants who received the experimental spiral physics curriculum and the traditional linear physics curriculum were given the opportunity to learn in both the critical think tank center and critical thinking center. The critical think tank center and critical thinking center also enabled the researcher to control the flow of students during the sessions of spiral and linear physics instruction. Both the critical think tank center and the critical thinking center had internet capabilities and all students were introduced to the Digital Library for Earth Science Education (DLESE).

Another component of the curriculum was a student contract (see Appendix F) that specified appropriate attire and behavior. The participating students were required to sign contracts stating that they would respect themselves and others, as well as maximize their learning experience by arriving prepared for class.

Since labs were conducted during every class session, all students were given white lab jackets to be worn during class, as well as security clearance badges with their names displayed. The displayed name tags provided easy identification of students in the study, increased the personalization of the classroom experience for the students, and added a level of reality for students by simulating a work experience in a professional scientific laboratory. An added benefit of the name tag was that it increased the researcher's ability to manage the classroom environment by easily identifying students and calling them by name.

Each campus classroom had think tank centers for the spiral and linear groups' critical think tank centers and critical thinking centers for group and individual problem solving respectively. The think tank centers and the critical thinking centers had desktop computers with internet access. Two cameras were set up in the rooms for recording the instructional sessions. Lab areas were also established with audiovisual capabilities. All of the campus classrooms were spacious and conducive for group activities. Daily class attendance rosters were kept on each campus. An example of the attendance roster is in appendix (G).

The Research Design: The Quantitative Solomon Four Group Design in the Pilot Study

The quantitative measure used a Solomon Four group design with random assignment of participants. This design was a combination of the pre-test, post-test, and control groups' design, each of which has its own major source of invalidity pre-test treatment interaction and mortality, respectively. The combination of these two treatments results in a design that controls for pre-test treatment interaction and for mortality.

Each campus' student population was placed randomly into one of four groups. The randomization process was accomplished by first placing the numbers one, two, three, and four on equal size pieces of paper that were placed in a box. Second, students randomly selected a number from the box identifying their assigned group. Groups one and three received a pre-test, while groups two and four did not receive a pre-test. Groups one and two received the experimental spiral physics curriculum and groups three and four were given the traditional linear physics curriculum. All four groups (one, two, three, and four) received the post-test.

Instructor for the Pilot Study

The researcher was the instructor for the pilot. To ensure credibility in the study, the following steps were taken: triangulation and corroboration to help ensure valid observations and the circumstances of the observation were examined, the data was checked for reliability, the motivations were assessed, and the biases were addressed. The triangulation was composed of surveys, interviews, observations and video taping.

The researcher's academic background consists of a Bachelor of Science degree with a major in geology and minor in mathematics along with several courses in physics, chemistry, biology, and marine science from the University of Miami, a Master of Science degree in geophysics from Stanford University, and a Master of Business Administration from the University of Texas. The researcher is currently a doctoral candidate in Education Curriculum and Instruction at Baylor University.

The researcher is the educational liaison for the Baylor University CASPER Project, as well as a member of CASPER's outreach program. The researcher is a graduate research assistant to the Baylor summer math program. The researcher developed and implemented science curriculum for Upward Bound programs at the University of Miami and Pennsylvania State University's Science program for girls. The researcher utilized her various academic and professional experiences in the development of the research design.

The Complete Spiral Physics Curriculum (SPC) Study

The SPC full study mimicked the pilot study in the design, testing instrument, and methodology. The complete study was implemented May 8 through May 19, 2006.

Changes Implemented in the Complete SPC Study as a Result of the Pilot Study

The first major change between the pilot study and the complete SPC study was that the number of student participants increased from 63 to 96 in order to be more reflective of the general population. The second change was improved time management in the interface between the researcher and school administration and better synchronization with each school to continuously communicate the SPC study time and dates to the participants. The third change was that the total number of schools participating in the study increased from three to four. The fourth school CMS was later dropped from the study due to no fault of the researcher. The fourth change was that a rural school and a suburban private school were added to the SPC study. The two new schools that were added to the study were CSI and WMS. BMS was dropped from the study; CMS and GMS were retained. The fifth change was that all of the student participants were enrolled in the sixth grade; no seventh and eighth graders participated in the final study. A sixth change from the pilot was that the instruction took place during the regular school year. A seventh change was that each principal designated specific sixth grade science classes to participate. The eighth change was that each instructional session was 40-50 minutes compared to 120 minutes per session in the pilot. A ninth change was that semi-structured interviews of the participants' science teachers were added to the study. A tenth change was that each participant's science teacher was asked to identify resilient students using the researcher's definition of resiliency. Additionally, an eleventh change was that the contract signed by the students was enlarged to poster size and placed in a highly visible area of the classroom.

The SPC study mimicked the pilot in that the participating school principals completed the survey and were also asked to identify resilient children (see Appendix C).

The Completed SPC Study–Methodology

Phase One—Participants in the Complete Study

The number of student participants were 96 sixth grade middle school students from CMS, CSI, GMS and WMS. CMS was later dropped from the study due to no fault of the researcher. The Grounded Theory method demands a rich data base, which would influence the data collection phase of the study. The random purposeful sampling stratified strategy was used to ensure credibility and to illustrate subgroups and facilitated comparisons as well as criterion sampling in the case of the resilient children. The criterion sampling entailed the researcher defining resilient children for the principals and teachers of the participating schools. The teachers and a principal then selected students that fit that criterion for the study.

The random purposeful sampling strategy was achieved by sampling the various social and economic strata that exist in Central Texas. For this study, CSI represented the rural and suburban area and the Anglo population, CMS represented the urban Latino population, GMS represented the urban African American population, and WMS represented the urban and suburban Anglos.

CSI is another school located in Central Texas McLennan County with same statistics as ZISD community which has a general population of 120,465 as of 2005. The economy is manufacturing, agribusiness and education based. The school district draws the rural student population. The ethnicity of the community is Anglos 61%, African American 23%, Latino and others 14 %, Asian 1%, and American Indian 1%. The CISD school district has one elementary school, one intermediate school, one middle school, one high school, and three colleges. The statistics of the CISD school district has a total enrollment of 1,880 students as follows: 755 elementary students represent 40.2 % of the total enrollment; 278 intermediate students represent 14.8%; 305 middle school students represent 16.2%; and 542 high school students' represent 28.8%. The ethnicity of the CISD school district indicates that Anglos students represent 86 % of the district population, Latino students represent 10% of the district population, and African-American represent 2% of the district population, and other represent 2% (CISD Annual Report, 2006; ZISD Annual Report, 2004).

All schools that were participants in the pilot study were public schools. The complete study included WMS. WMS is a private school located in Central Texas McLennan County. WMS' student population is primarily Anglo and draws both urban and suburban students. WMS' surrounding communities has the same statistics for general population and demographics as ZISD (U.S. Census, 1999).

Permissions in the Complete Study

Written consent was obtained from the CISD and ZISD superintendents, the Head of School of WMS, principals of the complete SPC study schools, participating teachers, parents of the participating students, and the participating students. Baylor University Institutional Review Board (IRB) gave permission for the complete SPC study to begin in May 2006.

The procedure for acquiring permission from the parents of the participating students required the principals to give the researcher a list of teacher and student participants. The researcher and principals distributed the consent forms to the teachers for student distribution so that the students could obtain their parents' consent. The students, principals, and teachers also signed consent forms. Principals announced incentives to students so that they would return the consent forms in a timely manner. Principals and the science teachers helped in the identification of the resilient students.

Phase Two—Implementation of the Complete Study

The complete SPC study was conducted on each of the school campuses. The researcher went to the students' schools to provide instruction. The researcher taught four sessions for ten days: 9:10 am to 10:00 am (50 minutes) at CSI; 11:10 am to 12:00 pm at WMS (50 minutes); 1:10 pm to pm 2:00 pm at CMS (50 minutes); and 2:50 pm to 3:30 pm at GMS (40 minutes). All sessions were held from May 8 through May 19, 2006. The researcher taught both the experimental spiral physics curriculum and the traditional linear physics curriculum to the student participants.

At each campus, the researcher randomly selected the members of each group by placing equal size squares of paper with the numbers one, two, three and four on each of the squares of paper in a box. Group one received the traditional linear curriculum and was pre-tested, group two received experimental spiral physics curriculum and was pre-tested, group three received the traditional linear curriculum and was not pre-tested and group four received the experimental spiral curriculum and was not pre-tested. The students picked a number to determine their group assignment. Again groups two and four received instruction using the experimental spiral physics curriculum and groups one and three received the traditional linear physics curriculum instruction. Groups one and two were pre-tested and three and four were not pre-tested. All four groups were post-tested.

The instructions were given and a physics evaluation pre-test (PET) was administered to the groups on the first day. The researcher conducted the instructional sessions. The first fifty percent of both the spiral and linear instructional sessions were a combination of lecture, demonstrations, discussion, and computer research; the remaining fifty percent was laboratory experiments.

The researcher was able to separate the student participants in the experimental spiral groups from the traditional linear groups at CSI and GMS by having an assisting science teacher take one group the computer lab to participate in the critical think tank and critical thinking centers. At WMS, one group would go to the back of the classroom where the computers were setup to participate in the critical think tank and critical thinking centers, while the other group received the spiral or linear instruction in the front of the classroom. The students in the critical think tank and critical thinking centers were instructed to go to the Digital Library for Earth Science Education (DLESE) to research topics related to the lesson of the day as assigned by the researcher/teacher. Both spiral and linear groups participated in the critical think tank and critical thinking centers.

Phase Three—Observations, Surveys, Interviews, and Videotapes in the Complete Study

The researcher performed observations of the students in order to study the resilient students in the sample population. The observations were participatory due to the high immersion of the researcher as the teacher of the curriculum. The researcher used observations in the data collection of the complete study. The purposes of the observations were to increase reliability and protect the quality of the complete study by being a part of the triangulation process. The observations helped increase reliability, ensure validity, and reduce bias by being a part of the process of clearing up questions in the analysis of the complete study. The observations were comprised of the researcher's reflections. The observation protocol can be found in appendix (B).

The principals of each campus took the survey. The purpose of the survey was to gather socio-economic information about the participants' schools and provide an opportunity for principals to state concerns about the study and science instruction on their campus. The surveys were a combination of quantitative and qualitative questions. The survey implementation mimicked the pilot study. The surveys can be found in appendix (C).

The researcher used video taping in the observation process of the instructional sessions on each campus. The purpose of the video taping was to increase reliability and protect the quality of observations/interviews by being a part of the triangulation process. Video taping can also help ensure the validity of the study as well as reduce bias as part of the observation process. The video taping increases reliability, validity, and reduces bias by helping in clearing up questions that may arise during the study's analysis. The video tapings were used whenever students were in the classroom. The video taping protocol can be found in appendix (D).

Phase Four—Resilient Students in the Complete Study

The resilient students were selected by the researcher and science teacher based on the teacher's insight and experience with the student. The informal interviews of the teachers occurred during set up and after class instructions. The researcher interviewed the identified resilient students throughout the study. Interview protocol for teachers can be found in appendix (E).

Curriculum—Design Components of the Complete Study

The complete study curriculum mimicked the pilot study curriculum with the adjustment of the contents covered to meet the demands of a 40 to 50 minute class schedule. The adjustment of the content entailed shortening the activities and lab time. The classroom design mimicked the pilot study classroom design with the addition of a poster sized contract that was placed in a highly visible area for the students to view throughout the study.

Research Design—The Quantitative Solomon Four Group Design for the Complete Study

Participants at each campus were randomly assigned to one of four groups using the same method that was performed in the pilot study. Group one received the traditional linear curriculum and was pre-tested, group two received experimental spiral physics curriculum and was pre-tested, group three received the traditional linear curriculum and was not pre-tested and group four received the experimental spiral curriculum and was not pre-tested. Again groups one and two received the pre-test; groups three and four did not receive a pre-test. Groups two and four received the experimental spiral physics curriculum, while groups one and three were given the traditional linear physics curriculum. All four groups one, two, three, and four took the post-test.

Instructor Background for the Complete Study

The instructor's credentials were the same as in the pilot study, with the addition of the gained experience from conducting the pilot in June of 2005 and the experimental spiral science TAKS intervention at PES in Central Texas from January 18, 2006 to April 18, 2006. The science TAKS intervention at PES produced an overall 32 percent increase in the pass rate of the fifth grade students of PES. The ZISD average on the science portion of the TAKS test was 58 percent. In 2005, only nine percent of African Americans students passed the science TAKS exam. In 2006, 54 percent of African American students passed the science TAKS exam. In 2005, 38 percent of the Latino students passed the science TAKS exam compared to 62 percent in 2006. In 2005, 57 percent of the Anglo students in ZISD passed the science TAKS exam, with 82 percent passing in 2006. In 2006, 65 percent of the students in ZISD that were classified as economically disadvantaged passed the science TAKS exam, compared to 28 percent in 2005. African American students had the most significant increase in their science pass rate with an increase of 45% (Davis & Curtis, 2007). The following paragraph explains the experimental design of the complete study.

Quantitative and Qualitative Data Collection in the Complete Study

Determining the effectiveness of teaching an experimental spiral physics curriculum to sixth grade students involved quantitative measures. The quantitative measure used an objective test. The objective test was the CASPER physics test and the researcher's self-designed physics evaluation test. The two tests were combined and were known as the physics evaluation test (PET).

The independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum. The dependent variable was the physics achievement of the subjects/participants. Nuisance variables may have been pre-test interactions and factors not known to the researcher that impacted physics achievement of students. The validation and reliability of the study are also important factors.

Validity and Reliability Issues

The study used the Solomon Four group design. Solomon Four group design controls for many sources of invalidity. The content validation consisted of multiple reviews of the content by the researcher along with Dr. Truell Hyde and the National Science Foundation Research Teacher fellows. Items identified by these individuals as not appropriately measuring the intended objective were revised and further reviewed. This process was iterated several times during the development of the instrument in order to assure agreement with the content of individual items and the integrity and completeness of the overall instrument. The content was also validated by the pilot study. The study's reliability was increased with the elimination of all test questions commonly answered correct or incorrect prior to being administered to the experimental groups in the complete study in 2006. The test was validated by the Cronbach alpha reliability method with an alpha of 0.740 for the pilot study and 0.799 for the complete study. The Cronbach alpha for the combined data set was 0.749. Cronbach's alpha measures how well a set of variables measures a single one-dimensional construct. Cronbach's alpha is a coefficient of reliability or consistency. Cronbach's alpha can be written as a function of the number of test variables and the average inter-correlation among the variables.

Qualitative Instrumentation in the Complete Study

The qualitative instrumentation consisted of surveys, interviews, observations. Surveys were given to the principals of the participating school, semi-structured interviews were given to the science teachers, video tapping of the instructional sessions was at each campus and observations of the students was performed by the researcher at each campus. Semi-structured interviews of the science teachers were used by the researcher to provide some structure, while at the same time enabling the researcher to have some flexibility during the interview session with the principals and teachers. The researcher performed the semi-structured interview in order to identify resilient children in the study. The protocols of the semi-interviews can be found in appendix (E).

Determining the effectiveness of teaching an experimental spiral physics curriculum to sixth grade students involved qualitative measures. The qualitative measures used surveys, interviews, observations, and video tapping. The Grounded Theory design was used in the qualitative portion of the study. Grounded Theory design is a methodical qualitative process that aims at generating a theory that explains, at a theoretical level, a progression, an action, or a concept (Creswell, 1998); the components are an empirical iterative approach to the collection and analysis of data and a constant comparative approach to the development of theory.

The Complete SPC Study–Limitations

The limitations of the study included the following:

1) The students may have had prior instruction in the physics content.
2) It was assumed that the multiple choice tests would accurately measure the students' learning in physics.
3) It was assumed that the teaching environment and conditions for all four groups were comparable.
4) It was assumed that parents' support of students learning physics was the same across all groups.
5) External or internal forces unknown to the researcher may have impacted physics achievement scores among the students.
6) It was assumed that the groups were representative of the population of the school they attended.
7) The researcher as the instrument may have introduced unknown bias into the study.
8) It was assumed that another researcher would get the same results observing the same phenomena.
9) It was assumed that other researchers observing the same phenomena could corroborate the findings.
10) It was assumed that all information provided on the survives and in interviews were accurate.

11) It was assumed that each student group represented the socio-economic and ethnic diversity of their school.

Summary

The subjects/participants of the pilot study were urban sixth through eighth graders from the urban ZISD system who were required to attend summer school in order to matriculate to the next grade, as well as some gifted and talented youth selected by the principals of the participating schools. In the case of the experimental complete study, the subjects/participants were urban, rural, and suburban sixth graders from the CSI, GMS, and WMS in the complete study. The complete study included rural, urban, and suburban students who represented all of the socio-economic and ethnic strata of Central Texas McLennan County. The data collection instrument for the quantitative part of the study was the physics evaluation test designed by Dr. Truell Hyde, NSF RET fellow, and the researcher. The dependent variable measured in the quantitative part of the study was student physics achievement. The qualitative instruments were surveys, interviews, observation and video taping. The qualitative measures sought to determine the attributes that made resilient children academically successful. The experimental groups in the quantitative part of the study were students receiving the experimental spiral physics curriculum and the traditional linear physics curriculum. The participants in the qualitative part of the study were resilient children identified by the teachers and principals after the researcher defined resiliency. The control groups in the study were subjects/participants that received the traditional linear physics curriculum and did not receive the pre-test. The traditional linear physics curriculum entailed the concepts built upon each other once mastery had been achieved. The quantitative measures collected the pre-test and the post-test scores on the PET from the subject/participants. The qualitative measures of the study required surveys, semi-structured interviews, observations, and video taping of the subjects/participants of the study. The quantitative portion of the study used the Solomon Four group research design and the qualitative portion of the study used a Grounded Theory with the express purpose of building on the strengths of both research designs. The quantitative random design permits the results, which in this case would be a measure of physics achievement, to be generalized to the larger population. The randomization factor enables the researcher to possibly infer from the sample population to the general population, if the results prove to be significant in the study.

The qualitative design enables the researcher to identify possible attributes of the resilient children that results in their academic success. These attributes can then be analyzed and validated to determine whether they are truly significant to academic success. Once the attributes are validated as significant to the academic success of the resilient students, then research can be performed to determine the best forms of implementation or transfer of these attributes to the non-resilient student population.

CHAPTER FOUR

Results

This chapter presents the quantitative and the qualitative findings for the pilot and for the complete study. The findings are presented for each research question.

Results of the Pilot Study by Research Question

Research Question One

Were there significant differences in physics achievement scores for female students who received instruction using an experimental spiral physics curriculum treatment as compared to female students who received the traditional linear physics curriculum treatment?

The Pilot Study Participant Gender. The genders of the students are described as follows: BMS had two females (29%) and five males (71%) as the pilot study participants. CMS had six females (75%) and two males (25 %) as part the pilot study participants. GMS had six females (60%) and four males (40 %) as part the pilot study participants (see Table 4.1).

Table 4.1

Spiral Physics Pilot Study Participant Gender

Gender	BMS % = Raw #	CMS % = Raw #	GMS % = Raw #
Female	29% = 2	75% = 6	60% = 6
Male	71% = 5	25% = 2	40% =4

To answer this research question about females' scores all three schools were combined. The scores were compared using Analysis of Variance (ANOVA) statistics. The term grand mean is used by the researcher to define the mean of the combined data set which includes all participants and all treatments for that subset or the entire sample set. The term treatments refers to the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment. The females' mean PET score was 48.67 with a standard deviation of 13.952. The F test was 2.665 with a significant value of 0.121 and effect size of 0.136. The significant value of 0.121 is above the $p < .05$ threshold in order to meet statistical significance. The effect size is small. This means that there was no statistically significant difference between the experimental spiral physics curriculum when compared to the traditional linear physics curriculum impact on females' physics achievement in the pilot study (see Table 4.2).

A statistically significant difference was not found in the female population that received the treatments; however, the female students that received the experimental spiral physics curriculum treatment did have a higher mean score of 58.60 with standard deviation of 13.145 than those who had the traditional linear physics curriculum treatment mean score of 34.57 with a standard deviation of 9.396. The point differential was 24.03 in favor of the experimental spiral physics curriculum treatment. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The random sample groups had students which represented the entire socioeconomic factors that existed in the general population. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Tables 4.2 and 4.3).

Table 4.2

Pilot Study Combined Inferential Statistics of Females Post-Test Scores

N	Mean	SD	F	df	Sig	Partial Eta Squared
21	48.67	13.952	2.665	1	0.121*	0.1365

*p<.05

Table 4.3

Pilot Study Descriptive Statistics of Gender Post-Test Scores

	N	Mean	Std. Deviation
Post Overall	21	48.67	13.962
Female	12	44.59	16.251
Male	9	54.11	8.115
Post Spiral	10	57.90	10.214
Female	5	58.60	13.145
Male	5	57.20	7.791
Post Linear	11	40.27	11.542
Female	7	34.57	9.396
Male	4	50.25	7.676

Summary Research Question One. All females showed an increase in science achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased physics achievement more than the linear curriculum but the difference was not statistically significant.

Research Question Two

Were there significant differences in physics achievement scores for male students who received instruction using an experimental spiral physics curriculum treatment as compared to male students who received the traditional linear physics curriculum treatment?

The males' mean was 54.11 with a standard deviation of 8.115. The F test was 2.665 with a significant value of 0.121 and effect size of 0.136. The significant value of 0.121 is above the p< .05 threshold in order to meet statistical significance. And the effect size is small. This means that there was no statistically significant difference between the experimental spiral physics curriculum when compared to the traditional linear physics curriculum impact on males' physics achievement in the pilot study (see Table 4.4).

Table 4.4

Pilot Study Inferential Statistics (Levene Test) of Males Post-Test Scores

N	Mean	SD	F	df1	Sig	Partial Eta Squared
11	54.11	8.115	2.665	1	0.121*	0.121

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

A statistically significant difference was not found in the male population that received the treatments; however; the male students that received the experimental spiral physics curriculum treatment did have a higher mean score of 57.20 with standard deviation of 7.791

than those who had the traditional linear physics curriculum treatment mean score of 50.25 with a standard deviation of 7.676. The point differential was 6.95 in favor of the experimental spiral physics curriculum treatment. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.3).

Summary Research Question Two. All males showed an increase in science achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased physics achievement more than the linear curriculum but the difference was not statistically significant.

Research Question Three

Were there significant differences in physics achievement scores for minority students who received instruction using an experimental spiral physics curriculum treatment as compared to minority students who received the traditional linear physics curriculum treatment?

The Pilot Study Participant Ethnicity. The ethnicity of the students is given in the chart found in Table 4.5. BMS' initial number of student participants in the pilot study was 20. The final number of BMS' students that participated in the pilot study was seven or (35%) of the initial sample population. The participating sample population ethnicity of BMS was three African Americans (43%) and four Latinos (57%) in the final sample. It is important to note that 20 students were identified by the principal and seven students accepted the invitation to participate in the study. The same seven students' daily participation in the pilot study was validated by the attendance log signed by the students each day (see Appendix J).

Table 4.5

Pilot Study Participant Scores

Group Treatment Number	BMS		CMS		GMS	
	Pre Scores	Post Scores	Pre Scores	Post Scores	Pre Scores	Post Scores
1 spiral	29	52	60	na	59	79
1 spiral			na	na	44	70
2 spiral		59				
2 spiral		51		64		
2 spiral		52		na		
3 linear	62	54	na	na	34	43
3 linear	34	51	na	na		
4 linear		59		64		52
4 linear		51				54
4 linear		52				46

CMS' initial number of student participants in the pilot study was 20. The final number of CMS student participants in the pilot study was eight which represented (40%) of the initial sample population. The participating sample population ethnicity of CMS student participants was eight Latinos which represented (100%) of the final sample. It is important to note that 20 students were identified by the principal and eight students accepted the invitation to participate in the study. The same eight students' daily participation in the pilot study was validated by the attendance log signed by the students each day (see Appendix J).

GMS' initial number of participants in the pilot study was 23 students. The final number of GMS student participants in the pilot study was ten which represented (44%) of the initial population. The participating sample population ethnicities of GMS student participants were nine African Americans (90%) and one Latino (10%) in the final sample. The same ten students' daily participation in the pilot study was validated by the attendance log signed by the students each day. The chart showing ethnicity in the pilot study is located below in Table 4.6.

Table 4.6

Spiral Physics Pilot Study Participant Ethnicity

Ethnicity	BMS % = Raw #	CMS % = Raw #	GMS % = Raw #
Anglo	0% = 0	0% = 0	0% = 0
African American	43% = 3	0% = 0	90% = 9
Latino	57% = 4	100% = 8	10% = 1

The minorities' post test mean was 48.67 with a standard deviation of 13.962. The F test was 0.304 with a significant value of 0 .591 and effect size of 0.023. The significant value of 0.591 is above the $p < .05$ threshold in order to meet statistical significance. And the effect size of 0.023 is small. This means that there was no statistically significant difference between the experimental spiral physics curriculum when compared to the traditional linear physics curriculum impact on minorities' physics achievement in the pilot study (see Table 4.7).

A statistically significant difference was not found in the minority population that received the treatments; however, the minority students that received the experimental spiral physics curriculum treatment did have a higher mean score of 57.90 with standard deviation of 10.214 than those who had the traditional linear physics curriculum treatment mean score of 40.27 with a standard deviation of 11.542. The point differential was 17.63 in favor of the experimental spiral physics curriculum treatment. African American (AA) minority students that received the experimental spiral physics curriculum treatment did have a higher mean score of 58.00 with standard deviation of 11.045 than those who had the traditional linear physics curriculum treatment mean score of 40.50 with a standard deviation of 14.154. The point differential was 17.50 in favor of the experimental spiral physics curriculum treatment. Latino minority students that received the experimental spiral physics curriculum treatment did have a higher mean score of 57.90 with standard deviation of 10.214 than those who had the traditional linear physics curriculum treatment mean score of 40.14 with a standard deviation of 11.542. The point differential was 17.76 in favor of the experimental spiral physics curriculum treatment. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Tables 4.7, 4.8 and 4.9).

Table 4.7

Pilot Study Inferential Statistics of Minorities Post-Test Scores

N	Mean	SD	F	df	Sig	Partial Eta Squared
21	48.67	13.952	0.304	1	0.591*	0.023

*p<.05

Table 4.8

Pilot Study Descriptive Statistics of Minorities Post- Test Scores

	N	Mean	Std. Deviation
Post Overall	21	48.67	13.962
AA	12	52.17	14.371
Latino	9	44.00	13.962
Post Spiral	10	57.90	10.214
AA	8	58.00	11.045
Latino	2	57.90	10.214
Post Linear	11	40.27	11.542
AA	4	40.50	14.154
Latino	7	40.14	11.542

Summary Research Question Three. All minorities showed an increase in science achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased physics achievement more than the linear curriculum but the difference was not statistically significant.

Research Question Four

Were there significant differences in physics achievement scores for resilient students who received instruction using an experimental spiral physics curriculum treatment as compared to resilient students who received the traditional linear physics curriculum treatment?

The resilient' mean post test score was 56.00 with a standard deviation of 15.864. The F test was 3.218 with a significant value of 0 .089 and effect size of 0.145. The significant value of 0.414 is above the $p < .05$ threshold in order to meet statistical significance. The effect size of 0.145 is small (see Table 4.9). This means that there was no statistically significant difference between the experimental spiral physics curriculum when compared to the traditional linear physics curriculum impact on resilient students' physics achievement in the pilot study

Table 4.9

Pilot Study Inferential Statistics of Resilient Students Post-Test Scores

N	Mean	SD	F	df	Sig	Partial Eta Squared
14	56.00	15.864	3.218	1	0.089*	0.145

*p<.05

A statistically significant differences was not found in the resilient population that received the treatments; however, the resilient students that received the experimental spiral physics curriculum treatment did have a higher mean score of 65.50 with standard deviation of 13.748 than those who had the traditional linear physics curriculum treatment mean score of 44.50 with a standard deviation of 15.864. The point's differential was 21.00 in favor of the experimental spiral physics curriculum treatment. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Tables 4.9 and 4.10).

Table 4.10

Pilot Study Descriptive Statistics of Resilient Students Post-Test Scores

	N	Mean	Std. Deviation
Post Overall	21	48.67	13.962
Resilient	7	56.00	15.864
Non Resilient	14	45.00	11.845
Post Spiral	10	57.90	10.214
Resilient	4	65.50	13.748
Non Resilient	6	52.33	4.227
Post Linear	11	40.27	11.542
Resilient	4	44.50	15.864
Non Resilient	7	42.50	10.573

Summary Research Question Four. All resilient students showed an increase in science achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased physics achievement more than the linear curriculum but the difference was not statistically significant.

Research Question Five

Were there significant differences in physics achievement scores for students from the BMS, CMS, and GMS who received instruction using an experimental spiral physics curriculum treatment as compared to students from the BMS, CMS, and GMS who received the traditional linear physics curriculum treatment?

The students' aggregated schools post-test mean was 48.67 with a standard deviation of 13.962. The F test was 0.768 with a significant value of 0.478 and effect size of 0.079. The significant value of 0.768 is above the $p < .05$ threshold in order to meet statistical significance. And the effect size is small. This means that there was no statistically significant difference between the experimental spiral physics curriculum to the traditional linear physics curriculum impact on student participants' physics achievement in the pilot study (see Table 4.11).

Table 4.11

Pilot Study Inferential Statistics of Schools Post-Test Scores

N	Mean	SD	F	df	Sig (two tail)	Partial Eta Squared
21	48.67	13.962	0.768	2	0.478	0.079*

*p<.05

A statistically significant differences was not found in the schools' population that received the treatments; however, the BMS' students that received the experimental spiral physics curriculum treatment did have a higher mean score of 53.50 with standard deviation of 3.697 than those BMS' students who had the traditional linear physics curriculum treatment mean score of 46.25 with a standard deviation of 8.808. BMS' point's differential was 7.25 in favor of the experimental spiral physics curriculum treatment. The CMS students that were selected for the experimental spiral physics curriculum treatment did have a higher mean score of 64.00 than those CMS' students who had the traditional linear physics curriculum treatment mean score of 27.00. The differential between the two CMS scores is not valid because the students did not complete the experimental spiral physics curriculum treatment. GMS' students that received the experimental spiral physics curriculum treatment did have a higher mean post score of 60.20 with standard deviation of 13.755 than those GMS' students who had the traditional linear physics curriculum treatment post mean score of 40.80 with a standard deviation of 12.276. The GMS point differential was 19.40 in favor of the experimental spiral physics curriculum treatment. The experimental spiral curriculum treatment produced the higher post mean scores; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Tables 4.11 and 4.12).

Table 4.12

Pilot Study Descriptive Statistics of Schools Post-Test Scores

	N	Mean	Std. Deviation
Post Overall	21	48.67	13.962
BMS	8	49.88	7.357
CMS	3	39.33	21.362
GMS	10	50.50	15.988
Post Spiral	10	57.90	10.214
BMS	4	53.50	3.697
CMS	1	64.00	na
GMS	5	60.20	13.755
Post Linear	11	40.27	11.542
BMS	4	46.25	8.808
CMS	2	27.00	Na
GMS	5	40.80	12.276

Summary Research Question Five. All schools showed an increase in post test mean physics achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased physics achievement more than the linear curriculum but the difference was not statistically significant.

Pilot Study—BMS Result Summary

As stated earlier, BMS' initial number of participants in the pilot study was 20 students. The complete number of BMS students that participated in the pilot study was seven or (35%) of the initial sample population.

All BMS students who received the experimental spiral physics curriculum treatment showed an increase in physics achievement on the post-physics evaluation test. All BMS students who did not take a pre–PET and received the traditional linear physics curriculum treatment showed increased achievement on the post-physics evaluation test (PET). However, the BMS students who received the experimental spiral physics curriculum treatment scored slightly higher than those who were taught the traditional linear physics curriculum treatment in the pilot study.

The BMS students' sample population attendance was stable which lent itself well to the experimental spiral physics curriculum treatment. The stable attendance assured that each student maximized their instructional learning time each day. One score did not follow the norm and was considered an outlier. The outlier was a BMS Latino male who received the traditional linear physics curriculum treatment. The BMS Latino males scored slightly higher on the pre-PET than the post-PET. The BMS African American female scored higher on the post-PET than the BMS Latino female (see Table 4.5). The BMS Latino female scored the lowest when compared to the overall group. The BMS African American males and Latino males scored similarly with the exception of the one outlier (see Table 4.5).

Pilot Study—CMS Result Summary

CMS' initial number of participants in the pilot study was 20 students. The final number of CMS student participants in the pilot study was eight which represented (40%) of the initial sample population. The attendance of CMS students in the population did not lend itself well to the experimental spiral physics curriculum treatment. The CMS students did not attend class regularly which in essence did not permit the students to maximize their instructional learning time. The instability in attendance of the group was primarily due to a last minute time change implemented by the school. Due to the attendance instability of the student sample population, those who were pre-tested were unable to be post-tested. Although the curriculum initially began as spiral in nature, it became a traditional linear physics curriculum treatment due to the instability in attendance of the student population. All remaining CMS students received the post–PET on the traditional linear physics curriculum treatment. Due to the repetitive nature of the spiral physics curriculum, the loss of days would not enable the students to receive the repetitive learning taught through the spiral physics curriculum. Therefore, the curriculum took on characteristics of a linear physics curriculum. One CMS Latino male received the pre–PET and initial spiral physics curriculum. However, due to the birth of a new baby brother, the student did not continue with the study. The CMS student expressed to the researcher that he was needed by his mother after the birth of the baby. The CMS Latino females performed better as a whole than CMS Latino males on the post–PET. The CMS Latino females scored the highest when compared to the CMS Latino males (see Table 4.5).

Pilot Study—GMS Result Summary

As stated earlier, the GMS initial number of participants in the pilot study was 23 students. The final number of GMS student participants in the pilot was 10 which represented (44%) of the initial sample population. The GMS student sample population attendance was stable lending itself well to the experimental spiral physics curriculum treatment. The stable attendance of the students assured that each student maximized their instructional learning. All GMS students that received the pre–PET and the experimental spiral physics curriculum treatment showed an increase in physics achievement on the post–PET. All GMS students that did not receive the pre–PET and received the traditional linear physics curriculum treatment also showed an increase in physics achievement. However, those GMS students receiving the experimental spiral physics curriculum treatment scored a slightly higher mean score than those given the traditional linear physics curriculum treatment.

The GMS African American females scored higher on the post–PET than the African American males and GMS Latino male at GMS. The GMS African American males and GMS Latino male scored similarly on the post–PET. All spiral physics curriculum post-test scores were slightly higher than the post traditional linear PET scores (see Table 4.5).

Pilot Study—Principals Survey Results

Principals of BMS, CMS, and GMS all participated in the survey. The results of the survey showed that the socio-economic income range was from $9,310 to $34,999. All principals supported an inquiry based, hands-on approach to physics. All the schools supported the Full Option Physics System (FOSS).

Pilot Study Resilient Student Results

Part of this study targets resilient students and their attributes for success. One resilient student for each campus was selected by the researcher and principals based on the student population, the observation, survey, and interview results, as well as the teacher's insight and experience with the student. The researcher constructed descriptive attributes for resilient students that include empathy factor ("E" factor), tenacity factor ("T" factor), spiritual factor ("S" factor), and relational factor ("R" factor). A discussion of these attributes and the resilient students in the pilot study will be given in the following paragraphs.

Pilot Study—BMS Resilient Student Results

An African American female student was identified as resilient student from BMS and became the subject in the qualitative study. The subject was randomly placed in the experimental spiral physics curriculum treatment group. The initial visit to the student's home began with the researcher walking in on a conversation of a police officer with the subject's grandmother concerning the location of a relative the police officer wanted to question. The subject quickly bonded to the researcher and began to reveal her world.

The first revelation was that her grandmother wanted her to be careful when she was outside because a known child sex offender lived across the street from her home. Toward the end of the study, the subject's father was killed. The subject continued to attend class. Initially, the subject did not have a goal in life. However, toward the end of the study, she decided that she would like to work in educational television.

The subject possessed a great ability to rouse empathy from administrators and teachers. The researcher observed her interactions with the principal, staff, teachers and peers. The researcher observed an easy ability to converse with all and explain issues and concerns in her world. The researcher observed that all listened and responded to the subject's issues and concerns. The researcher called this ability the empathy factor, or "E" factor, which was quite evident whenever one would interface with the subject. Another attribute of the student was tenacity. The subject continued to participate in the pilot after her father was killed. The researcher called this ability the tenacity factor, or "T" factor, which was also quite evident in the subject as observed by the researcher. An attribute pronounced by the researcher and teacher was the spiritual factor. The researcher called this ability the "S" factor, although this was more pronounced in the subject's grandmother than the actual subject. The grandmother took on the roles of guardian and surrogate parent of her granddaughter. The subject was very relational and demonstrated the relational factor. The researcher calls this ability the "R" factor. The researcher observed that the subject was concerned about what was happening in the worlds of the people that impacted her world. The subject did demonstrate academic resiliency in that she performed well on the post test of the study. The subject also shared with the researcher/teacher that she had passed all of her summer classes which would enable her to be promoted to the next grade (see Appendix M).

Pilot Study—CMS Resilient Student Results

The resilient student who was chosen by the researcher from CMS was a Latino male for the qualitative portion of the study. The subject had been randomly placed in the pre-tested spiral curriculum group. The subject was highly engaged in the lessons. He took the leadership role whenever the class performed experiments and was quite verbal in explaining his views.

He was able to communicate about the condition of the world in which he lived and evoked empathy from the researcher/teacher. The subject demonstrated the attribute of evoking empathy. The researcher observed the subjects communications with his classmates and staff. The subject could easily draw others into his world. The researcher called this ability the “E” factor. The subject explained that his mother was having a baby and that he would be responsible for helping the family with the care of the new sibling. The subject’s hair was initially black in color; and toward the end of the study he came to class with blonde hair. The researcher/ teacher inquired about the response of the student’s mother to the change in hair color. He stated that his mother did not really care. The subject continued to be totally engaged in the class lessons; however, just before the end of the pilot study his mother had the baby. The researcher observed an aptitude for physics which could translate to academic resiliency. The researcher concluded that the subject had an intuitive understanding of the subject. He left the pilot study to help assist his mother in the care of his siblings (see Appendix M).

Pilot Study—GMS Resilient Student Results

The resilient student chosen by the researcher from GMS was an African American female. The GMS subject was randomly placed in the pre–PET spiral group. The initial observation of her home life included the meeting of the student’s father who supported her involvement in the pilot study. The GMS subject was attentive and quickly grasped the physics concepts. The GMS subject had established the goal of becoming a doctor, specifically a pediatrician. The GMS subject was engaged in lessons and was very helpful to her peer group. The GMS subject took on the leadership role in her group (see Appendix M). The GMS subject demonstrated a high relational characteristic which translates to what the researcher calls the "R" factor.

One similarity of resilient students seems to be the experience of a life impacting event, such as the death of a father at an early age. All appeared to have rough starts in school, but adjusted and later became productive in the school environment. All of the students had to choose to disengage from individuals that inhibited their advancement in the classroom.

The Pilot and Complete Studies Grounded Theory Analysis with Becker's Inductive data-Analysis Methodology on Physics Achievement Test in Resilient Students

The qualitative measure included is a Grounded Theory design using Becker's inductive data-analysis methodology on the participants, which looked at the resilient students found in the population. In Becker's description of analytic induction, data analysis begins while data is being gathered, which is unlike most quantitative approaches where analysis begins subsequent to data acquisition (Becker, 1958).

Grounded Theory is a logical qualitative method that aims at generating a theory that explains, at a theoretical level, a process, an action, or a concept (Gay and Airasian, 2003). These components are an empirical, iterative approach to the collection and analysis of data and a constant comparative approach to the development of theory. Becker's analytic-induction method of data-analysis was used to support the Grounded Theory design due to the fact that a hypothesis and some categories have been identified prior to the study, such as an approach to sampling which is theoretical, and this theory develops from a descriptive to abstract levels with constant comparison (Star, 1996).

In 1967 Glasner and Strauss developed a systematic way to gather and analyze data that they called Grounded Theory (Glasner & Strauss, 1967). Later, Strauss and Corbin further developed Grounded Theory to include the systematic derivation of a theory from the data that acknowledges the close relationship of data collection, data analysis and the eventual derivation of a theory from the data itself (Strauss & Corbin 1990, 1998). Grounded Theory holds a dual role in qualitative research, because as a theory it enables the researcher to approach the data in an inductive manner, whereas while analyzing and comparing the data, the researcher looks for relationships until a theory emerges. As a methodology, this guides the researcher with methods of coding, grouping, fracturing, and synthesizing the data so that an emerging theory is revealed (Strauss & Corbin, 1998). Strauss and Corbin stated that the value of the methodology is in its ability to generate theory and to ground that theory in data. Both theory and data analysis involve interpretation, which is based on systematically carried out inquiry (Strauss & Corbin, 1998).

The qualitative portion of the experiment was to identify "resilient" students from the four groups for observation. The resilient students were studied further using Grounded Theory design with Becker's inductive data-analysis methodology Grounded Theory has three basic components: concepts, categories and propositions. The major building block for theory development is concepts (Corbin & Strauss, 1990). The theory is derived from the "raw data" where the researcher analyzes a precursor of the phenomena and gives it a label. As the researcher encounters other precursors or events prior to the studied phenomenon, the researcher may give that event the same label. It is the comparing of the precursor or event prior to the studies' phenomena that a theory is derived. The second component of grounded theory is categories. Corbin and Strauss define categories as higher in level representation of concepts (Corbin & Strauss, 1990).

The same analysis that is used to define concepts is used to define categories. Categories are considered the "cornerstones" of the grounded theory. It is through categories the concepts are weaved together. The researcher may discover three or more different concepts; however, these concepts represented events that precede similar processes and enable the researcher to group these concepts under a higher level of representation of these concepts (Corbin & Strauss, 1990). The third component of grounded theory is a proposition which is some correlation between relationships of categories. Glaser and Strauss first termed this interwoven relationship between categories "hypotheses" (Glaser & Strauss, 1967). Whetten corrected this by calling the "hypotheses" "propositions" because "hypotheses" is a quantitative research term which requires a measured relationship, whereas "proposition" requires a conceptual relationship (Whetten, 1989). Grounded Theory produces a conceptual relationship.

The deriving of concepts, categories, and propositions is an iterative process. Grounded theory as defined by Strauss and Corbin as a theory that is inductively derived from the study of the phenomenon it represents. The theory is discovered, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon. Therefore, data collection, analysis, and theory should stand in equal relationship with each other. One begins with an area of study and what is relevant to that area is allowed to emerge (Strauss & Corbin, 1990).

The data used in the grounded theory analysis was derived from four different sources: science teachers' interviews, which identified resilient students who participated in the study; video taping of the participating sixth grade classes; principals' surveys and informal interviews; and the researcher's observations. To date, no Grounded Theory has been derived concerning the characteristic and attributes of resilient students that could be transferred to all students. The preliminary information does show some similarities in children that are identified as resilient. The similarities were good communications skill, good in relating to others, highly engaged in classroom activities, inquiring about lessons and how it related to the real world and consistent in attending class and maximizing their instructional learning time . The number one cited description for learning style for resilient children was rote by some of the science teachers. The number two cited description for learning style for resilient children was tactile or kinesthetic. The researcher observed that peer to peer learning appeared to positively impact learning for resilient students. The resilient students helped assist their classmates with labs and classroom activities. The resilient student communicated freely among peers any question or concerns they may have had with the lessons. Lab work seemed to enhance resilient students' learning experience. Resilient students responded positively to the critical think tank and critical thinking centers set up in their classroom. The researcher observed the resilient students researching to learn more about the concepts. Each campus classroom had think tank centers for group critical thinking sessions and individual critical thinking session for individual problem solving. The think tank centers and the critical thinking centers had personal computers set up with internet access. The internet site was programmed to Digital Library for Earth Science Education (DLESE).

Table 4.13

Complete Study Participant Scores

Group Treatment Number	CSI		WMS		GMS	
	Pre Scores	Post Scores	Pre Scores	Post Scores	Pre Scores	Post Scores
1 spiral	48	77	55	80	32	50
1 spiral.	41	77	45	80	28	53
1 spiral	30	62	32	89	32	70
1 spiral	43	73	35	37	45	50
1 spiral	32	48			27	45
2 spiral		75		58		35
2 spiral		62		95		45
2 spiral		62		80		50
2 spiral		88		47		50
3 linear	40	80	35	85	0	37
3 linear	18	48	55	88	23	35
3 linear	48	90	45	82	15	40
3 linear	45	62				
4 linear		70		73		58
4 linear		43		67		52
4 linear		63		83		50
4 linear		78				65
4 linear		53				48
4 linear		33				43
4 linear		48				

Complete Study Results by Research Questions

The researcher will discuss research questions one and two together in the case of the complete study.

Research Question One

Were there significant differences in physics achievement scores for female students who received instruction using an experimental spiral physics curriculum treatment as compared to female students who received the traditional linear physics curriculum treatment?

Research Question Two

Were there significant differences in physics achievement scores for male students who received instruction using an experimental spiral physics curriculum treatment as compared to male students who received the traditional linear physics curriculum treatment?

The gender for the students is described as follows: CMS had 25 females which represented (69%) and 11 males which represented (31 %) of the participants in the complete SPC study. CSI school had 16 females which represented (73%) and six males which represented (27%) of the participants in the complete SPC study. GMS had 22 females which represented (96%) students and one male which represented (6 %) student participation in the complete SPC study. And WMS had 10 which represented (71%) female students and 4 males which represented (27%) students participated in the complete SPC study (see Table 4.14).

Table 4.14

The Complete SPC Study Gender

Gender	CMS % = Raw #	CIS % = Raw #	GMS % = Raw #	WMS % = Raw #
Female	69%=25	73% = 16	96% =21	71%=10
Male	31%=11	27% = 6	4% =1	29%=4

The complete study pre and post achievement scores for the females and males' are described Table 4.16 below. The females' pre–PET mean score of 34.10 with SD 14.291 was slightly higher than males' pre–PET mean score of 34.10 with SD 21.585, with a point differential of 10. The females' post–PET mean score of 63.79 with SD 16.385 was higher than the male's post–PET mean score of 57.91 with SD 21.517, with a point differential of 5.88. In the case of the females and the males, both experienced increased physics achievement with the experimental spiral physics curriculum treatment and the traditional linear physics achievement (see Table 4.15).

Table 4.15

Complete Study Descriptive Statistics of Gender and School Pre and Post-Test

	N	Mean	Std. Deviation
Pre	32	34.09	14.641
Female	29	34.10	14.291
Male	3	34.00	21.517
Post	54	62.59	17.503
Female	43	63.79	16.385
Male	11	57.91	21.585

Females in the Complete Study. The table below table 4.16 gives Inferential statistics of the impact of the complete study on females. The final sample size for all females was 22 subjects/participants. The mean of the sample population was 64.23 with a SD 18.032 and a t test of |11.163| with 21 total degrees of freedom and a significance of 0.000 which did meet the $p<.05$ requirement. This would enable the researcher to have a 95 % confidence that the experimental spiral physics curriculum and the traditional linear physics curriculum treatments impacted the dependent variable of student physics' achievement. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.16).

The correlation value of 0.721 does support a direct relationship between the female's physics achievement which means that when the female and male population received the experimental spiral physics curriculum and the traditional linear physics curriculum it did increase their physics achievement. The correlation's significance value of 0.000 does meet the $p<.05$ standard in order to give the researcher a 95% confidence in the results. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show a t test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.16).

Table 4.16

Complete Study Inferential Statistics of Females Post –Test Scores

N	Mean	SD	Correlation	Sig	t	df	Sig (two tail)
22	64.23	18.032	0.721	0.000	-11.163	1	.000*

*p<.05

A statistically F value of 2.372 and a significant difference of 0.029 was found in favor of the female students that received the experimental spiral physics curriculum treatment and had a higher post tests 64.46 mean score of than those who had the traditional linear physics curriculum treatment post test score of 62.95. A statistically t value of |1.129| with a significant difference of 0.461 was not found in the male students that received the experimental spiral physics curriculum treatment; however, males did have a higher mean score than those who had the traditional linear physics curriculum treatment.

Both females and males had an increase in physics achievement after receiving the experimental physics curriculum and the traditional linear physics curriculum treatment. However, the experimental spiral physics curriculum treatment produced higher post test mean score of 64.75 versus the 54.00 post test mean score for the traditional linear curriculum (see Table 4.17). The table 4.18 below describes the complete study descriptive statistics for the experimental spiral physics curriculum treatment impact on females and males. The females' experimental spiral physics curriculum treatment sample size was 24 with a mean of 64.46 and SD 16.000. The males' experimental spiral physics curriculum treatment sample size was 4 with a mean of 64.75 and SD 27.281 (see Table 4.17). The females' traditional linear physics curriculum treatment sample size of 19 had a mean of 62.95 and SD 17.261 which reflects a 1.51 points advantage for the experimental spiral physics curriculum treatment. The males' traditional linear physics curriculum treatment sample size of 7 had a mean of 54.00 and SD 18.850 which reflects a 10.75 points advantage for the experimental spiral physics curriculum treatment.

Table 4.17

Complete Study Descriptive Statistic of Gender Post-Test Spiral and Linear

Comparison Categories	Spiral Post-Test Group C (N=28)	Linear Post-Test Group D (N=26)	Totals (N=54)
Female N	24	19	43
Female Mean	64.46	62.95	63.79
Female (SD)	(16.000)	(17.261)	(16.385)
Male N	4	7	11
Male Mean	64.75	54.00	57.91
Male (SD)	(27.281)	(18.850)	(21.585)

The table 4.17 gives descriptive statistics of the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment impact on females and males. The final sample size for the complete study was 54 subjects/participants. The females' combined spiral and linear post test mean of the sample population was 63.79 with a SD 16.385 and a F test of 2.372 with 42 total degrees of freedom and a significance of 0.029 which did meet the $p<.05$ requirement. The experimental spiral curriculum treatment produced the higher mean score of 64. 46 and the differential was large enough to overcome the high variability within and between groups in order to show an F test value of 2.373 with a significance value of 0.029. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.18). This would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of female physics' achievement.

Table 4.18

Complete Study Inferential Statistics (Levene Test) of Females Post-Test

N	Mean	SD	F	df1	Sig
43	63.79	16.385	2.372	1	0.029*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups. *p<.05

Males in the Complete Study. The males' combined spiral and linear mean of the sample population was 57.91 with a SD of 21.585 and a t test value of | 1.129 | with 1 total degree of freedom and a significance of 0.461 which did not meet the p<.05 requirement which would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of male physics' achievement (see Table 4.19). The experimental spiral curriculum treatment given to the males produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show a t test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum. The Equal Variance assumption of ANOVA can be checked formally using Levene's test. Levene's test for equality of population variances and can be used when you have independent group samples (see Table 4.18 and 4.19).

Table 4.19

Complete Study Inferential Statistics (Levene Test) of Males and Method Post-Test

N	Mean	SD	T	df1	Sig (two tail)
11	57.91	21.585	-1.129	1	0.461*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

The 4.20 table below gives inferential statistics of the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment impact on females and males. The final sample size for the complete study was 54 subjects/participants. The F value of 1.306 with 53 total degrees of freedom and a significance of 0.283 which did not meet the p<.05 requirement that would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of female and male physics’ achievement. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics’ achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.20).

Table 4.20

Complete Study Inferential Statistics (Levene Test) of Gender Post-Test

N	F	df1	df2	Sig
54	1.306	2	50	0.283*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

The table 4.21 below describes the complete study inferential statistics for gender. The following is the inferential statistics of the impact of the design, gender and method on the study. The F value for design in relationship to gender was 0.663 with a significance of 0.579 and effective size of 0.038 which is small.

Table 4.21

Complete Study Inferential Statistics of Gender and Methods Post-Tests

Source	df	F	Sig	Partial Eta Squared Effect Size
Design Model	3	.663	.579	.038
Gender	1	.492	.486	.010
Gender/Methods	1	.561	.457	.011
Error	50			
Total	54			

The inferential statistic for the design indicates that the design did not impact on predicting physics achievement based on gender and that the effect was not significant and the size of the effect of the design was small. The F value for gender was 0.492 with a significance of 0.486 and effect size of 0.010 which is small. The inferential statistic indicates that the impact on predicting physics achievement based on gender and that the effect was not significant and the size of the effect of the gender was small.

The F value for the experimental spiral physics curriculum and the traditional linear physics curriculum treatments in relationship to gender was 0.561 with a significance of 0.457 and effect size of 0.011 (see Table 4.21).

The inferential statistic for the treatments indicated that the experimental spiral physics curriculum and the traditional linear physics curriculum treatments had no impact on predicting physics achievement based on gender and that the effect was not significant and the size of the effect of the design was small. The experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.21).

Table 4.22 describes below by schools, the females' complete study post achievement scores for the spiral and linear curriculum. The CSI experimental spiral physics curriculum treatment sample size was 10. The CSI traditional linear physics curriculum treatment sample size was 6. The post mean score of 71.20 with SD 12.656 was slightly higher than the traditional linear physics curriculum treatment post–PET mean score of 70.17 with SD 15.237, with a point differential of 1.03. The GMS experimental spiral physics curriculum treatment sample size was 9. The GMS traditional linear physics curriculum treatment sample size was 8. The post mean score of 49.78 with SD 9.244 was slightly higher than the traditional linear physics curriculum treatment post–PET mean score of 48.13 with SD 10.439, with a point differential of 1.65. The WMS experimental spiral physics curriculum treatment sample size was 5. The CSI traditional linear physics curriculum treatment sample size was 5. The post mean score of 77.40 with SD 11.524 was slightly lower than the traditional linear physics curriculum treatment post–PET mean score of 78.00 with SD 7.681, with a point differential of 0.60 (see Table 4.22).

Table 4.22

Complete Study Descriptive Statistics of Females, Method and School Post-Test

School	Method	N	Mean	SD
CSI	Spiral	10	71.20	12.656
	Linear	6	70.17	15.237
	Total	16	70.81	13.182
GMS	Spiral	9	49.78	9.244
	Linear	8	48.13	10.439
	Total	17	49.00	9.546
WMS	Spiral	5	77.40	11.524
	Linear	5	78.00	7.681
	Total	10	77.70	9.238
Total	Spiral	28	64.50	17.343
	Linear	26	60.54	17.781
	Total	54	62.59	17.503

The 4.23 table below gives inferential statistics of the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment impact on males. The final sample size for the complete study was 11 subjects/participants.

The F value of 1.306 with 53 total degrees of freedom and a significance of 0.283 which did not meet the p<.05 requirement that would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of male physics' achievement (see Table 4.23).

Table 4.23

Complete Study Inferential Statistics (Levene Test) of Males and Method Post-Test Scores

N	Mean	SD	F	df1	Sig
11	57.91	21.585	1.306	1	.283*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

A statistically significant difference was not found for males; however, the male students that received the experimental spiral physics curriculum treatment did have a higher mean score that those who had the traditional linear physics curriculum treatment. As may be the case here, one of the pitfalls of statistics reveals that not finding evidence of a difference does not constitute evidence that there is not a difference.

The males' complete study pre and post achievement scores are described below in Table CSSMB1. The pre–PET sample size was 3. The pre–PET mean score was 34.00 with SD 21.517. The post–PET sample size was 11. The post–PET mean score was 57.91 with SD 21.585. The differential of 23.91 indicates the complete SPC study did increase physics achievement in males (see Table 4.24).

Table 4.24

Complete Study Descriptive Statistics of Males Pre and Post-Test

Test	N	Mean	Std. Deviation
Pre	3	34.00	21.517
Post	11	57.91	21.585
Valid N (list wise)	2		

The Table 4.25 describes below males by schools complete study post achievement scores. The CSI sample size was 6. The post means score of 54.50 with SD 17.420. The GMS sample size was 1. The post means score of 43.00. The WMS sample size was 4. The post means score of 66.75 with SD 29.010 (see Table 4.25).

Table 4.25

Complete Study Descriptive Statistics of Males and Schools Post-Test

School	N	Mean	SD
CSI	6	54.50	17.490
GMS	1	43.00	na
WMS	4	66.75	29.010

The table 4.26 below gives descriptive statistics of the males' complete study. The final sample size for the complete study was 11 subjects/participants. The mean of the sample population was 57.91 with a SD 21.585 and a F value of 1.306 with 53 total degrees of freedom and a significance of .283 which did not meet the $p<.05$ requirement that would enable the researcher to have a 95 % confidence that the treatments. The

Equal Variance assumption of ANOVA can be checked formally using Levene's test. Levene's test for equality of population variances and can be used when there are independent group samples (see Table 4.26).

Table 4.26

Complete Study Inferential Statistics (Levene Test) of Males and School

N	Mean	SD	F	df1	Sig
11	57.91	21.585	1.306	1	.283*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

The table 4.27 correlation value described below was 1.00. The 1.00 value supports a direct relationship between the males' physics achievement and the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment which means that the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment increases males' physics achievement. The significance value of this correlation was 0.000 which did meet the p<.05 standard in order to give the researcher a 95% confidence that the direct relationship is valid. However, a sample size of two is not sufficient to make such a conclusion (see Table 4.27).

Table 4.27

Complete Study Inferential Statistics (Correlations) of Males Pre and Post-Test

Males	N	Correlations	Sig.
Pair 1: Pre & Post	2	1.000	.000*

*p<.05

Summary Research Question One and Two. All females showed an increase in science achievement after receiving the spiral and the linear curriculum and the spiral curriculum increased post test scores more than the linear curriculum post test scores and the difference was statistically significant with a value of 0.029.

All males showed an increase in science achievement after receiving the spiral and the linear curriculum; however, the spiral curriculum increased post test scores more than the linear curriculum but the difference was not statistically significant with a value of 0.461.

Research Question Three

Were there significant differences in physics achievement scores for minority students who received instruction using an experimental spiral physics curriculum treatment as compared to minority students who received the traditional linear physics curriculum treatment?

The Complete Study—SPC Participants Ethnicity. The ethnicity of the students is described in the table 4.28. CMS participants totaled 59 students initially as participants in the complete SPC study. CMS' final number of participants in the complete SPC study was 36 which represented (65%) of the original sample population. The number of Latino students was 33 which represented (92%) and three African American students which represented (8 %) that participated in the complete study of the final sample population. CSI had a total of 24 students initially to participate in the complete SPC study. CSI's final number of participants in the complete SPC study was 23students or (96%) participation. The number of CSI students was 22 (96%) represented by Anglo students and one (4%) Latino student who participated in the complete SPC study. GMS had a total of 22 students initially to participate in the complete SPC study. GMS' final number of participants in the complete SPC study was 18 students or (82%) participation. The number of GMS students was 17 (94%) African American students and one (6%) Latino in the final sample population who participated in the complete SPC study. Finally, WMS had a total of 16 students initially to participate in the complete SPC study. WMS' final number of participants in the complete SPC study was 14 students which represented (88%) of the original sample population. WMS had 12 (86%) Anglo student participants and two (14%) Latino students in the complete SPC study of the final sample population (see Table 4.28).

Table 4.28

Spiral Physics Curriculum Study Participant's Ethnicity

	CMS	CSI	GMS	WMS
Ethnicity	% = Raw #	%= Raw #	% = Raw #	% = Raw #
Anglo	0%=0	96% = 23	0% =0	86%=12
African American	8%=3	0% = 0	94% =17	0%=0
Latino	92%=33	4% = 1	6% =1	14%=2

In the case of the pilot all students were minorities; however, in the case of the complete study the ethnicity included both minorities and the majority. Table 4.29 below gives inferential statistics of the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment impact on males. The final sample size for the complete study was 54 subjects.. The minority and majority students' F value of 5.177 with 53 total degrees of freedom and a significance of 0.009 which did meet the p<.05 requirement that would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of physics' achievement by ethnicity. This means that the experimental spiral curriculum increased physics achievement in minority and majority students. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.29).

Table 4.29

Complete Study Inferential Statistics (Levene Test) of Ethnicity Post-Test

N	Mean	SD	F	df1	df2	Sig
54	62.59	17.503	5.177	2	51	.009*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups Design: Intercept + Ethnicity.
*p<.05

A statistically significant difference with a F value of 5.177 with a statistically significant value of .009 which is below the p<.05 was found in favor of the minority and majority students that received the experimental spiral physics curriculum treatment. Also the experimental spiral physics curriculum mean score was higher mean score that those who had the traditional linear physics curriculum. The table 4.22 describes the complete study in relationship to ethnicity pre and post achievement scores based on ethnicity. The African Americans sample size was 16. The mean score was 48.81 and SD 9.921. The Latinos sample size was 5. The mean score was 63.00 with a SD 21.178. The Anglos sample size was 33. The mean score was 69.21 with a SD 16.280 (see Table 4.30).

Table 4.30

Complete Study Descriptive Statistics of Ethnicity Combined Post-Test

Ethnicity	N	Mean	Std. Deviation
African American	16	48.81	9.921
Latino	5	63.00	21.178
Anglo	33	69.21	16.280

Table 4.31 below describes the complete study of ethnicity descriptive statistics for the experimental spiral physics curriculum treatment. The African American experimental spiral physics curriculum treatment sample size was 7 with a mean score of 50.43 and SD of 10.470 The traditional linear physics curriculum treatment sample size of 9 had a mean score of 47.56 and SD 9.914 which reflects a 2.87 points advantage for the experimental spiral physics curriculum treatment . The Latino experimental spiral physics curriculum treatment sample size was 4 with a mean score of 58.00 and SD 20.769. This shows that the spiral physics curriculum did increase physics achievement of the targeted population. The traditional linear physics curriculum treatment sample size of one had a score of 83.00 which reflects a 25 points advantage for the traditional linear physics curriculum treatment. The Anglos experimental spiral physics curriculum treatment sample size was 17 with a mean score of 71.82 and SD 15.212. The traditional linear physics curriculum treatment sample size of 16 had a mean score of 66.44 with SD 17.397 which reflects a 5.38 points advantage for the experimental spiral physics

curriculum treatment. This shows that all students increased in physics achievement where the Anglo students had the highest, Latino had the second highest and African Americans had the third highest increase in physics achievement (see Table 4.31).

Table 4.31

Complete Study Descriptive Statistics of Ethnicity and Method Post-Test

Method	Ethnicity	N	Mean	Std. Deviation
Spiral		28		
	African American	7	50.43	10.470
	Latino	4	58.00	20.769
	Anglo	17	71.82	15.212
Linear		26		
	African American	9	47.56	9.914
	Latino	1	83.00	na
	Anglo	16	66.44	17.397

Table 4.32 describes below the complete study by school post achievement scores by ethnicity. The CSI African American sample size was 0. The CSI Latino sample size was one with the post mean score of 48.00. The CSI Anglo sample size was 21 with the post mean score of 67.24 and SD 15.722. The GMS African American sample size was 16 with the post mean score of 48.81 and SD 9.921. The GMS Latino sample size was 2 with the post mean score of 47.50 and SD 3.536. The GMS Anglo sample size was 0. The WMS sample size was 4. The post mean score was 66.75 with SD 29.010. The WMS African American sample size was 0. The WMS Latino sample size was two with

the post score of 86.00 with SD 4.243. The CSI Anglo sample size was 12 with the post score of 72.67 and SD 17.354. In summary, this shows that all races had an increase in physics achievement after receiving the spiral and the linear physics curriculum; however, in the majority of the cases the experimental spiral physics curriculum produced the highest means with the exception of one Latino student (see Table 4.32).

Table 4.32

Complete Study Descriptive Statistics of Ethnicity and School Post-Test

School	Ethnicity	N	Mean	SD
CSI	African American	0	[a]	na
	Latino	1	48.00	na
	Anglo	21	67.24	15.722
GMS	African American	16	48.81	9.921
	Latino	2	47.50	3.536
	Anglo	0	[a]	na
WMS	African American	0	[a]	na
	Latino	2	86.00	4.243
	Anglo	12	72.67	17.354

[a]This level combination of factors is not observed

Table 4.33 below gives inferential statistics of the method for the complete study by ethnicity. The final sample size for the complete study was 54 subjects/participants. The mean score of the sample population was 62.59 with a SD 17.503 and a F test of 2.789 with 53 total degrees of freedom and a significance of .011 which did meet the

$p<.05$ requirement. This would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of physics' achievement in relation with method based on students' ethnicity. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.33).

Table 4.33

Complete Study Inferential Statistics Ethnicity, Method, and School Post-Test

N	Mean	SD	F	df1	df2	Sig
54	62.59	17.503	2.786	9	44	.011*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
Design: Intercept+ Ethnicity + Method + School+ Ethnic*Method+ Ethnic*School + Method* School + Ethnic * Method * School.
*$p<.05$

Ethnicity and Design. Table 4.34 below describes the complete study inferential statistics for the traditional linear physics curriculum treatment pre and post pairwise data. The inferential statistics include the impact of the design and ethnicity. The F value for design was 9.723 with a significance of 0.000 and effective size of 0.276. The inferential statistic for the design indicate that the design had an impact on predicting physics achievement in students based on ethnicity and that the effect was significant and the size of the effect of the design was small. The researcher can be 95% confident in this result. The F value for ethnicity was 9.723 with a significance of 0.000 and effective size of 0.276. The inferential statistic for the ethnicity indicate that the schools had a impact on predicting physics achievement in students based on ethnicity and that the effect was significant and the size of the effect of the schools was small. The researcher can be 95% confident in this result. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.34).

Table 4.34

Complete Study Inferential Statistics of Ethnicity and Design Post-Test

Source	df	F	Sig	Partial Eta Squared Effect Size
Design Model	2	9.732	.000*	.276
Ethnic	2	9.732	.000*	.276
Error	51			
Total	54			

Note. R Squared .276 = (Adjusted R Squared = .248)
*p<.05

Anglos, African Americans, and Latinos, showed an increase in physics achievement once they received the treatment of the experimental spiral physics curriculum treatment. It is important to note that the traditional linear physics curriculum treatment also increased physics achievement in Anglos, African Americans, and Latinos; however, the mean scores were lower than the experimental spiral curriculum (see Table 4.31).

Complete Study Summary Research Question Three. All races showed an increase in science achievement after receiving the spiral and the linear curriculum and the spiral curriculum increased post test scores more than the linear curriculum and the difference was statistically significant with a F value of 9.732 and a F value of .000 well below the $p<0.05$. This means that there was statistically significant difference between the experimental spiral physics curriculum to the traditional linear physics curriculum impact on students' physics achievement based on ethnicity.

Research Question Four

Were there significant differences in physics achievement scores for resilient students who received instruction using an experimental spiral physics curriculum treatment as compared to resilient students who received the traditional linear physics curriculum treatment?

The selection process for resilient students involved input from the schools science teachers, principals, and the researcher. A total of 10 students identified as resilient who represented five pairwise students for the analysis. The 4.35 table below gives the complete study inferential statistics of pre and post pairwise comparison of the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment impact on resilient students. The final sample size for the complete study pair wise comparison for resilient students was 5 subjects/participants.

The resilient students' t value of |7.130| with 4 total degrees of freedom and a significance of 0.002; which did meet the p<.05 requirement that would enable the researcher to have a 95 % confidence that the experimental spiral physics curriculum and the traditional linear physics curriculum treatments impacted the dependent variable of physics' achievement by resilient students. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show a t test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.35).

Table 4.35

Complete Study Inferential Statistics of Resilient Students Pre/Post-Test

	N	Mean	SD	t	df	Sig.(2-tailed)
Pair 1 Pre & Post	5	66.60	15.485	-7.130	4	0.002*

*p<.05

A statistically significant difference with a t value of |7.130| and a significance value of 0.002 which below the p< 0.05 found in favor of the resilient students that received the traditional linear physics curriculum treatment and had a higher mean score that those who had the experimental spiral physics curriculum treatment. Table 4.36 below describes the complete study pre and post achievement scores for the resilient students. The resilient pre–PET mean score was 36.40 with SD 8.019. The resilient students' post–PET mean score was 66.60 with a

SD of 15.485. The resilient students had a combined post mean score point differential of 30.20. The case of the resilient students also experienced increased physics achievement with the experimental spiral physics curriculum treatment and the traditional linear physics achievement (see Table 4.36).

Table 4.36

Complete Study Descriptive Statistics of Resilient Students Pre/Post-Test

Test	N	Mean	Std. Deviation
Pre	5	36.40	8.019
Post	5	66.60	15.485

Table 4.37 below describes the complete study of resilient students sample size, mean score, and SD. The resilient students' combined post means score was 69.10 with a SD of 14.464 (see Table 4.37).

Table 4.37

Complete Study Descriptive Statistics of Resilient Students Post-Test

N	Mean	SD
10	69.10	14.464

Table 4.38 below describes the complete study descriptive statistics for the experimental spiral physics curriculum treatment. The experimental spiral physics curriculum treatment sample size was 28 with a mean of 64.50 and SD 17.343. The traditional linear physics curriculum treatment sample size of 26 had a mean of 60.54 and

SD 17.781 which reflects a 3.96 points advantage for the experimental spiral physics curriculum treatment (see Table 4.38).

The table 4.38 below describes the complete study descriptive statistics for the experimental spiral physics curriculum treatment. The experimental spiral physics curriculum treatment sample size was 8 with a mean of 68.00 and SD 15.538. The traditional linear physics curriculum treatment sample size of 2 had a mean of 73.50 and SD 12.021 which reflects a 5.50 points advantage for the traditional linear physics curriculum treatment (see Table 4.38). This could mean that the traditional linear physics curriculum was more effective in producing post-test means scores than the experimental spiral physics curriculum.

Table 4.38

Complete Study Descriptive Statistics of Resilient Students and Method Post-Test

Method	Students	N	Mean	SD
Spiral	All	28	64.50	17.343
	Resilient	8	68.00	15.538
Linear	All	26	60.54	17.781
	Resilient	2	73.50	12.021

Table 4.39 below describes the complete study resilient students by schools post achievement scores. The CSI sample size was 3. The post mean score was 70.33 with SD 20.404. The GMS sample size was 4. The post mean score was 59.50 with SD 9.539. The WMS sample size was 3. The posts mean score was 80.87 with SD 1.155 (see Table 4.39). Once again this could me that the traditional linear physics curriculum

was more effective in producing post-test means scores than the experimental spiral physics curriculum; however a sample size of 2 in the case of the traditional linear curriculum is too small to validate this finding.

Table 4.39

Complete Study Descriptive Statistics of Resilient Students and Schools Post-Test

School	N	Mean	Std Deviation
CSI	3	70.33	20.404
GMS	4	59.50	9.539
WMS	3	80.67	1.155
Total	10	69.10	14.464

Note. The mean difference is significant at the $p<.05$.

Table 4.40 below describes the complete study by schools of the resilient students' post achievement experimental spiral physics curriculum treatment scores and the traditional linear physics curriculum treatment scores. The CSI resilient students sample size was three with the experimental spiral physics curriculum treatment post score of 70.33 with SD 20.404. The CSI resilient students sample size was 0 for the traditional linear physics curriculum treatment. The GMS resilient sample size was three with the experimental spiral curriculum post mean score of 57.67 and SD 10.789. The GMS resilient sample size was one with the traditional linear physics curriculum treatment post mean score of 65.00. The WMS resilient sample size was two with the experimental spiral curriculum post mean score of 80.00. The WMS resilient sample size was one with the traditional linear physics curriculum treatment post mean score of 82.00

(see Table 4.40). This means that all resilient students did increase in physics achievement once receiving the experimental and the traditional linear curriculum treatments. However, some students had a larger deficit in physics knowledge to overcome than others.

Table 4.40

Complete Study Descriptive Statistics of Resilient Students Method and Schools Post-Test

School	Method	N	Mean	Std. Deviation
CSI	Spiral	3	70.33	20.404
	Linear			
GMS	Spiral	3	57.67	10.789
	Linear	1	65.00	na
WMS	Spiral	2	80.00	na
	Linear	1	82.00	na

Table 4.41 correlation value below was 0.863. The 0.863 value supports a direct relationship between the dependent variable physics achievement and the experimental spiral physics curriculum and the traditional linear physics curriculum treatments, which means that the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment increased physics achievement in resilient students. The significance value of this correlation was 0.059 which did not meet the $p<.05$ standard in order to give the researcher a 95% confidence that the direct relationship is due to the treatments the experimental spiral physics curriculum treatment and the traditional physics.

Table 4.41

Complete Study Inferential Statistics (Correlations) of Resilient Students Pre/Post-Test

	N	Correlations	Sig.
Pair 1: Pre & Post	5	0.863	0.059

Table 4.42 below gives inferential statistics of the complete study resilient students. The final sample size for the complete study was 10 subjects/participants. The mean of the sample population was 66.60 with a SD 15.485 and a t value of |7.130| with 4 total degrees of freedom and a significance of a two tail test of 0.002 which did meet the $p<.05$ requirement. This would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of student physics' achievement of resilient students. The experimental spiral curriculum treatment produced the higher mean score, and the differential was large enough to overcome the high variability within and between groups in order to show a t test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.42).

Table 4.42

Complete Study Inferential Statistics of Resilient Students Pre/Post-Test

	N	Mean	SD	t	df	Sig.(2-tailed)
Pair 1 Pre & Post	5	66.60	15.485	-7.130	4	0.002

Note. The mean difference is significant at the $p<.05$.

Summary Research Question Four. The resilient students showed an increase in physics achievement once they had received the experimental spiral physics curriculum treatment. The resilient students also showed an increase in physics achievement after receiving the traditional linear physics curriculum treatment. However, the traditional linear physics curriculum treatment scores in the majority of the cases were statistically significantly higher than the experimental spiral physics curriculum treatment by a value of 0.002.

Research Question Five

Were there significant differences in physics achievement scores for students from the ZISD, CISD, and WMS who received instruction using an experimental spiral physics curriculum treatment as compared to students from the ZISD, CISD, and WMS who received the traditional linear physics curriculum treatment?

The table below 4.43 gives descriptive statistics of the complete study. The final sample size for the complete study was 54 subjects/participants. The mean of the sample population was 63.413 with a SD 17.503 and a F value of 3.554 with 53 total degrees of freedom and a significance of 0.008 which did meet the $p<.05$ requirement. This would enable the researcher to have a 95 % confidence that student physics' achievement is also impacted by other factors beyond the treatment. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.43).

Table 4.43

Complete Study Descriptive Statistics by Schools Post-Test

N	Mean	SD	F	df1	df2	Sig
54	63.413	17.503	3.554	5	48	.008

Note. The mean difference is significant at the $p<.05$.

A statistically significant difference with a F value of 3.553 and significance value of 0.008 which below the $p< 0.05$ was found in favor of the students at the schools that received the experimental spiral physics curriculum treatment and had a higher mean score that those who had the traditional linear curriculum.

Table 4.44 describes the complete study by schools post achievement scores for the experimental spiral physics curriculum treatment and traditional linear physics curriculum treatment. The CSI experimental spiral physics curriculum treatment sample size was 11. The CSI traditional linear physics curriculum treatment sample size was 11. The post mean score was 72.00 with SD 12.296 was higher than the traditional linear physics curriculum treatment Post–PET mean score of 60.73 with SD 17.567, with a point differential of 11.27 in favor of the experimental spiral physics curriculum treatment . The GMS experimental spiral physics curriculum treatment sample size was 9. The GMS traditional linear physics curriculum treatment sample size was 9. The post mean score of 49.78 with SD 9.244 was slightly higher than the traditional linear physics curriculum treatment post–PET mean score of 47.56 with SD 9.368, with a point differential of 2.22 in favor of the experimental spiral physics curriculum treatment. The WMS experimental spiral physics curriculum treatment sample size was 8. The WMS traditional linear physics curriculum treatment sample size was 6. The post mean score of 70.75 with SD 11.524 was lower than the traditional linear physics curriculum treatment post–PET mean score of 79.67 with SD 7.992, with a point differential of 8.92 in favor of the traditional linear curriculum. Please note CMS was dropped from the study at no fault of the researcher (see Table 4.44).

Table 4.44

Complete Study Descriptive Statistics by Schools and Method Post-Test

School	Method	N	Mean	SD
CSI	Spiral	11	72.00	12.296
	Linear	11	60.73	17.568
	Total	22	66.36	15.882
GMS	Spiral	9	49.78	9.244
	Linear	9	47.56	9.368
	Total	18	48.67	9.368
WMS	Spiral	8	70.75	20.852
	Linear	6	79.67	7.992
	Total	14	74.57	16.723
Total	Spiral	28	64.50	17.343
	Linear	26	60.54	17.781
	Total	54	62.59	17.503

Table 4.45 below gives inferential statistics of the complete study based on schools. The final sample size for the complete study was 54 subjects/participants. The mean of the sample population was 62.59 with a SD 17.503 and an F test of 15.233 with

50 total degrees of freedom and a significance of 0.000. The size of the effect was 0.388 which is considered medium. The significance value of 0.000 did meet the p<.05 requirements which would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of student physics' achievement is also impacted by school. The experimental spiral curriculum treatment produced the higher mean score at CSI and GMS and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum. In the case of WMS the traditional linear curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.45).

Table 4.45

Complete Study Inferential Statistics by Schools Post-Test

	N	Mean	SD	df	F	Sig	Partial Eta Squared Effect Size
Contrast	54	62.59	17.503	2	15.233	.000	.388*
Error				48			

Note. The F tests the effect of School. This test is based on the linearly independent pairwise Comparisons. The mean difference is significant at the p<.05.

Complete Study Summary Research Question Five. All schools showed an increase in science achievement after receiving the spiral and the linear curriculum; however the spiral curriculum increased post-test scores more than the linear curriculum and the difference was statistically significant with a F value of 15.233 and a significant of 0.000 level which is below the $p<0.05$ giving the researcher a 95% confidence level that the methods at the does increase physics achievement in students.

The Complete Study Analysis and Results of Principals and Heads of School Surveys

The researcher reviewed the quantitative and the qualitative responses and compiled the following response. The actual survey can be found in appendix (see Appendix C). CMS Principal, CSI School Principal, GMS Principals and WMS Heads of School responded to surveys. The results of the surveys showed that the socio-economic category ranged from $9,310 to $74,999. BMS, CMS and GMS had a socio-economic range of $9,310 to $34,999. WMS had a socio-economic range of $75,000-$99,999. All principals and WMS Heads of School supported an inquiry based, hands-on approach to science. ZISD schools used the Full Option Physics System (FOSS) science curriculum; however CSI and WMS did not use FOSS.

The Complete Study CSI School Resilient Student

An Anglo female student who attended CSI was identified as a resilient student became the subject in the qualitative study. The subject had been randomly placed in the experimental spiral physics curriculum treatment group. The subject was reserved in classroom discussion, but quite attentive. The researcher had an informal interview with the subject where she discussed her home life. The subject was happy that her father permitted her to participate in the study. The subject worked well with her peer group. The subject was able to communicate to the researcher/teacher evoking empathy from the researcher/teacher. The subject demonstrated the empathy factor or “E” factor and ability to elicit support from the researcher/teacher. The subject demonstrated tenacity during the study and demonstrated the tenacity factor or “T” Factor and was very relational in demonstrating the “R” factor. The subject demonstrated academic resiliency by performing well in the experimental SPC study.

The Complete Study GMS Resilient Student

The resilient student chosen from GMS was an African American female. The subject was randomly placed in the pre-tested spiral group. The resilient student demonstrated an ability to rouse empathy in teachers and administrators and elicit the support of the researcher/teacher. The subject was very relational indicating the “R” factor. The empathy factor was exhibited by the subject when evoking the “E” factor in others. The resilient student also demonstrated high tenacity factor or “T” factor despite the distraction she continued to pursue the path of learning. The subject also demonstrated academic resiliency by performing well during the study.

The Complete Study WMS Resilient Student

An Anglo female student from WMS was identified as a resilient student. The subject had been randomly placed in the experimental spiral physics curriculum treatment group. The subject worked well with her peer group and demonstrated leadership skill. The subject was able to create empathy in the researcher/teacher and their by elicit empathy from the researcher/teacher. The subject demonstrated the ability to create empathy in the researcher/teacher. The empathy factor or the “E” factor enables the subject to elicit support from the researcher/teacher. The subject demonstrated tenacity in participating in the study and demonstrated the tenacity factor or "T" factor. The subject also demonstrated the helper factor of "H" factor. The subject tried to make herself of value to the researcher and teacher by rendering services in the classroom such as handing out materials or locating need materials. The helper factor or H factor quickly endeared the subject to the researcher/teacher. The subject was very relational in demonstrating the "R" factor. The subject demonstrated academic resiliency by performing well in the experimental SPC study.

The Complete Study Solomon Four Group Design—CRF Results

Because the Solomon Four Group Design was used as the experimental design for the spiral physics curriculum experiment, a separate analysis was performed to measure the impact of this design. The Solomon Four Group Design was not listed as a research question. The results of this analysis are discussed here.

The Solomon Four Group Design was analyzed by the Complete Randomized Factorial (CRF) program. The CRF analysis yielded a higher degree of freedom, which in turn provided a more powerful test versus other analyses (Kirk, 1995). Students that received the experimental spiral physics curriculum treatment had an average mean score of 64.500 points on the PET compared to a 61.320 points average mean score of students receiving the traditional linear physics curriculum treatment. The difference between the spiral and linear physics curriculum was 3.18 points in favor of the spiral physics. The students that received the spiral curriculum pre–PET had an average mean score of 63.643 points on the PET. Students that had not received the linear curriculum pre–PET had an average mean score of 63.108 points on the PET. The difference between the spiral pre-tested and spiral non pre-tested students was 1.72 points. In the case of the O_2, the students that had been pre-tested and received the experimental spiral physics curriculum treatment had an average mean score of 63.643 points on the PET with a standard deviation of 16.298 points. The O_4 identifies students that were pre-tested and receive the traditional linear physics curriculum treatment. Their average mean score was 64.700 points on the PET with a standard deviation of 22.789. The O_5 students were not pre-tested and received the experimental spiral physics curriculum treatment; their average mean score was 65.36 points on the PET and the standard deviation was 18.907 points. The O_6 identifies the students that were not pre-tested and received the traditional linear physics curriculum treatment; their average mean score was 57.940 points on the PET and the standard deviation was 14.021 points.

R	O_1	X	O_2
R	O_3	X	O_4
R		X	O_5
R		X	O_6

R = row; O_1 = observation one pre-PET; X = treatment, O_2 observation two post-test O_3 = observation one pre-PET; X = treatment, O_4 observation two post-test, O_5 observation no pre test, O_6 observation no pre-test

Figure 1. Design Layout for Complete Study of Overall Differences between the Spiral and Linear Physics Curriculum Effect on Physics Achievement Test Scores for Students

The Complete Study—CRF Analysis

To analyze data resulting from application of the completely random factorial (CRF) design is to use a 2X2 (two by two) factorial with treatment and control groups, crossed with pre-testing and non-pre-testing (Gay & Airasian, 2003). There are two control groups in this design: treatment/control and pre–PET/no pre–PET. The 2X2 factorial analysis tells the researcher whether the treatment is effective and whether there is an interaction between the treatment and the pre–PET. Simply stated, if the pre-tested experimental group performs differently on the post–PET than the non/pre-tested experimental group, there is probably a pre–PET treatment interaction. If no pre–PET-treatment interaction is found, then the researcher can have more confidence in the generalizability of treatment differences across pre-tested and non pre-tested treatments. Solomon Four-group design controls for many sources of invalidity such as history, maturation, testing, instrumentation, regression, selection, mortality, selection interactions, pre–PET interactions, and multiple-interference (Gay & Airasian, 2003).

Treatment B

	No X Linear	X Spiral	
Treatment A	**O4** n=10 Pre Linear Mean= 64.700 SD= 22.789	**O2** n=14 Pre Spiral Mean= 63.643 SD= 16.298	Pre Y (mean) Pre–PET= 64.170
	O6 n=16 No Pre Linear Mean= 57.94 SD= 14.021	**O5** n=14 No Pre Spiral Mean= 65.360 SD= 18.907	No Pre–PET Y (mean) No Pre–PET = 61.650
	Y No X (mean) Linear = 61.320 (*mean includes outlier)	Y X (mean) Spiral = 64.500	

1) Test of treatment X: Compare Y No X and Y X (Treatment B)
2) Effects of pre-testing: Compare Y Pre and Y No Pre (Treatment A)
3) Interaction effects of pre-testing: Compare cell means: O4 versus O_6 and O_2 versus O_5 (Kirk, 1995).

Figure 2. Another Approach CRF 22 Design

The sixth grade physics scores of students in CISD, ZISD, and WMS were analyzed based on physics evaluation test (PET) to determine if there was a statistically significant difference. An ANOVA was utilized on a Solomon Four group design in order to statistically analyze the PET scores in physics for public and private middle schools.

The analysis of variance (ANOVA) for the physics mean scores of the students exposed to the experimental spiral physics curriculum treatment showed an increase in achievement, as did the students exposed to the traditional linear physics curriculum treatment . The experimental spiral physics curriculum treatment had the highest mean scores when compared with the traditional linear physics curriculum treatment mean scores; however, the F test for significance showed no significance. The researcher believes that no significant was found due to high variability within and between groups.

The Complete Study Analysis of Spiral and Linear Physics Curriculum Effect on Physics Evaluation Test Scores for Students

A research question not included in the original proposal concerns differences in PET post scores for all students in the study. This section reports these results.

The mean score of the students that received the experimental spiral physics curriculum treatment was 65.36 points with SD 18.907 on the PET. The traditional linear physics curriculum treatment mean score was 57.94 with SD 14.021 points on the PET. The higher mean score for the spiral physics curriculum shows promise as confirmed by Dr. Tubbs, chairman of Baylor's Department of Statistic. The experimental spiral physics curriculum treatment performed slightly better than the traditional linear physics curriculum treatment by 7.42 points on the PET. The students that received the pre–PET in the complete SPC study mean score was 63.64 points with SD 16.298 on the PET compared to the 1.72 points in favor of the post–PET; this could imply that there was no interaction effect due to pre-testing.

The difference between the experimental spiral science curriculum mean scores compared to the traditional linear science curriculum was the high mean score of the experimental spiral science curriculum. Also, the pilot study produced a higher experimental spiral physics curriculum treatment score of 77.545 on the post PET compared to the traditional linear physics curriculum treatment score of 54.625 on the post PET. The difference between the experimental spiral physics curriculum treatment score and the traditional linear physics curriculum treatment score was 22.92 points on the post PET in favor of the experimental spiral physics curriculum treatment.

The differences between the experimental spiral physics curriculum and traditional linear physics curriculum for all students in the study are discussed below.

The Complete Study Summary of Quantitative Analysis

It is important to note that the majority of student populations of African Americans, Latinos and Anglos, Males and Females, as well as resilient students, scored higher on the PET test after exposure to the experimental spiral physics curriculum treatment. There were a few exceptions which will be addressed later. Each campus class was heterogeneous in its composition of gifted and talented, above average, average and special education students placed in the same class. The experimental spiral physics curriculum treatment increased physics achievement in all groups based. The traditional linear physics curriculum treatment also increased physics achievement in all groups; however, the experimental spiral physics curriculum treatment had a higher mean score than the traditional linear physics curriculum treatment in most cases.

The final results from the experimental spiral physics curriculum complete study showed that the post–PET scores of the students who received the experimental spiral physics curriculum treatment were the highest with a mean score of 62.59 and standard deviation (SD) 17.503 when compared to the traditional linear physics curriculum treatment score of 60.54 and SD 17.781. The mean score of the students who received the experimental spiral physics curriculum treatment pre–PET was 37.39 points on the PET with SD 13.552 is described in table 4.37 found below. The mean score of students that received the experimental spiral physics curriculum treatment and did not receive a pre–PET was 63.64 points with SD 16.298 on the PET. The students that received the pre test and the traditional linear physics curriculum treatment had a higher mean score of 6.76 points compared to the post–PET traditional linear physics curriculum treatment mean scores which would imply a pre-treatment interaction (see Table 4.46). Another impact to students' achievement was students' attendance during the pilot study. The students' attendance, which factored into the outcome of the preliminary results, is reported in Appendix K.

Table 4.46

Complete Study Descriptive Statistics of Method Pre and Post-Test

Test	Method	N	Mean	SD
Pre	Spiral	18	37.39	13.552
	Linear	10	29.86	15.382
	Total	32	34.09	14.641
Post	Spiral	28	64.50	17.343
	Linear	26	60.54	17.781
	Total	54	62.59	17.503

The Complete Study Overall Differences Between the Spiral and Linear Physics Curriculum Effect on Physics Achievement for All Students

The complete study pre and post achievement scores for the spiral and linear curriculum is described below. The experimental spiral physics curriculum treatment pre–PET mean score of 63.64 with SD 16.298 was slightly lower than the traditional linear physics curriculum treatment pre–PET mean score of 64.70 with SD 22.789, with a point differential of 1.06. The experimental spiral physics curriculum treatment post–PET mean score of 65.36 with SD 18.907 was higher than the traditional linear physics curriculum treatment post–PET mean score of 57.94 with SD 14.02, with a point differential of 7.42. In the case of the experimental spiral and the traditional linear physics curriculum treatment, both increased physics achievement with the experimental spiral physics curriculum treatment having 7.42 points advantage over the traditional linear physics curriculum treatment. However, this differential was not enough to overcome the high variability within and between groups and therefore there was no significant difference between the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment.

The table 4.47 below gives descriptive statistics of the complete study. The final sample size for the complete study was 54 subjects/participants. The mean of the sample population was 63.413 with a SD of 17.503 and an F test of 2.893 with 53 total degrees of freedom and a significance of 0.004. This did meet the $p<.05$ requirements which would enable the researcher to have a 95 % confidence that the treatments impacted the dependent variable of student physics' achievement (see Table 4.47).

Table 4.47

Complete Study Inferential Statistics Method Post-Test Score

N	Mean	SD	F	df1	df2	Sig
54	63.413	17.503	2.893	28	25	0.004*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
*p<.05

The table 4.48 below describes the complete study descriptive statistics for the experimental spiral physics curriculum treatment. The experimental spiral physics curriculum treatment sample size was 28 with a mean of 64.50 and SD 17.343. The traditional linear physics curriculum treatment sample size of 26 had a mean of 60.54 and SD 17.781 which reflects a 3.96 points advantage for the experimental spiral physics curriculum treatment.

Table 4.48

Complete Study Descriptive Statistics of Method Post-Test

Method	N	Mean	Std. Deviation
Spiral	28	64.50	17.343
Linear	26	60.54	17.781

The correlation value below was 0.710. The 0.710 value supports a direct relationship between physics achievement and the experimental spiral physics curriculum and the traditional linear physics curriculum treatments; which means that both the experimental spiral physics curriculum and the traditional linear physics curriculum treatments increased physics achievement. The significance value of this correlation was

.000 which did meet the $p<.05$ standard in order to give the researcher a 95% confidence that the correlation is due to the treatments of the experimental spiral physics curriculum treatment and the traditional physics curriculum (see Table 4.49).

Table 4.49

Complete Study Inferential Statistics (Correlation) of Method Pre/Post-Test

	N	Correlation	Sig
Pair 1: Pre & Post	24	.710	0.000*

*p<.05

The table 4.50 below describes the complete study inferential statistics for the traditional linear physics curriculum treatment pre and post pairwise data. The inferential statistics of the traditional linear physics curriculum treatment pre and post pairwise data sample size was 23 with a mean score of | 61.32 |and a SD 13.239. The t test was |10.624| and two tail significance score of 0.000. The 0.000 test of significance is below the required $p<.05$ which would give the researcher a 95% confidence that the traditional linear physics curriculum treatment did impact the dependent variable of physics' achievement. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show a t test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.50)

Table 4.50

The Complete Study Inferential Statistics of Linear Curriculum Method Pre/Post-Test

	Mean	df	SD	t	Sig. (2tailed)
Pair 1: Pre & Post	61.32	23	13.239	-10.624	0.000*

*p<.05

Solomon Four Group Design and Method

Another research question not included in the original proposal concerned the Solomon Four Group design and the effectiveness of an experimental spiral physics curriculum compared the traditional linear physics curriculum.

The table 4.51 below describes the complete study inferential statistics of the impact of the Solomon Four group design and Method. The inferential statistics of experimental spiral physics curriculum treatment pre and post pairwise data sample size was 54 with a mean score of 62.59 and a SD of 17.503. The F test 2.849 had a significance score of 0.047. The 0.047 test of significance is below the required p<.05 which would give the researcher a 95% confidence that the experimental spiral curriculum did impact the dependent variable of physics' achievement. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.51).

Table 4.51

Complete Study Inferential Statistics (Levene Test) Post-Test

N	Mean	SD	F	df1	df2	Sig
54	62.59	17.503	2.849	3	50	0.047*

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
Design: Intercept+Group+Method+Group*METHOD.
*p<.05

The traditional linear physics curriculum treatment correlation value of 0.865 supports a direct relationship between physics achievement and the traditional linear physics curriculum treatments; which means that the traditional linear physics curriculum treatment did increase science achievement. The significance value of the correlation was 0.001 which does meet the p<.05 standard in order to give the researcher a 95% confidence that there is a direct correlation between physics achievement and the traditional linear physics (see Table 4.52).

Table 4.52

Complete Study Inferential Statistics (Correlation) of Linear Method Pre/Post-Test

	N	Correlation	Sig
Pair 1: Pre & Post	10	0.865	0.001*

*p<.05

The experimental spiral physics curriculum treatment correlation value of 0.500 does not supports a direct relationship between the experimental spiral physics curriculum treatment and physics achievement; which means that the experimental spiral physics curriculum treatment can not be directly linked to physics achievement in this case. It is important to note that this finding is not statically significant. The significance value of the correlation was 0.069 does not meet the p<.05 standard in order to give the researcher a 95% confidence in the results. This means that the aggregated data showed no direct correlation between the experimental spiral physics curriculum and physics achievement in the pilot study (see Table 4.53).

Table 4.53

Complete Study Inferential Statistics (Correlation) by Spiral Method Pre/Post-Test

	N	Correlation	Sig
Pair 1: Pre & Post	14	.500	0.069*

*p<.05

The table 4.54 below describes the complete study inferential statistics for the experimental spiral physics and the traditional linear physics curriculum, treatment pre and post pairwise data. The inferential statistics includes the impact of the Solomon Four Group Design, Schools, and treatment methods on the study. The F value for design was 6.928 with a significance of 0.000 and effective size of 0.419. The inferential statistic for the design indicates that the design had an impact on predicting physics achievement in students and that the effect was significant and the size of the effect of the design was medium. The researcher can be 95% confident in this result. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum.

The F value for schools was 15.233 with a significance of 0.000 and effective size of 0.388. The inferential statistic for the schools indicates that the schools had an impact on predicting physics achievement in students and that the effect was significant and the size of the effect of the schools was medium. The researcher can be 95% confident in this result. The experimental spiral curriculum treatment produced the higher mean score and the differential was large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The random sample groups had students which represented the entire socioeconomic factors that existed in the general population. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.54).

The F value for the aggregated experimental spiral physics curriculum or the traditional linear physics curriculum treatments was 0.153 with a significance of 0.697 and effective size of 0.003. The inferential statistic for the methods indicates that the method did not show statistical significance between the experimental spiral curriculum and the traditional linear curriculum. It is important to note that the experimental spiral curriculum treatment produced the higher mean score; however the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum (see Table 4.54).

Table 4.54

The Complete Study Inferential Statistics of Design

Source	df	F	Sig	Partial Eta Squared Effect Size
Design Model	5	6.928	0.000	0.419
Schools	2	15.233	0.000	0.388
Methods	1	0.153	0.697	0.003
Spiral/Linear				
Schools/Methods	2	2.204	0.121	0.084
Error	48			
Total	54			

Note. The mean difference is significant at the $p<.05$.

The Complete Study—Quantitative Results Summary

Although the aggregated data set did not show statistical significance difference between the experimental spiral physics curriculum and the traditional linear curriculum, the subgroups or disaggregated data set did show statistically significant differences between the spiral physics curriculum and the traditional linear curriculum. The experimental spiral physics curriculum treatment showed promise of increasing the physics achievement in all students and in heterogeneous classrooms where gifted and talented, above average, average, and special education students are all represented. The traditional linear physics curriculum treatment also showed promise of increasing the physics achievement in all students and in heterogeneous classrooms; however, as in the pilot the mean scores of the experimental spiral physics curriculum treatment were higher than the mean scores of the traditional linear physics curriculum treatment. The interaction effect of the pre–PET was much smaller in the complete study than in the pilot study.

The phenomenon of increasing physics achievement in a heterogeneous class was also true for the pilot in June-July, 2005, as well as the experimental spiral science curriculum intervention implemented in January-April, 2006 by the researcher/teacher prior to the complete SPC study. The researcher implemented the complete SPC study in May, 2006.

A phenomenon where siblings of the participants in the complete SPC study would approach the researcher/teacher and communicate to her a recent concept taught to their bother or sister occurred more than once. This phenomenon demonstrated that those particular participants had moved to another level of understanding the physics concepts by teaching their sibling the physics concepts they had learned in class. These participants demonstrated a higher cognitive ability by teaching physics to their sibling.

The research study examined quantitative data and qualitative data which indicated that the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment did improve physics achievement scores; however, due to the time and sampling strategy the F and t test showed no significant difference between the spiral and linear physics curriculum.

The mean scores of each school clearly show an increase in physics achievement once the experimental spiral physics curriculum treatment and the traditional linear physics curriculum treatment were administered. The mean scores of each school also indicate that the experimental spiral physics curriculum treatments scores were higher than the mean scores of the traditional linear physics curriculum treatment, which may indicate that the experimental spiral physics curriculum treatment has advantages in increasing physics achievement in middle school students with the exception of a subgroup of WMS.

Heterogeneous groups that had gifted and talented, above average, average, special education, and resilient students all increased in physics achievement once they had received the experimental spiral physics curriculum treatment. Also, heterogeneous groups that had gifted and talented, above average, average, special education, and resilient students all increased in physics achievement once they had received the traditional linear physics curriculum treatment ; however, the mean scores of the traditional linear physics curriculum treatment were lower than the experimental spiral physics curriculum treatment.

CHAPTER FIVE

Conclusion

The content of Chapter Five focuses on the complete study. The researcher in the complete study compared the effectiveness of teaching physics using an experimental spiral physics curriculum in the sixth grade to teaching a traditional linear physics curriculum. Both the experimental spiral physics curriculum and the traditional linear physics curriculum increased physics achievement; however, there was no statistically significant difference in effectiveness of teaching experimental spiral physics curriculum in the sixth grade compared to the traditional linear physics curriculum in the aggregated data set. The high variability within sample groups and between sample groups masked the variance due to the difference between the experimental spiral physics and the traditional physics curricula. Each sample group was characterized by high variability that was the result of a broad range of socioeconomic factors such as income, race and gender which was present within and between groups. However, it is important to note in the analyzes of the subgroups of gender, ethnicity, resiliency and schools, the experimental spiral physics curriculum was statistically more significant in its effect on physics achievement than the traditional linear physics curriculum in the majority of the subgroups. The data also showed that the experimental spiral physics curriculum did produce higher mean scores in the majority of the subgroups.

Summary of Results for the Subgroups Gender, Ethnicity, Resilient Students and Schools

Gender—Females

In the case of the complete study the subgroup of females, the data showed that there was a statistical significant difference in the effectiveness of teaching experimental spiral physics curriculum when compared to the traditional linear physics curriculum. The subgroup of female that received the experimental spiral physics curriculum produced statistically significant higher mean scores than the group receiving the traditional linear physics curriculum.

Gender—Males

The complete study data showed that the males also increased in physics achievement once receiving the treatment of the experimental spiral curriculum; however, the subgroup of males sample size was not adequate to prove statistically significance.

Ethnicity

The complete study data of the subgroups for African Americans and Anglos showed that there was a statistically significant difference in the effectiveness of teaching experimental spiral physics curriculum when compared to traditional linear physics curriculum. The subgroups of African Americans and Anglos that received the experimental spiral physics curriculum produced significantly higher mean scores than the group receiving the traditional linear physics curriculum. However, in the case of the Latinos, the subgroup was inadequate in size to prove statistical significance.

Resilient Students

The complete study subgroups of resilient student's data showed that there was a statistically significant difference in the effectiveness of the experimental spiral physics curriculum when compared to traditional linear physics curriculum in favor of the traditional linear physics curriculum. For the subgroups of resilient children, the physics achievement mean scores in the case of the traditional linear curriculum were higher than the experimental spiral physics curriculum.

The researcher used a Grounded Theory method to search for attributes of academic success of resilient student in order to transfer such attributes to the non-resilient population. The Grounded Theory analysis produced no conclusive theory; however, it did suggest some promising categories for future studies such as the empathy factor ("E" factor), the tenacity factor ("T" factor), the spiritual factor ("S" factor), and the relational factor ("R" factor).

Schools

The complete subgroups of schools showed that there was a statistically significant difference in the effectiveness of the experimental spiral physics curriculum when compared to traditional linear physics curriculum. All the urban, suburban, rural, and public school's data showed an increase in physics achievement for students receiving the spiral physics curriculum. The exception was the private school where the traditional linear curriculum means score were higher than the experimental physics curriculum means score. It is important to note that it was in the case of the private school that the groups were rotated to the back of the classroom when not receiving the experimental spiral physics or traditional physics curriculum. In the case of all other schools the experimental spiral physics and the traditional physics curriculum groups were totally separated when receiving their instructions.

In-Depth Interviews

The interviews and home visits revealed similarities between the resilient students such as they all had an experience of a life impacting event, for example, the death of a father at an early age. All appeared to have rough starts in school, but adjusted and later became productive in the school environment. All of the students had chosen to disengage from individuals that inhibited their advancement in the classroom.

The qualitative Grounded Theory portion of the study could benefit from more extensive in-depth interviews of the resilient students' families, teachers and mentors. The richer data set of interviews may yield more information about the attributes and eventually a theory of how one develops an academically successful resilient student.

Summary of Solomon Four Group Design Results and Method

The experimental spiral physics curriculum and the traditional linear physics curriculum treatments for the Solomon Four Group Design analysis indicated that the methods aggregated results were not statistically significant. Due to the high variability found within and between groups in the Solomon Four Group Design. On the aggregated level, the methods could not be used as predictor of student's physics achievement; however on the disaggregated subgroup level methods could be used as a predicator of student's physics achievement. Both the experimental spiral physics curriculum and the traditional linear curriculum produced an increase in physics achievement. It is important to note that the experimental spiral curriculum treatment produced the higher mean score in the majority of the subgroups; however, the differential was not large enough to overcome the high variability within and between groups in order to show an F test of significance. The high variability was due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The random sample groups had students which represented the entire socioeconomic factors that existed in the general population. The dependent variable was physics' achievement and the independent variables were the experimental spiral physics curriculum and the traditional linear physics curriculum. Another important point was that the subgroup level showed promise for future research.

The experimental spiral physics curriculum treatment for the subgroups continued to show an increase in the physics achievement for the majority of the students. The increase was evident in heterogeneous classrooms where gifted and talented, above average, average, and special education students were all represented and no lesson modification were given. All heterogeneous groups received either the experimental spiral physics curriculum or the traditional linear physics curriculum. The traditional linear physics curriculum treatment also showed promise of increasing the physics achievement in all students and in heterogeneous classrooms; however, as in the pilot the mean scores of the experimental spiral physics curriculum treatment were higher than the mean scores of the traditional linear physics curriculum treatment for the majority of the student participants.

Discussion

Sampling Strategy

The researcher concluded that the sampling strategy of a purposeful stratified random sample played a major part in producing the high variability within and between sample subgroups. The rational for such a strategy was to create a rich data base for the qualitative Grounded Theory analysis as well as to help facilitate the comparisons between subgroups in the quantitative Solomon Four group analysis. The sampling strategy produced high variability in the quantitative analysis due to the broad range of socioeconomic factors such as income, race and gender present within and between groups. The random sample groups had students which represented the entire socioeconomic factors that existed in the general population. The qualitative analysis needed the highly diverse data set in order to make the comparative analysis in the Grounded Theory analysis more productive. The researcher concluded that if a similar sampling strategy is pursued for future research then other variables such as grades, GPA, and IQ scores should be used in an analysis of co-variance in order to explain some of the variability within and between sample groups. Research has shown that student's grades, GPA's and IQ's scores can be used as a predictor of student's achievement to explain some of the high variability. This would in turn enable the researcher to validate the variance due to the spiral physics curriculum. (Gay and Airasian, 2003).

Attendance and Instructional Time

The researcher also concluded that the length of time for the study contributed to the results of the study. Research has showed that the more instructional time given the higher student's achievement (Elliot, et al., 2000). A future longitudinal study may give statistically significant results when comparing the experimental spiral physics curriculum to the traditional linear physics curriculum. It is important to note that attendance also impacts instructional time in that if a student does not attend class they cannot receive instruction.

Heterogeneous Classrooms

The experimental spiral physics curriculum continued to show promise of increasing the physics achievement in all students included in heterogeneous classrooms where gifted and talented, above average, average, and special education students are all represented. The traditional linear physics curriculum also showed promise to increase the physics achievement in all students and in heterogeneous classrooms. In all cases of experimental spiral physics and traditional physics curriculum instructions the classes had a mixture of gifted and talented, above average, average, and special education students and all groups increased in physics achievement. However, in the majority of the cases the experimental spiral physics curriculum produced the higher post means scores.

Spiral Curriculum in Science

Dr. Taba strongly believed that all involved in education should participate in the development of important ideas and the development of thinking skills (Taba, 1962; Durkin, and Fraenkel, 1971). Taba established an organizational sequence of learning experiences which are present in the experimental spiral physics curriculum. The first learning experience was the continuity of learning. Each learning experience served as a prerequisite for those that followed and built on those learning experiences that came earlier, thus providing a challenge without going beyond the students' capabilities. The experience moves from the concrete learning experiences to more specific learning experiences. Taba required increasingly more abstract reasoning on the part of the student which served a variety of functions in student learning.

Taba realized that not all learning experiences could accomplish the same function. Some learning experiences provided only for the intake of information. For some, the learning experiences helped students to organize information that they had acquired; while for others, the learning experiences helped students demonstrate what they had learned. Still, learning experiences enabled more students to express in a new form what they had learned in the previous activities. According to Dr. Taba, all four learning experiences had to be present for learning to take place (Parry, 2000; Ngozimba, 2001).

Hilda Taba emphasized that while the learning objectives were important to students learning the selection, the organization of content and the learning experiences were also critical to students learning. The planning and development of a series of innovative teaching strategies to help students learn to think and evaluate in both the cognitive and effective domains was also important to learning. Teaching strategies performed the equivalent task for the teacher that learning activities performed for the student. Teaching strategies are the actual procedures that teachers were to use in order to implement the learning objectives and to teach the content of the curriculum. The innovative feature of Dr. Taba's curriculum was that it included teaching strategies particularly designed to promote the development of children's cognitive skills, such as comparing and contrasting, conceptualizing, generalizing, and applying previously learned relationships to new and different situations (Fraenkel, 1994; and Ngozimba, 2001).

> The selection and organization of content implements only one of the four areas of objectives—that of knowledge. The selection of content does not develop the techniques and skills for thinking, change patterns of attitudes and feelings, or produce academic and social skills. These objectives only can be achieved by the way in which the learning experiences are planned and conducted in the classroom. […] Achievement of three of the four categories of objectives depends on the nature of learning experiences rather than on the content (Taba, 1967, p. 11).

The spiral physics curriculum in the pilot and the complete study embodied the four learning experience necessary in order for the student to learn. The spiral physics curriculum met the first learning experience of continuity of learning through the recursive approach to the learning of concepts. Second, the learning experience of assisting student to organize information that they had acquired also occurs as the students were taught to observe, record, see patterns, and categorize thru out the recursive nature of the lessons. Third, the learning experience created an environment where the student was not overwhelmed with knowledge. The student was given time to digest what they had learned and to verbalize through questions and by demonstrating their grasp of the principles or concepts to their peers and the teacher. Fourth, the learning experiences progressive and recursive modes invited the student to take what they had learned and express it in a new way. The progressive recursive method of the spiral physics curriculum gave the students a pattern to follow. The students was able to move from an active experimentation phase of learning and go to the next level of developing a concrete learning experiences then to moving on to reflective observation type learning experiences and eventually to an abstract conceptualization mode of learning from their experiences.

Recommendations for Future Research

The researcher concluded that the complete study should be followed up by another study that addresses the sampling strategy of a purposeful stratified random sample which was a major contributor to the high variability within and between sample subgroups. Additional data should be gathered on the subjects such as GPA and grades. This could help explain some of the variability. The qualitative and the quantitative studies should be separated and the researcher could pursue different sampling strategies that would complement the experimental designs for the quantitative and the qualitative studies. The limitations of classroom design should also be addressed in the future research. The groups should be completely separated during the instructional times so that the instructional session that the students receive is the only instruction that could cause the increase in physics achievement. Increasing the instructional learning time may enable the researcher to see more differentials between the experimental spiral physics curriculum and the traditional linear physics curriculum. Once these concerns are addressed, one could better infer conclusions.

In the case of the qualitative portion of the study, permitting the resilient students to carry a camcorder around with them in order to chronicle their lives during the study may also yield some promising data about the attributes of resilient children who are academically successful. It is hoped that these attributes can eventually be transferred to the non-resilient population. Theoretical and conceptual work in the area of resiliency has hypothesized that there are factors that can be altered to facilitate resiliency among at-risk students. Rutter (1987), for example, suggested four ways to facilitate resiliency: reduce risk impacts and change students' exposure to risks, reduce negative chain reactions that often follow exposure to risks, improve students' self-efficacy or self-esteem, and open up or create new opportunities for students.

The experimental design should be enhanced in order to gather more data from additional observations one, two and three in order to explore the transferability of these observations into the classroom practice.

APPENDICES

APPENDIX A

Baylor University Center for Astrophysics, Space Science and Engineering Research (CASPER) Physics Curriculum Project

Pre and Post Physics Evaluation Test (PET)

Light Exam

1. A means of carrying energy from one place to another is

   a.) frequency b) a wave c.) an amplitude d.) an intensity

2. The electromagnetic waves that carry the most energy are

   a.) radio waves b) light wave c.) ultraviolet light wave d.) gamma wave

3. The bouncing of a light wave off of a surface is

   a.) reflection b) refraction c.) amplitude d.) frequency

4. A magnifying glass uses

   a) convex mirrors b) concave mirrors c.) convex lenses d.) concave lenses

5. Waves that pass through a material are

   a.) absorbed b) reflected c.) transmitted d.) louder

6. The bottom of a light wave is its

   a.) crest b) wavelength c.) amplitude d.) trough

7. A material that does not allow light to pass through it is

   a) clear b) transparent c.) translucent d.) opaque

8. The invisible range of light we feel as heat is

   a.) infrared b) visible c.) ultraviolet d.) bright

9. The change in direction (bending) of light when it enters or exits
Exit a material such as glass or water

a.) refraction b) reflection c.) transverse waves d.) compressional waves

10. A surface that allows light to travel through it with a distorted image is

a) clear b) transparent c.) translucent d.) opaque

11. Radio energy waves travel in

a.) transverse waves b) compressional waves c.) oceanic waves

d.) latitudinal waves

12. A sunburn comes from skin being overexposed to

a.) sound waves b) radio waves c.) red light d.) ultraviolet light

13. A special source of light of only one wavelength which is in phase is called a

a.) laser b) transformer c.) vector d.) vacuum

14. Light waves in which the vibrations occur in a single plane are

a.) compressed b) polarized c.) displaced d.) diverged

15. The speed of light is approximately

a.) 98 million kilometer per second b) 5,700 kilometers per second

c.) 300,000 kilometers per second d.) 740 kilometers per second

16. Which of the following is not an example of unpolarized light?

a.) light emitted by a lamp b) a laser light
c.) light emitted by the sun d.) light emitted by a candle flame

17. X-rays are high energy waves which are used

a.) for medical application b) by Superman/Clark Kent
c.) for inspecting welds d.) both a and c e.) all of the above

18. Radio waves are used to transmit

a.) electromagnetic radiation b) radio signals
c.) television signals d.) radio and television signals

19. The _____ the wavelength of the radiation, the ______ the energy

a.) shorter and higher b) shorter and lower
c.) longer and higher d.) longer and lower

20. How do astronauts communicate when on a space walk

a.) they talk on the plane b) they use walkie-talkies
c.) they use radio waves d.) they use microwaves

21. What makes it possible to see in the dark

a.) gamma rays b) microwaves c.) x-rays d.) infrared radiation

22. What are gamma rays used for in medicine

a.) organ transplants b) physical therapy c.) cancer treatments
d.) HIV/AIDS research

23. How does light travel

a.) fast at a rate of 150,000 miles per second
b.) relatively fast at a rate of 80,000 miles per second
c.) slow at a rate of 180 miles per hour
d.) fast at a rate of 186,000 miles per second

24. We can control light in three basic ways

a.) block it with something opaque, reflect it, bend it
b.) construct it, reflect it, bend it
c.) block it with something transparent, reflect it , bend it
d.) translate it, reflect it, theorize it

25. What important technological advances depend on being able to produce, control and/ or detect light in special ways?

a.) photocopiers and fax machines
b.) projectors
c.) CD players
d.) weather and spy satellites
e.) all of the above

26. A laser is a special source of light and has:

a.) several different wavelengths
b.) only one wavelength which is in phase
c.) has only one wavelength but is not in phase
d.) special spots containing a lot of energy

27. Lasers are used:

a.) for cutting metal and for scalpels in some types of surgery
b) in "reading" bar codes
c.) to make holograms
d.) all of the above

28. A __________ is used to transform unpolarized light into polarized light.

a.) unpolarization file b) polaroid camera
c.) polaroid filter d.) polaroid file

29. Electromagnetic radiation visible to the human eye is called

a.) wave crests b) wave troughs
c.) refraction d.) light

30. A transverse wave has

a.) an electric element b) a magnetic element
c.) both a and b d.) none of the above

APPENDIX B

Observation Protocols

Researcher's Observations

Participant Observation

Reflexivity is a higher order cognitive process that calls upon the qualitative researcher to carefully deconstruct her/his actions in qualitative research design, data collection and analysis.

Apply this reflexive process to provide your insights and pose your questions regarding the act of participant observation and interviewing that you engaged in as a form of qualitative research practice.

School

Questions	Descriptive Notes (detailed, chronological notes about what the observer sees, hears; what occurred; the physical setting)	Reflective Notes (Concurrent notes about the observer's thoughts, personal reactions, experiences)	
1. Describe the environment and physical			
2. Describe the people and overall human interaction			
3. Who are the people involved in the social action?			
4. What individual activities are people engaged in?			
5. What group activities are people engaged in?			
What are the objects people uses?			
6. What is the sequence of activity that takes place over time?			
7. What things are people trying to accomplish?			
8. What emotions are expressed?			
9. What languages are being used?			

APPENDIX C

The Pilot and Complete Study Principal's Survey

Demographic Information and Principal's Perceptions

Please answer the following questions about your school.

I. The School

A. What is the average income of the community that your school serves? (check only one)

_____ $ 9,310- $ 31,570 _____$ 50,000- $ 74,999

_____$ 31,570- $ 34,999 _____$ 75,000- $ 99,999

_____$ 35,000- $ 49,999 _____$ 100,000 and over

B. What is the ethnic distribution for students in your school? (Please give most current percentages)

_____African American _____White/Caucasian
_____ Latino (a) _____Native American
_____Asian _____Other

C. What is the ethnic distribution of non-teaching employees in your school? (Please give most current percentages)

_____ African American _____White/Caucasian
_____Latino (a) _____Native American
_____Asian _____Other

D. What is the ethnic distribution of the teachers in your school? (Please give most current percentages)

_____ African American _____White/Caucasian
_____Latino (a) _____Native American
_____Asian _____Other

E. What is the ethnic distribution of administrators in your school? (Please give most current percentages)

_____ African American _____White/Caucasian
_____Latino (a) _____Native American
_____Asian _____Other

F. What is your ethnicity?

_____ African American	_____White/Caucasian
_____Latino (a)	_____Native American
_____Asian	_____Other

G. What is the percentage of economically disadvantaged students in your school? (Please give most current percentage)

H. What type of science instruction is taught in the school?

I. What instructional method is used in teaching science?

J. How much time is spent in science education?

K. What concerns do you have about your school?

L. What advantages do your students have at their school?

M. What concerns do have about the study?

N. Comments

APPENDIX D

Video Taping Protocol and Analysis

Brief Introduction

Video Taping can offer detailed portrayals of human social behavior. The task is to analyze from an ethnographic perspective the behaviors and events depicted in the video tapes. The purpose is to think carefully about the human actions and events portrayed in the video tape. Then, to make sense of this video tape, record what is observed in the video tape using Unobtrusive Observation field notes style and ethnographic analysis.

It is important to review the video tapes at least once. (Two viewings may offer a distinct advantage). Reviewing notes and readings regarding Unobtrusive Observation, record the actions that appear to be occurring the events in the video tapes

In organizing the observation Field Notes:

(a) describe the relevant scene;

(b) describe in detail the dialogue, actions, behaviors, interactions, etc. that you believe are relevant, bringing in research findings as much as possible; and

(c) elaborate on how the selected viewings conform and/or fail to conform to a grounded theory that may have developed or are beginning to identified by the researcher.

Background

Introduction

.

Video Participants:

Researcher/Teacher: Edith Davis
Science Teacher:
Student Participants:
Resilient Student Participant:

Unobtrusive Observation

Field Notes Scenes	Field Notes Description Empirical	Field Notes Description Phonically	Field Notes Conform/Not Conform to Grounded Theory	Methodology Notes	Theoretical Notes	Personal Notes
Opening frame						
Frame #2						
Frame #3						
Frame #4						
Frame #5						
Frame #6						

Coding

Researcher/Teacher Student Participant Resilient Participant

Analysis

What are you conscious of?

What is your focus?

Where are there tensions?

What were the hardest things?

What was the easiest?

How does it get easier?

What is happening to you that make it easier?

How is your self esteem holding up?

APPENDIX E

The Complete SPC Study Interview of Teachers who Identify Resilient Children

Information and Perceptions

Teachers please answer the following questions for each of your resilient children.

I. The Resilient Child

A. How would you describe your student?

B. How would you describe the races/ethnicities of your student?

_____African American	_____White/Caucasian
_____ Latino (a)	_____Native American
_____Asian	_____Other

E. What type of learner is your resilient student?

F. What instructional method does your resilient student best respond to?

G. How much instructional time do you spend with your resilient student?

H. What concerns do you have about your resilient students?

I. What concerns do you think your resilient student has, i.e. science education, school, family, and future?

J. Why do you believe your student is a resilient child?

J. What concerns do have about the study?

K. Comments

APPENDIX F

Student's Contract for the Complete SPC Study

Spiral Physics Curriculum

Edith Davis' Dissertation The Complete SPC Study

I ________________________hereby pledge to respect my fellow classmates and leadership. I will be ready to learn and to maximize every learning experience presented to me. I will have fun and will endeavor to help others to have fun in the learning environment. I understand that I can choose to make good decisions, which will reap for me good consequences; however, I also understand that if I choose to make bad or poor decisions that bad or poor consequences will more than likely follow. I accept responsibility for my choices and actions.

I understand that my good choices can impact my fellow classmates in a positive way, as well as my bad or poor choices will impact my fellow classmates in a negative way. I pledge to make good choices from this day forward.

I will respect other people's ideas. Respect does not mean agreement, but that I protect the rights of others to think differently than myself. I look forward to the bright future that good choices and consequences will bring me over time.

I will try to conduct myself with a thankful attitude for having the privilege to learn and to be placed in a learning environment.

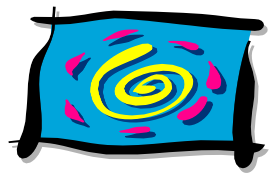
Sincerely,

____

APPENDIX G

Attendance Page for the Complete SPC Study

Spiral Physics Curriculum



Edith Davis' Dissertation The Complete SPC Study

	Print Name	Sign Name
1.	______________________	______________________
2.	______________________	______________________
3.	______________________	______________________
4.	______________________	______________________
5.	______________________	______________________
6.	______________________	______________________
7.	______________________	______________________
8.	______________________	______________________
9.	______________________	______________________
10.	______________________	______________________
11.	______________________	______________________
12.	______________________	______________________
13.	______________________	______________________
14.	______________________	______________________
15.	______________________	______________________

APPENDIX H

Consent Forms

B A Y L O R
BAYLOR UNIVERSITY

Parental Informed Consent Form

This form asks for your consent and your child to participate in the educational research during the summer of 2005, fall of 2005 and spring of 2006, semesters academic year This study is an investigation of the effects of teaching Physics using an experimental Spiral Physics curriculum on a valid sample set of Texas' students as well as will be a grounded theory design on the participants and, in particular, will look at the resilient children that are found in this population. For this study you will be asked to respond to written questions, provide demographic information, and provide general family history. Additionally, your consent will be needed to conduct classroom observation of your child as well as you and your child to be interviewed. The observations and interviews will be taped (audio and video).
The audios and videos tapes will be destroyed upon completion of the study to protect your privacy.

There will be no physical risks at any time as well as all benefits gained in the study will not be withheld. You and your child may elect, either now or at any time during the survey, to withdraw your participation, with no penalty or loss of benefits. You and your child have been selected to participate in this procedure based on your participation in a Spiral Physics education program. You should understand that you and your child compliance are completely voluntary.

We have no interest in knowing how a specific individual responds to the interview. A limited amount of demographic data will be collected from you and your child related to the Spiral Physics Program. A code will be used to identify each participant's responses so you are guaranteed of complete confidentiality. All participant responses (written, audio and video) will be kept in a locked cabinet in the researcher's office. Data will be reported in both aggregate and response form.

This study meets the American Psychological Association's standards for "Minimal Risk" and poses no major risks or dangers for you as a participant.

Responses to the survey questions and interviews will be analyzed and used as part of the researcher's doctoral dissertation and to inform the revision of the Baylor University School of Education's Program. A summary of the responses will be published and participants may receive a copy by contacting Edith G. Davis. A copy of this consent form is available for participants.

Please direct all inquiries pertaining to the study itself to Edith G. Davis or Dr. Tony Talbert, Department of Curriculum and Instruction, School of Education, Baylor University, P. O. Box 97314, Waco, TX 76798-7314. Mrs. Davis may also be reached at 254-710-7594.

If you have any questions regarding you and your child's rights as a participant, or have other questions about this research as it relates to your participation, please contact the Baylor University Committee for the Protection of Human Subjects, Dr. Matthew S. Stanford, Chair, Baylor University, Department of Psychology and Neuroscience Baylor University, One Bear Place # 97334 Waco, TX 76798-7334, or call him at 254-710-6759.

I have read and understand this form, am aware of my rights and my child's as a subject, and have agreed to participate in this study.

________________________________ ____________________

Name Date

B A Y L O R
BAYLOR UNIVERSITY

Student's Informed Consent Form

This form asks for your consent to participate in the educational research during the summer of 2005, fall of 2005 and spring of 2006, semester's academic year the summer, fall and spring semesters of the 2005-06 academic years. This study is an investigation of the effects of teaching Physics using an experimental Spiral Physics curriculum on a valid sample set of Texas' students as well as will be a grounded theory design on the participants and, in particular, will look at the resilient children that are found in this population. For this study you will be asked to respond to written questions, provide demographic information, and provide general family history. Additionally, your consent will be needed to conduct classroom observations and interviews of you. The observations and interviews will be taped (audio and video). The audios and videos tapes will be destroyed upon completion of the study to protect your privacy.

There will be no physical risks at any time well as all benefits gained in the study will not be withheld. You may elect, either now or at any time during the survey, to withdraw your participation, with no penalty or loss of benefits. You and your child have been selected to participate in this procedure based on your participation in a Spiral Physics education program. You should understand that your compliance is completely voluntary and that your participation or lack of participation, in this study will not affect your grade or your end of semester evaluation.

We have no interest in knowing how a specific individual responds to the interview. A limited amount of demographic data will be collected from you and your child related to the Spiral Physics education program. A code will be used to identify each participant's responses so you are guaranteed of complete confidentiality. All participant responses (written, audio and video) will be kept in a locked cabinet in the researcher's office. Data will be reported in both aggregate and response form.

This study meets the American Psychological Association's standards for "Minimal Risk" and poses no major risks or dangers for you as a participant.

Responses to the survey questions and interviews will be analyzed and used as part of the researcher's doctoral dissertation and to inform the revision of the Baylor University School of Education's Program. A summary of the responses will be published and participants may receive a copy by contacting Edith G. Davis. A copy of this consent form is available for participants.

Please direct all inquiries pertaining to the study itself to Edith G. Davis or Dr. Tony Talbert, Department of Curriculum and Instruction, School of Education, Baylor University, P. O. Box 97314, Waco, TX 76798-7314. Mrs. Davis may also be reached at 254-710-7594.

If you have any questions regarding you and your child's rights as a participant, or have other questions about this research as it relates to your participation, please contact the Baylor University Committee for the Protection of Human Subjects, Dr. Matthew S. Stanford, Chair, Baylor University, Department of Psychology and Neuroscience Baylor University, One Bear Place # 97334 Waco, TX 76798-7334, or call him at 254-710-6759.

I have read and understand this form, am aware of my rights as a subject, and have agreed to participate in this study.

________________________________ ______________________
Name Date

BAYLOR
BAYLOR UNIVERSITY

Teacher's Informed Consent Form

This form asks for your consent to participate in the educational research during the summer of 2005, fall of 2005 and spring of 2006, semester's academic year. This study is an investigation of the effects of teaching Physics using an experimental Spiral Physics curriculum on a valid sample set of Texas' students as well as will be a grounded theory design on the participants and, in particular, will look at the resilient children that are found in this population. For this study you will be asked to respond to written questions, provide demographic information, SES (social economic status) information, and provide general school history. Additionally, your consent will be needed to conduct classroom observations and interviews of you. The observations and interviews will be taped (audio and video). The audios and videos tapes will be destroyed upon completion of the study to protect your privacy.

There will be no physical risks at any time well as all benefits gained in the study will not be withheld. You may elect, either now or at any time during the survey, to withdraw your participation, with no penalty or loss of benefits. You and your school have been selected to participate in this procedure based on your participation in a Spiral Physics education program. You should understand that your compliance is completely voluntary and that your participation or lack of participation, in this study will not affect your grade or your end of semester evaluation.

We have no interest in knowing how a specific individual responds to the interview. A limited amount of demographic data will be collected from you and your school related to the Spiral Physics education program. A code will be used to identify each participant's responses so you are guaranteed of complete confidentiality. All participant responses (written, audio and video) will be kept in a locked cabinet in the researcher's office. Data will be reported in both aggregate and response form.

This study meets the American Psychological Association's standards for "Minimal Risk" and poses no major risks or dangers for you as a participant.

Responses to the survey questions and interviews will be analyzed and used as part of the researcher's doctoral dissertation and to inform the revision of the Baylor University School of Education's Program. A summary of the responses will be published and participants may receive a copy by contacting Edith G. Davis. A copy of this consent form is available for participants.

Please direct all inquiries pertaining to the study itself to Edith G. Davis or Dr. Tony Talbert, Department of Curriculum and Instruction, School of Education, Baylor University, P. O. Box 97314, Waco, TX 76798-7314. Mrs. Davis may also be reached at 254-710-7594.

If you have any questions regarding you and your school's rights as a participant, or have other questions about this research as it relates to your participation, please contact the Baylor University Committee for the Protection of Human Subjects, Dr. Matthew S. Stanford, Chair, Baylor University, Department of Psychology and Neuroscience Baylor University, One Bear Place # 97334 Waco, TX 76798-7334, or call him at 254-710-6759.

I have read and understand this form, am aware of my rights as a subject, and have agreed to participate in this study.

__________________________________ ______________________

Name Date

B A Y L O R
BAYLOR UNIVERSITY

Principal's Informed Consent Form

This form asks for your consent to participate in the educational research during the summer of 2005, fall of 2005 and spring of 2006, semester's academic year. This study is an investigation of the effects of teaching Physics using an experimental Spiral Physics curriculum on a valid sample set of Texas' students as well as will be a grounded theory design on the participants and, in particular, will look at the resilient children that are found in this population. For this study you will be asked to respond to written questions, provide demographic information, social economic status (SES) information, and provide general school history. Additionally, your consent will be needed to conduct classroom observations and interviews of you. The observations and interviews will be taped (audio and video). The audios and videos tapes will be destroyed upon completion of the study to protect your privacy.

There will be no physical risks at any time well as all benefits gained in the study will not be withheld. You may elect, either now or at any time during the survey, to withdraw your participation, with no penalty or loss of benefits. You and your school have been selected to participate in this procedure based on your participation in a Spiral Physics education program. You should understand that your compliance is completely voluntary and that your participation or lack of participation, in this study will not affect your grade or your end of semester evaluation.

We have no interest in knowing how a specific individual responds to the interview. A limited amount of demographic data will be collected from you and your school related to the Spiral Physics education program. A code will be used to identify each participant's responses so you are guaranteed of complete confidentiality. All participant responses (written, audio and video) will be kept in a locked cabinet in the researcher's office. Data will be reported in both aggregate and response form.

This study meets the American Psychological Association's standards for "Minimal Risk" and poses no major risks or dangers for you as a participant.

Responses to the survey questions and interviews will be analyzed and used as part of the researcher's doctoral dissertation and to inform the revision of the Baylor University School of Education's Program. A summary of the responses will be published and participants may receive a copy by contacting Edith G. Davis. A copy of this consent form is available for participants.

Please direct all inquiries pertaining to the study itself to Edith G. Davis or Dr. Tony Talbert, Department of Curriculum and Instruction, School of Education, Baylor University, P. O. Box 97314, Waco, TX 76798-7314. Mrs. Davis may also be reached at 254-710-7594.

If you have any questions regarding you and your school's rights as a participant, or have other questions about this research as it relates to your participation, please contact the Baylor University Committee for the Protection of Human Subjects, Dr. Matthew S. Stanford, Chair, Baylor University, Department of Psychology and Neuroscience Baylor University, One Bear Place # 97334 Waco, TX 76798-7334, or call him at 254-710-6759.

I have read and understand this form, am aware of my rights as a subject, and have agreed to participate in this study.

______________________________ ____________________
Name Date

APPENDIX I

Dunn-Šidák (t_{DS})

The Complete Study Results Statistical Analysis by Hypotheses Dunn Šidák

Another method of evaluating results is the use of Dunn Šidák. Dr. Roger Kirk assisted the researcher in the use of the Dunn Šidák method. Dunn Šidák is a way of evaluating a portion of the above design which could validate that the treatment significantly affected the dependent variable (physics achievement) in students through the analysis of contrast (Kirk, 1995). The researcher's rationale for using the Dunn-Šidák method of evaluating the above design was that the design was priori and non-orthogonal. The Dunn-Šidák (t_{DS}) statistics for H1: $O_2 > O_1$ where the t_{DS} was 4.974*, meaning that the pre-tested group that received the experimental spiral physics curriculum (O_2) scored significantly higher than students who had not received the new experimental spiral physics curriculum (O_1).

The pre-tested students receiving the experimental spiral physics curriculum compared to the students that were pre-tested (O_2) and received the traditional linear physics curriculum (O_4) and showed no significant difference for H1: $O_2 > O_4$ where the t_{DS} was -0.13. This meant that the difference between the experimental spiral physics and the traditional linear physics curriculum was not significant. The analysis revealed that there was no significant difference between students who were not pre-tested and received the experimental spiral physics curriculum and students that were not pre-tested and received the traditional linear physics curriculum. The researcher's hypothesis for (H1); H1: $O_5 > O_6$ where the t_{DS} was 1.23, means that the difference between the experimental spiral physics and the traditional linear physics curriculum was not significant. The analysis also revealed that there was a significant difference between students that were not pre-tested and received the experimental spiral physics curriculum (O_5) when compared to students who had not received the experimental spiral physics curriculum (O_6). The researcher's hypothesis for H1: $O_5 > O_3$ where the t_{DS} was 5.45*, meaning that the group receiving no pre–PET and the experimental spiral physics curriculum (O_5) scored significantly higher than the group that had not received the spiral physics curriculum (O_3).

If all of the following contrasts are positive, it suggests that the treatment did affect the dependent variable (Kirk, 1995) (see Figure 2).

1. $O_2 > O_1$	4.974*	(is significant)
2. $O_2 > O_4$	-0.13	(is not significant)
3. $O_4 > O_3$	4.484*	(is significant)
3. $O_5 > O_6$	1.23	(is not significant)
4. $O_5 > O_3$	5.45*	(is significant)

Figure 3. Dunn-Šidák (t_{DS}) Analysis—The Complete Study

The Complete Study—Dunn-Šidák (t_{DS}) Analysis

The multiple comparison procedure for a priori contrasts where the contrasts are non-orthogonal is the Dunn-Šidák (t_{DS}) analysis (Kirk, 1995). In making the multiple comparisons, the researcher/teacher already had formulated a specific hypothesis that she wished to test via an experiment such as the Solomon Four group design, a priori or planned test. In most cases, an infinite number of contrasts can be derived or expressed as a linear function of another contrasts. In some cases, these contrasts are redundant, or in other words they can be described as a linear function of another contrast or non-orthogonal contrast (Kirk, 1995). When contrasts are mutually non-redundant they are called orthogonal contrasts; no other contrast can express the linear function of these contrasts (Kirk, 1995). In this study, the hypothesis was expressed prior to the performance of the experiment, making it a priori and the contrast could be expressed by the linear functions of other contrasts or non-orthogonal. In the case of this study, the recommended multiple comparison test would be the Dunn-Šidák test (Kirk, 1995). The Dunn-Šidák (t_{DS}) analysis of contrast showed significance, which means the treatment did affect the dependent variable and that the experimental spiral physics curriculum does increase physics achievement in students. A common error made in using the Dunn-Šidák (t_{DS}) analysis is the correct use of the tables to find the correct critical value. Dr. Roger E. Kirk and Fanni Natanegara of Baylor University discovered that researchers tend to double α in a two-tailed t table to obtain the critical value in a one tail test. The problem lies in the fact that doubling α in a one-tailed test will give the researcher a critical value that is too small. This particular error was avoided in this analysis (Kirk and Nataegara, 2001).

APPENDIX J

Pilot Study

The Pilot Study Participant Attendance

The attendance during the study had a direct relationship to the amount of instructional time each participant received during the pilot study. The amount of instructional time received by each participant has a direct relationship on the amount of learning the participant achieved and therefore had a direct relationship on the dependent variable physics achievement. The dependent variable of physics achievement was the variable the pilot study and the complete study measured in order to verify the effectiveness of the spiral physics curriculum. The attendance of the pilot study participants can be found in table J.1

Table J.1

Pilot Study Participant Attendance

Pilot Study Days	B M S # of Students Present	C M S # of Students Present	G M S # of Students Present
1- Monday	7	2	8
2-Tuesday	7	2	9
3-Wednesday	7	2	10
4-Thursday	7	8	9
5-Friday	6	5	9
6- Monday	7	8	10
7-Tuesday	7	5	9
8-Wednesday	7	4	10
9-Thursday	7	2	10
10-Friday	7	2	10

APPENDIX K

Complete Study

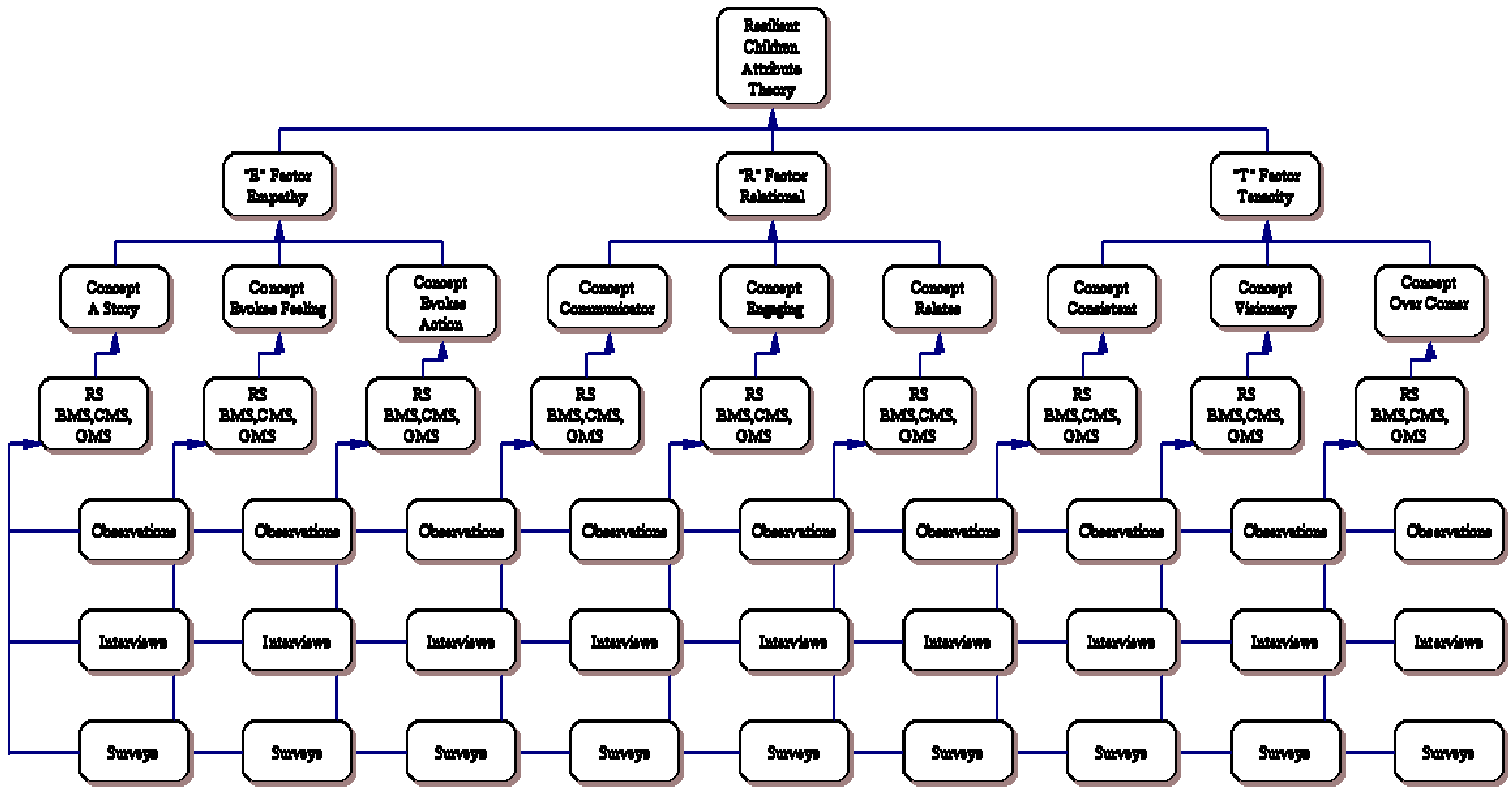
Table K.1

The Complete SPC Participants Attendance

Study Days	C M S # of Students Present	C I S # of Students Present	G M S # of Students Present	W M S # of Students Present
1-Monday	33	0	5	14
2-Tuesday	25	22	19	14
3-Wednesday	31	19	12	13
4-Thursday	24	15	16	13
5-Friday	33	13	5	9
6-Monday	0	13	15	10
7-Tuesday	0	14	16	13
8-Wednesday	0	19	17	14
9-Thrusday	0	18	0	13
10-Friday	0	9	13	14

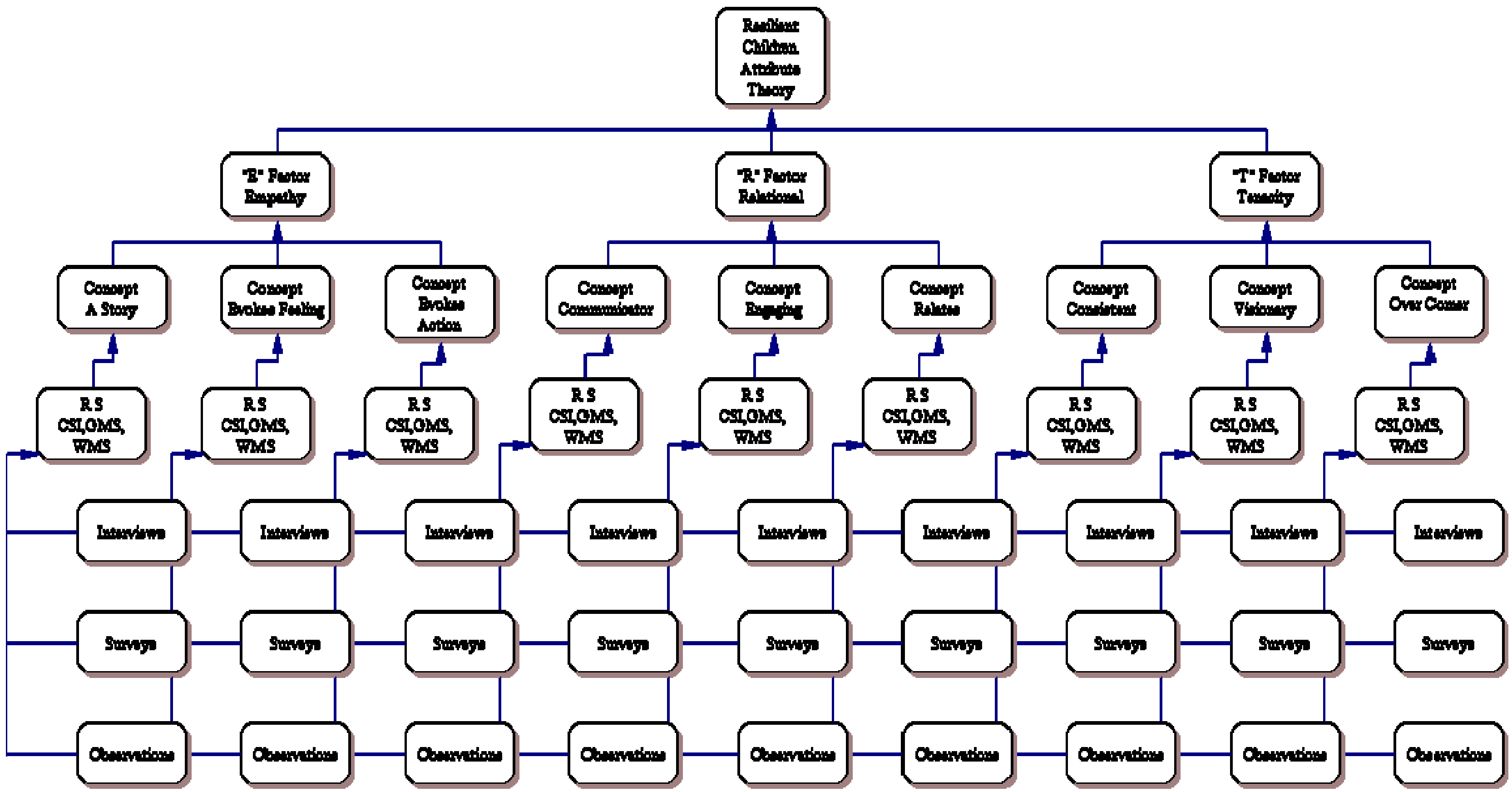
APPENDIX L

Grounded Theory Flow Chart- Pilot Study



APPENDIX M

Grounded Theory Flow Chart-Complete Study



APPENDIX N

Qualitative Observation Rubrics

Resilient Children Grounded Theory Analysis Complete Study: May 18-May 20, 2006

CSI Observation

	CSI		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	She expresses her thoughts clearly.	One of the first to greet me in the morning	She worked hard to understand the concepts and the labs
Events/concepts	Talked to me about why she is living with her father and how her mother left them	She often walks with me within the campus	She came prepared to learn
Events/concepts	She told me how happy she was that her father permitted her to participate in the class	She would quietly stand next to me	She asked insightful questions
Events/concepts		She works well with other students	
Events/concepts		She would help me carry materials from my car to the classroom	

GMS Observation

	GMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	She expresses her thoughts well	Talked to me about her school	She moved quite a bit, but it did not deter her from coming to class
Events/concepts	Talked to me about her family and the relationships between her siblings	One of the first to greet me in the afternoon	
Events/concepts	She would come to class excited and ready to learn	She met me at my car and helped me take materials upstairs to the classroom	
Events/concepts		Help me with cameras	
Events/concepts	Talked to me about why he dyed his hair blond	I would see her near her home from time to time…she would be happy to see me	

WMS Observation

	WMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	She would talk to be about her relationships at home and school	She would meet me at my car and help me take materials to class	She did not miss a single day of class
Events/concepts		She helped me with set-up in the classroom	She worked hard to understand the concepts
Events/concepts		She took on the leadership role with her classmates during the study	

CSI Semi Structured Interview

	CSI		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Students' mother is very resilient. Training and modeling by the mother.		She is very determined and tenacious
Events/concepts	Resiliency may be genetic mother is very resilient		She loves to learn and responds well to all methods.
Events/concepts			She loves research.

GMS Semi-Structured Interview

	GMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	She expresses her thoughts well	Talked to science teacher about her family	She had a tough start, but did not give up. She is now doing well in class

WMS Semi-Structure Interview

	WMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	She had a normal social life	She is wants to do the right thing	She is very determined. Her mother and father are divorced and remarried.
Events/concepts		She helped the science teacher with set-up in the classroom	She responds best with lessons with examples

CSI Principal Survey

	CSI		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic same as community	Socio-Economic same as community	Socio-Economic same as community

GMS Principal Survey

	GMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic same as community	Socio-Economic same as community	Socio-Economic same as community

WMS Head of School Survives

	WMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic not the same as the community	Socio-Economic not the same as the community	Socio-Economic not the same as the community

BMS Observation

	BMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	The subject quickly bonded to the researcher and began to reveal her world.	Initially, the subject did not have a goal in life. However, toward the end of the study, she decided that she would like to work in educational television.	The initial visit to the student's home began with the researcher walking in on a conversation of a police officer with the subject's grandmother concerning the location of a relative the police officer wanted to question.
Events/concepts	The subject possessed a great ability to rouse empathy from administrators and teachers.	The researcher observed her interactions with the principal, staff, teachers and peers. The researcher observed an easy ability to converse with all and explain issues and concerns in her world.	Toward the end of the study, the subject's father was killed. The subject continued to attend class.
Events/concepts	The researcher observed that all listened and responded to the subject's issues and concerns.	The researcher observed that the subject was concerned about what was happening in the worlds of the people that impacted her world.	

CMS Observation

	CMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	He was able to communicate about the condition of the world in which he lived and evoked empathy from the researcher/teacher	The subject was highly engaged in the lessons. He took the leadership role whenever the class performed experiments and was quite verbal in explaining his views.	The subject explained that his mother was having a baby and that he would be responsible for helping the family with the care of the new sibling.
Events/concepts	The researcher observed the subjects communications with his classmates and staff. The subject could easily draw others into his world.		

GMS Observation

	GMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	The GMS subject took on the leadership role in her group.	The GMS subject was engaged in lessons and was very helpful to her peer group.	The GMS subject was attentive and quickly grasped the physics concepts. The GMS subject had established the goal of becoming a doctor, specifically a pediatrician.

BMS Principal Survey

	BMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic same as community	Socio-Economic same as community	Socio-Economic same as community

CMS Principal Survey

	CMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic same as community	Socio-Economic same as community	Socio-Economic same as community

GMS Principal Survey

	GMS		
	Resilient Children Grounded Theory		
Categories	"E" Factor	"R" Factor	"T" Factor
Events/concepts	Socio-Economic same as community	Socio-Economic same as community	Socio-Economic same as community

APPENDIX O

Waco Independent School District

501 Franklin Avenue

Waco, TX 76708

April 8, 2005

To Whom It May Concern:

I am writing a letter of support for the proposal submitted by Ms. Edith G. Davis. She is submitting a proposal for the Baylor's IRB committee for Review of Research.

The Proposal will be implemented at Baylor University and it will be a study of how effective is a spiral physics curriculum on the greater Waco independent school district's student population.

Waco ISD is in full support of this proposal and look forward to having it conducted at the Baylor University campus with our students. We feel that the study will be very beneficial in planning the best science education instruction for our individual students and how it should be incorporated in the Greater Waco ISD classroom.

Sincerely,

Dr. Karleen K. Noake
Assistant Superintendent of Curriculum

Dr. Jerry Major Superintendent

APPENDIX P

Micro Spiral Curriculum

The concept of a spiral curriculum is one in which there is an iterative revisiting of concepts, subjects or themes throughout the course. A spiral curriculum is not simply the repetition of a concepts taught, but a deeper understanding of a concept with each successive encounter building on the previous encounter.

Hilda Taba's version of the spiral curriculum built upon Ralph Taylor's 1969 rationale of curriculum design. Taba's spiral curriculum contains multiple educational objectives versus Taylor's single educational objective. Taba's multiple objectives enable basic knowledge, thinking skills, attitudes, and academic skills to each be addressed in the learning experiences of students (Krull, 2003).

The researcher characterizes Taba's spiral curriculum as a macro curriculum because it addresses K-12 grades and had multiple educational objectives. The researcher built upon Taba's work and spiral the concepts within lesson plans. The researcher characterizes the spiraling of concepts within lesson plans, as a micro spiral. Phase one of the micro spiral begins with a synopsis of previous concepts. In phase two, the lesson progresses to a presentation of the current concept. In phase three, a future concept is introduced. The spiraling of concepts within the lesson progresses during the day adding more information to the concept. The next day the present concepts become the past, the future concepts become the present concept taught that day, and another future concept is introduced. The cycle continues throughout the week with information being added deepening the knowledge base of the student in regards to the concept.

Below is a table showing the methodology of a week of micro spiral concepts.

Table O.1

Micro Spiral of Concepts

Phase	Monday	Tuesday	Wednesday	Thursday	Friday
Past (Phase One)	Electromagnetic Spectrum	Visible Light	Reflection	Refraction	“Angle of Incident” (Reflection)
Present (Phase Two)	Visible Light	Reflection	Refraction	“Angle of Incident” (Reflection)	Snell’s Law (Refraction)
Future (Phase Three)	Reflection	Refraction	“Angle of Incident” (Reflection)	Snell’s Law (Refraction)	Indices of Refraction

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