The Impact of a STEM Program on Academic Achievement of Eighth Grade Students in a South Texas Middle School

A Dissertation

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Norma Olivarez

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ABSTRACT

The Impact of a STEM Program on Academic Achievement of Eighth Grade Students in a South Texas Middle School

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Norma R. Olivarez

BBA, St. Mary’s University, San Antonio, Texas

MBA, University of Texas at Austin

MPH, Loma Linda University- Loma Linda, California

The primary purpose of the study was to examine the impact of a science, technology, engineering, and mathematics (STEM) educational program on academic achievement. The study was delimited to 8th graders and outcome measures of mathematics, science, and reading. An ex-post facto, causal-comparative research design was employed. The characteristic-present group consisted of 73 eighth grade students in a STEM academic program. The comparison group consisted of 103 eighth grade students in a non-STEM academic program. On the basis of the centroids, the STEM group outperformed the non-STEM group on all outcome measures. It is concluded that participation in a STEM academic program, where teachers use Project-Based Learning (PBL), collaborative learning, and hands-on strategies, positively impacted eighth grade students’ academic achievement in mathematics, science, and reading.

DEDICATION

My parents were deprived of the opportunity to pursue their education and ensured that their children would not suffer the same fate. They supported and encouraged academic achievement through their actions and sacrifices. I dedicate this effort and the accomplishment it represents to the late Manuel and Vickie Olivarez.

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CHAPTER 1

INTRODUCTION

Background and Setting

After the end of WWII in the 1940s, America invested in educational programs such as the G.I. Bill for military personnel to pursue higher education. Funds were also provided for research and development projects to encourage American innovation. The successful launch of Sputnik in 1957 by the Soviet Union increased the focus on science and engineering education. The United States underwent decades of identifying, recruiting, and educating individuals who represented the best and the brightest citizens to create a generation of leaders in scientific and technological innovation (NSB 07-114, 2007).

The focus and investment in science, technology, engineering, and mathematics (STEM) education, in addition to research and development, resulted in the creation of new jobs, technologies, and enterprises. Many Americans benefitted directly and indirectly from the results of these efforts. The gains and innovations, which were made during the 1950s and 1960s, elevated the United States to the status of a world leader in scientific innovation. The focus and energy, which were spent on developing STEM education, were diminished significantly by the 1970s. The gains which were realized through American innovation during the 19th and 20th century have been deteriorating in recent years as other countries have succeeded in training and preparing students in fields which were once exemplified by American achievement (NSB 07-114, 2007).

Other countries have made significant gains in fields involving science and technology, while the number of American students pursuing higher education in STEM fields declined. The changes, which have taken place in recent years in the areas of science, technology, engineering, and mathematics education, have created growing concerns that the United States is losing its competitive edge on a global stage. Globalization and a knowledge-based economy have made technology and scientific innovation critical elements of retaining a worldwide leadership position (Campbell, Hombo, & Mazzeo, 2000).

The urgency of correcting the course and preparing future generations of STEM leadership and graduates is reminiscent of the Sputnik era. The economic future and security of America as a nation makes this race even more critical because the basis of a democratic society includes involvement by all citizens rather than a selected few who are educated enough to understand what is at risk. In 1983, the *A Nation At Risk* report was generated after research was conducted by the National Commission on Excellence in Education, which was formed in 1981, to evaluate the quality of the American educational system. The report concluded that the high expectations, investment, commitment, and disciplined effort, which defined the Sputnik era, had deteriorated significantly in the American education system as a whole (Gardner & Larsen, 1983). Competitors such as Japan, Korea, and Germany, however, are preparing their citizens to operate in a knowledge-based economic system (NSB 12-01, 2012).

Changing economic drivers and demographic changes in the U.S. are contributing to the challenges which must be met in order to retain a competitive workforce on a global level. Science and mathematics performance indicators are particularly low for minority students who represent a growing demographic in the U.S. As Latinos become an increasingly larger percentage of the American population, their involvement and performance in STEM education will reverberate throughout society (Kuenzi, 2008).

World leaders in a global economy recognize the impact of educational accomplishments and innovations generated by current and future generations. Since 1995, Trends in International Mathematics and Science Study (TIMSS) has generated reports which track performance trends in mathematics and science of students in various countries. In 2007, eighth grade science scores were lower than those in 9 countries located in Asia or Europe. The U.S. was still experiencing higher scores for eighth grade science in 35 of 47 other countries, but only 10% of those students scored at or above the advanced international benchmark in science (Gonzales, Williams, Jocelyn, Roey, Kastberg, & Brenwall, 2008). America faces increased challenges to its worldwide standing as a leader in STEM fields.

In an effort to increase the performance of students in STEM subjects, the Texas High School Project was created in 2003 and involves collaboration between public and private entities. The mission of the project is to improve the postsecondary readiness of low income students in low performing schools. The STEM academies were developed in selected schools dedicated to developing innovative methods for instruction aimed at improving science and mathematics achievement. The alignment of middle school and high school programs with curriculum requirements of competitive higher education institutions and 21st century jobs is a cornerstone of the STEM focused instruction and learning models (Avery, Chambliss, Truiett, & Stotts, 2010).

Statement of the Problem

There is a middle school in an urban South Texas city, hereafter referred to as the Middle School, which has been implementing a STEM program as a choice for students. The ethnicity distribution of the Middle School, at the time of the study, was 92.9% Hispanic, 4.6% African American, and 2.5% White. Economically disadvantaged students comprise 88.5% of the student body (TEA, 2009-2010).

Implementation of the STEM program at the Middle School, partnered with a STEM program at a local high school, began with the 2007-2008 academic year. At the Middle School, the STEM program is referred to as the Innovation Academy. Funding for the program began with a grant from the Texas High School Project and has expanded to include local business partners. At the Middle School, the program began only with the sixth grade students and was extended to the seventh and eighth grade levels as the pilot students progressed to the higher grade levels. Students can apply to continue their participation in the STEM program at the high school level after completion of their middle school education. The effectiveness of the STEM program had not been systematically evaluated at the Middle School.

Theoretical Framework

The study was grounded on Jerome Bruner's Discovery Learning theory. Bruner, a psychologist and a cognitive learning theorist, extensively studied the interaction of culture and brain activity as they relate to learning. His theory includes the belief that active engagement by students including experiments, exploration, and discoveries of the world around them leads to increased understanding and knowledge. Students who are interested in the material they are learning will be more motivated and creative in developing problem-solving skills which will enhance their ability to gain knowledge in the subject area. He suggested that students must find meaning within their cultural context in their education. The way students create and transform meaning is impacted by the world around them and teachers should create conditions for learners to use their individual learning styles to create meaningful connections (Bruner, 1963).

The basic foundation upon which STEM programs are built relies heavily on principles espoused by the theory of Discovery Learning. The basis of the theory incorporates the role of intuition as students solve problems and increase their knowledge base. The STEM programs are designed to incorporate project-based learning which relies on student creativity and problem solving skills. Bruner referred to this approach as a *spiral curriculum*, which included the concept that children are active problem solvers. By building on a structure, which draws from prior knowledge and facilitates the formation of new knowledge, students repeatedly review concepts and achieve a deeper level of understanding (Bruner, 1963).

Changes in technology have made resources available to current students which provide greater opportunities for student engagement in deliberate inquiries into areas of interest. Inquiry science instruction, for example, is incorporated into the guidelines for developing the STEM curriculum. Inquiry learning, as well as discovery learning, incorporates hands-on learning, facilitates problem solving, and promotes inductive reasoning to achieve meaningful learning (The Inquiry Synthesis Project, 2006). Attributes of discovery learning such as exploring and problem solving, spiraling, and group activities, are also incorporated into the STEM curriculum guidelines (Bicknell-Holmes & Hoffman, 2000).

Bruner’s view that knowledge is a process in which motivation plays a major role is also reflected in the STEM academy guidelines. When students are motivated to learn, they are more likely to gain a deeper understanding of underlying concepts. Encouraging students to pursue work on projects, which are of interest to them, increases their motivation for learning (Bruner, 1963). Academic achievement has been researched along with motivation and retention. The findings suggest that discovery learning may lead to increased academic achievement in areas which do not rely on fact-based teaching strategies. Discovery learning also requires more preparation and learning time and benefits from smaller class sizes. Suggestions made for the STEM programs incorporate limits on class sizes and commitments by teachers to invest the additional time required to provide for such learning (Bicknell-Holmes & Hoffman, 2002). In order to receive funding, it is stipulated that the STEM programs must meet benchmark requirements regarding academic content and student achievement standards (NSB 07-114, 2007).

Purpose of the Study

The purpose of the study was to examine the impact of the STEM program on academic achievement of eighth grade students. Academic achievement was established based on performance measures provided through the Texas Assessment of Knowledge and Skills (TAKS) test scores for mathematics, science, and reading objective test scores. The National Center for Education Statistics monitors student academic achievement by collecting and analyzing data in specific cities throughout the United States. The data are used to generate the National Assessment of Educational Progress (NAEP) report, which makes state level comparisons of academic achievement on the basis of standardized test scores in mathematics, science, and reading available (Aud, Hussar, Johnson, Kena, Roth, Manning, Wang, Zhang, & Notter, 2012).

The eighth grade was chosen because it was the only middle school grade which included TAKS testing in all three abovementioned areas. It had been hypothesized that the STEM students would outperform the non-STEM students on academic achievement. The study was guided by the following questions:

1. What is the impact of the STEM program on mathematics achievement among eighth grade students?
2. What is the impact of the STEM program on science achievement among eighth grade students?
3. What is the impact of the STEM program on reading achievement among eighth grade students?

Operational Definitions

Mathematics achievement was measured by the proportion of correct answers to questions in each of the following TAKS mathematics objectives:

Objective1: Numbers, operations, and quantitative reasoning

Objective 2: Patterns, relationships, and algebraic reasoning

Objective 3: Geometry and spatial reasoning

Objective 4: Concepts and uses of measurement

Objective 5: Probability and statistics

Objective 6: Mathematical processes and tools

Science achievement was measured by the proportion of correct answers to questions in each of the following TAKS science objectives:

Objective 1: Nature of science

Objective 2: Living systems and the environment

Objective 3: Structure and properties of matter

Objective 4: Motion, forces, and energy

Objective 5: Earth and space systems

Reading achievement was measured by the number of correct answers to questions in each of the following TAKS reading objectives:

Objective 1: Basic understanding

Objective 2: Applying knowledge of literary elements

Objective 3: Using strategies to analyze

Objective 4: Applying critical-thinking skills

Glossary of Terms

Texas Assessment of Knowledge and Skills (TAKS) are statewide standardized tests used in Texas primary and secondary schools to assess students' attainment of skills required under Texas education standards for mathematics, science, reading, writing, and social studies.

Texas Essential Knowledge and Skills (TEKS) are statewide standards for knowledge of the required curriculum which students should have and skills which they should be able to perform.

Delimitations, Limitations, and Assumptions

The study was delimited to 8th graders in one middle school in South Texas and to the outcome measures of mathematics, science, and reading. Due to the non-probability nature of sampling, external validity was limited to study participants. Due to non-experimental nature of the study, no causal inferences were drawn. The study assumed 1) the quantitative data received from the Texas Education Agency (TEA) were accurate and 2) teachers taught their courses in accordance with the district and TEA curriculum guidelines.

Significance of the Study

The study provided comparative data on student achievement on TAKS tests for students in a STEM versus a non-STEM academic program. Results from the study could provide support and documentation for the continuation of funding for the STEM programs at the middle school level. The current financial challenges faced by school districts increase the significance of grant funded programs. Improved student performance at the middle school level is likely to increase student performance at the high school level and beyond. An educated population is essential to maintaining a democratic society, and academic achievement influences the pursuit of educational goals for many students.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

The growing concerns that the United States is losing its competitive edge on a global stage has created initiatives at the local, state, and national levels aimed at preparing citizens to have the necessary skills required in the 21st century. Chapter 2 provides a systematic review of the literature and research related to student academic achievement and STEM education. The chapter is organized by eight major areas, namely, 1) history of the Texas STEM (T-STEM) program, 2) the theoretical framework, 3) student engagement, 4) changing demographics, 5) teacher effectiveness, 6) student achievement 7) educational funding, and 8) summary. In retrieving the literature for the study, the researcher utilized the following databases and search engines: the Mary and Jeff Bell Library databases at Texas A&M University – Corpus Christi, EBSCO, ERIC, SAGE, Web of Science, Google, and Google Scholar.

Texas Science, Technology, Engineering, and Mathematics (T-STEM)

In an effort to prepare the Texas workforce to have the necessary skills required by employers, the Texas High School Project was developed in 2003 by an alliance among public-private sectors including the Texas Education Agency (TEA), Office of the Governor, Bill and Melinda Gates Foundation (BMGF), Texas Legislature, Michael and Susan Dell Foundation (MSDF), Texas Higher Education Coordinating Board (THECB), Communities Foundation of Texas (CFT), Wallace Foundation, Meadows Foundation, and the Greater Texas Foundation. The alliance provided $375 million in grant funding dedicated to STEM education reform in Texas. The goal of the program was to produce a leading technical workforce in Texas by aligning educational and economic development sectors. Implementation of the program began with the 2006-2007 school year (SRI, 2011). The initial aim of the T-STEM was to improve science and mathematics academic achievement and stimulate student interest in STEM careers. The program was intended to provide students with a rigorous academic curriculum as well as support systems which will nurture student interest in STEM careers.

The T-STEM academies Design Blueprint provides guidelines for the development and implementation of the STEM programs. Many of the programs were implemented as small schools or as a school within a school. The seven benchmarks of the design blueprint include 1) mission-driven leadership, 2) T-STEM culture, 3) student outreach, recruitment and retention, 4) teacher selection, development and retention, 5) curriculum, instruction, and assessment, 6) strategic alliances, and 7) academy advancement and sustainability (Avery et al., 2010).

There are currently 51 Texas STEM (T-STEM) academies throughout the state, comprised of 20 campuses serving grades 9-12 and 31 campuses serving grades 6-12. There are five T-STEM centers associated with universities which are designed to develop innovative curriculum, research-based educational resources for STEM areas, professional development for teachers, and classroom support (Fontenot, Chandler, Talkmitt, & Sullivan, 2007).

Through the use of an engineering design process as an instructional framework, the STEM programs are designed to engage students in rigorous inquiry and project-based learning. Project-based learning is used as a vehicle to allow students to use their knowledge in addressing real world problems through which they learn and apply high content standards as they search for solutions. The approach is designed to help students develop skills which will help them succeed in higher education and the workforce. The STEM programs include the development of problem solving, teamwork, communication, and critical thinking skills. The T-STEM initiative challenges the traditional way of teaching mathematics and science in grades 6-12 by incorporating hands-on applications. The T-STEM programs are serving schools with high populations of students who are economically disadvantaged and are underrepresented in STEM fields (Fontenot et al., 2007).

Theoretical Framework

Bruner's inquiry-based constructivist learning theory is influenced by earlier educational theories developed by Jean Piaget and John Dewey. Constructivism includes concepts such as incorporating the teacher as a guide to learning, allowing children to be led by their natural curiosity and interests, and working cooperatively with others as they construct knowledge. These guidelines are also the cornerstones of project-based learning (Warde & Novak, 1960). Constructivism is based on sociology and centers on evaluating how individuals report their perceptions, beliefs, and world views in a particular setting (Patton, 2002).

Project-based learning (PBL) is a constructivist-based learning approach which is designed to encourage student motivation and promote academic rigor. Students are given projects which include finding solutions to open-ended problems incorporating group work, scaffolding, and multiple subject area integration (Ravitz, 2010). The projects encourage the development and use of skills such as critical thinking, collaboration, and communication as students create and present artifacts demonstrating and explaining what they have learned. Successful PBL instruction requires extensive planning, professional development, tools and strategies for effective instruction, and a supportive environment (Ravitz, 2010).

Discovery learning philosophies are incorporated into project-based learning by encouraging students to employ hands-on activities as they attempt to solve problems with real life applications (Reigle-Crumb, Moore, & Ramos-Wada, 2011). Project-based learning is a student-centered instructional strategy which encourages student collaboration as they work in small groups to answer questions, solve problems, and reflect on their experiences. Employing critical thinking skills, creativity, and a desire to learn more as they discover by doing was described by a panel of teachers as the ultimate educational goal for their students (Reigle-Crumb, et al., 2011). Bicknell-Holmes and Hoffman (2000) described discovery learning as having the following three main attributes: 1) activities which encourage scaffolding new knowledge into existing knowledge for the learner; 2) exploring and problem solving to create, integrate, and generalize the learner’s knowledge; and 3) student driven, interest-based learning activities.

There are five main characteristics identified by Joyce A. Castronova (2002) as differentiating discovery learning from traditional learning models. The first includes active student participation and hands-on learning rather than the transfer of knowledge from teacher to students. The second suggests that by encouraging mastery and application of concepts, the emphasis of learning should be on the process rather than the end product. The third involves the lessons learned from failure as encouragement to continue searching for solutions. The fourth suggests that collaboration and discussions among students allows for a deeper understanding of the subject area. And the fifth characteristic involves satisfying natural human curiosity by student driven, interest-based learning (Castronova, 2002).

Discovery learning, inquiry learning, project-based learning, teaching by problem-solving, and inductive methods are all terms used over a period of 30 years of research, which were categorized together under the umbrella of inquiry learning (The Inquiry Synthesis Project, 2006). While the approaches are varied, the basic components of these strategies include aspects emphasizing student responsibility for learning, student motivation, and student active thinking. Student outcomes of programs of interest, utilizing the framework of inquiry instruction, particularly in science, were tracked as part of numerous studies in an effort to develop inquiry-science-instruction measurement protocols (The Inquiry Synthesis Project, 2006).

Student Engagement

The benefits of inquiry-based learning and student engagement have been of interest to many researchers since John Dewey published his classic works which spanned almost 50 years. The inquiry learning method has been applied in subjects such as science, mathematics, and social studies. A study involving adolescents suggests that problem-based learning for them may be more productive when it incorporates small group collaborative learning (Memory, Yoder, Bolinger, & Warren, 2004). Adolescents were more motivated and engaged in their learning when they were allowed to choose tasks, topics, and investigations to solve a problem they were given. Working in groups allowed the students to share prior knowledge and develop thinking, collaborative, and investigative skills required for more complex PBL tasks (Memory et al., 2004).

The instructional model of problem-based learning (PBL) was developed in medical school programs. Students using PBL are given projects based on real life problems and purposeful learning takes places as the search for solutions to those problems is sought. The instructor serves as a coach as students work in collaborative groups seeking answers to solve assigned problems which are vague by (Goodnough, 2006). The problems which students are given do not have a single right way to reach a solution, and creative responses promote long-term retention of information.

The National Research Council (NRC) established the National Science Education Standards in 1996 (NRC, 1996). In the year 2000, those standards were expanded to include inquiry as an integral part of science instruction and student learning (NRC, 2000). The Principles and Standards for School Mathematics, established by the National Council of Teachers of Mathematics (NCTM), also included inquiry as an essential part of mathematics instruction (NCTM, 2000). Inquiry-based science and mathematics instruction is believed to contribute to greater learning and deeper understanding when students are provided the opportunity to construct knowledge through inquiry and are engaged in their learning. The Learning Cycle is an approach which incorporates inquiry and can be applied to most subjects in order for students to become more engaged in the lessons which are presented (Luera, Killu, & O’Hagan, 2003).

A program implemented in an urban school’s sixth grade class integrating mathematics and science instruction found significant academic achievement differences between students included in the integration program compared to those in a traditional instructional setting (Hill, 2004). Students in the integration program worked in groups as they were asked to solve real world problems which required hands-on applications of mathematics and science knowledge. Improved scores on standardized testing for students in the integration group, including at-risk and special education students, suggested a deeper understanding and knowledge of mathematics was attained by those students (Hill, 2004).

A study by Goodnough (2006) was conducted to investigate students' PBL work in a 9th grade biology class consisting of 39 students. Students were allowed to integrate their own interests with biology in developing the questions, design their information gathering methods, and apply their knowledge of the scientific method in searching for solutions. The majority of the students reported a sense of ownership in their projects and enjoyed working on projects which allowed them to be actively involved in their own learning (Goodnough, 2006).

Inquiry-based learning includes the benefit of greater engagement by students and the disadvantage of requiring additional time and efforts from both students and teachers (Heppner, Kouttab, & Croasdale, 2006). Concerns regarding rigor, student developmental levels, and future goals suggest that inquiry learning must be combined with conventional teaching methods to meet the needs of a greater number of students. Following students' progress through high school and college may provide greater insight into the benefits of inquiry-based learning as students' maturity levels increase (Heppner, Kouttab, & Croasdale, 2006).

Factors which have been identified as affecting student learning and achievement include motivation, attitudes towards learning, attitudes towards a particular subject, and self-concept (Baseya & Francis, 2011). A study conducted to analyze the impact of inquiry-oriented science labs on freshman and sophomore college students at the University of Colorado at Boulder found that student attitudes and excitement level depended on the perceived difficulty of the lab itself. Students preferred a guided instruction style over a project-based learning environment for labs which they perceived as being more difficult. Greater preparation provided through more in-depth pre-lab material for labs which were perceived as difficult were suggested by the authors as positively impacting student attitudes towards project-based learning (Baseya & Francis, 2011).

The creation of small, reform-oriented high schools designed to promote student readiness for skills required for the 21st century has been made possible through private investment and legislative changes. Project-based learning is a key feature of reform models which include cultural and organizational practices to support the effective use of PBL (Ravitz, 2010).

Research in human cognition has demonstrated that active engagement contributes to deeper learning. The *National Science Education Standards* (NSES) established inquiry as a highly effective learning strategy which is useful in learning subjects in addition to science (NSES, 2000). Higher education has incorporated more inquiry-based learning which requires students to develop and apply skills that include analyzing and exploring alternative explanations for results obtained in non-laboratory teamwork settings. Students' individual accountability includes the ability to defend their answers by applying concepts learned and understanding gained through their inquiries (Flory, Ingram, Heidinger, & Tintjer, 2005).

Changing Demographics

Public school data, comparing student demographics since 1993-1994 to 2005-2006, indicated a greater than 55% increase in Hispanic student populations. Data gathered by the Pew Hispanic center for those years indicated a growing proportion of public elementary/secondary school students represented by Black and Hispanic students and a decreasing share of White students. The number of public schools with nearly all minority students increased from 5,498 to 10,135 during the same period, while the number of nearly all-White schools fell from 25,603 to 16,679 (Fry, 2007).   Data provided by The National Center for Education Statistics regarding public school ethnicity information between 1972 and 2007 showed that the percentage of public school students who were White decreased from 78% to 56%. During that same period, the Hispanic student population increased from 6% to 21% and represented the fastest growing group of school-age children (Fusarelli, 2011).

The U.S. Census bureau projected that the Hispanic school age population, ages 5 to 17, would increase 166% by 2050, while the non-Hispanic white school age population, ages 5 to 17, would increase by only 4% during the same time period (Fry & Gonzales, 2008). In 2006, Hispanics represented the largest minority groups in public schools in 22 states. More than half of Hispanic students in public schools were enrolled in schools in Texas and California. Nearly 70% of Hispanic students are of Mexican origin and 84% of all Hispanic students were born in the United States (Fry & Gonzales, 2008).

The majority of African American and Hispanic children live in urban areas which are more likely to have high concentrations of poverty and joblessness (Fusarelli, 2011). The Brookings Institution (2010) identified changes in metropolitan areas as having five realities which are impacting the demographics in such areas including 1) growth and outward expansion of the population, 2) income polarization, 3) uneven higher educational attainment, 4) increasing ethnic diversity, and 5) an aging population. The number of children living in poverty reached 15.6 million in 2010, as the economic challenges faced by the U.S. resulted in increased numbers of parental unemployment (Young & Fusarelli, 2011). The gap in academic attainment in mathematics, reading, and science in the U.S. was influenced by factors such as teacher qualifications, parental education, and father's occupation (Houtenville & Conway, 2008).

The inequality in educational opportunities is expected to widen the achievement gap as income polarization increases. The challenges for public schools are exacerbated as programs targeted to meet the needs of low income children are reduced or eliminated (Young & Fusarelli, 2011). The National Center for Education Statistics defines high-poverty schools as those in which at least 76% of children were eligible for free or reduced lunch. The majority of those schools are located in urban areas: 34% of Blacks and 46% of Hispanics attend high poverty schools compared to only 14% of Whites (Aud, Hassar, Planty, & Snyder, 2010).

Teacher Effectiveness

Student achievement, as a measure of teacher effectiveness, was the basis for research performed by The Brookings Institution. The study found that the weakest teachers tend to be concentrated in the poorest schools. In Los Angeles, for example, schools with 90% of their student population on free or reduced lunch programs were 2.5 times more likely to have teachers who were in the bottom quartile based on teacher evaluations than did schools with less than 10% of students on free or reduced lunch (Gordon, Kane, & Staiger, 2006).

The National Science Foundation reported chronic shortages of qualified teachers who are adequately prepared to effectively teach STEM subjects in K-12. This lack of preparation is particularly evident at the elementary and middle school levels. According to the U.S. Department of Education data from 2002, 51.5% of middle-school mathematics teachers and 40% of middle-school science teachers did not have a major or minor in those subjects (Kuenzi, 2008). The report also noted that, in 2004, White fifth graders were 51% more likely to be taught with teachers with a master's or advanced degrees than did Latino or African American students (Museus, Palmer, Davis, & Maramba, 2011). Minority students in low economic schools were twice as likely to be taught by teachers with three years experience or less, compared with schools with predominantly White student populations (Museus et al., 2011).

Research on teacher quality conducted over a 20 year period revealed that student achievement in mathematics and science is significantly affected in a positive manner when instructors have a major in the subject which they teach (Kuenzi, 2008). High school teachers were more likely to have majored or minored in the subjects which they taught. Only 14.5% of those who taught mathematics and 11.2% of those who taught science in high school did not have a major or minor in those subjects. Students who were taught high school mathematics by higher quality teachers who had more college level mathematics classes achieved at higher academic levels than did the comparison group (Pey-Yan, Liou, Desjardins, & Lawrenz, 2010).

The educational experience for students is impacted to a great extent by the quality and effectiveness of teachers (Nathan, Tran, Atwood, Prevost, and Phelps, 2010). The Engineering Education Beliefs and Expectation Instrument (EEBEI), designed to compare teachers' beliefs and expectations about pre-college engineering instruction and college preparation, was used to examine the beliefs and expectations of Project Lead the Way (PLTW) teachers and non-PLTW teachers. The non-PLTW teachers agreed more strongly that high school academic achievement in mathematics and science was necessary for prospective engineering students. The PLTW teachers were more likely to report that engineering activities should integrate science and mathematics content and academic achievement in high school should not be the only determinant in identifying prospective engineering students (Nathan et al., 2010). Practicing engineers described communications skills, interdisciplinary cooperation, good experimental skills, problem solving, and creativity as skills essential to success in their profession. Contrasting views by teachers help shape the instruction, recruitment, and assessment practices in K-12 classrooms and influence decisions made regarding the potential of students as future engineers (Nathan et al., 2009).

In the fall of 2009, the Bill & Melinda Gates Foundation created the Measures of Effective Teaching (MET) project to gather information on best teaching practices. Information was gathered over two years and included feedback from over 3000 teachers in school districts throughout the nation. The MET project included partnerships with academic institutions such as Harvard University, nonprofit organizations such as the RAND Corporation, educational consultants such as Teachscape, and teacher organizations such as The American Federation of Teachers (Kane & Cantrell, 2009).

The MET project’s goal was to identify effective teaching methods which could be used to help develop more effective teachers. The basis for this project was that in order to improve student achievement, better teaching methods must be identified and taught to current and future teachers (Kane & Cantrell, 2009).

Student Achievement

Identifying students with the potential to be developed into high academic achievers requires training for dealing with those who may otherwise fall through the cracks. The adjectives which were used to describe such children included “gifted,” “talented and motivated,” and “high-ability” students. Spatial and quantitative talents of those who eventually earned doctorates in a STEM field were apparent in elementary school (NSB 10-33, 2010). Developing guidelines to identify a broad pool of students with the ability and interest to pursue a STEM education is necessary for proper development and training at all educational levels (NSB 12-01, 2012).

The disparity between academic achievement of Hispanic and their non-Hispanic white peers has been documented in numerous studies. A large percentage of Hispanic students have parents who did not complete high school or pursue higher education. Students whose parents achieved higher levels of education or valued academic achievement were less pervasive in Hispanic communities (Fry & Gonzales, 2008). Parental involvement and high expectations for their children regarding academic achievement was reflected in higher grades and higher scores on standardized tests. Parental expectations were also linked to student motivation and aspirations for higher education which were communicated in diverse socio-cultural contexts (Houtenville & Conway, 2008).

An ASHE higher education evaluation report (2011) included factors which impacted the success of minority students success in the STEM circuit in kindergarten through grade 12 (K-12). Inadequate levels of academic preparation for college level courses negatively impacted the successful pursuit of STEM careers for many students. The most important predictor of students' ability to complete a STEM baccalaureate degree was found to be the academic intensity of their high school curriculum (Museus et al., 2011). The report identified eight factors in K-12 education which contributed to the inadequate preparation of minority students in STEM subjects as: 1) school district funding disparities, 2) unqualified teachers, 3) underrepresentation in AP courses, 4) low teacher expectations, 5) tracking into remedial courses, 6) oppositional culture, 7) stereotype threat, and 8) premature departure from high school (Museus et al., 2011).

Hispanics graduating from high school are less qualified for admission to a four-year college than their white counterparts. Latinos were also more likely to have lower test scores across subjects and less likely than non-Whites to take advanced coursework (Reigle-Crumb & Callahan, 2009). Using the category of “minimally qualified” for admission to a four-year college, 53% of Hispanic high school graduates, compared to nearly 70% of White high school graduates, were prepared to pursue higher education at a four-year college. Only 19% of Hispanics, compared to 35% of White students, met the criteria for “highly qualified” for pursuing their education at a four-year college (Campbell, Hombo, & Mazzeo, 2000). Data gathered from 1991 to 2002 by the U.S. Department of Education indicated that the student graduation rates of those who graduated from public high schools and college-ready in 2002 were approximately 40% for White students, 23% for African American students, and 20% for Hispanic students.

The study counted only regular graduation rates of students who obtained a high school diploma and excluded those who pursued equivalency tests (Greene & Winters, 2005).

Having friends with higher parental education was found to promote academic achievement of Hispanic students. Relationships with non-Latino White peers were shown to positively promote assimilation and academic achievement. Ties formed with dominant culture students were found to provide students access to families with higher educational and economic attainment which improved students' insight, information, and motivation to succeed in an academic setting (Reigle-Crumb & Callahan, 2009).

According to data gathered by the Bill and Melinda Gates foundation, of the 1.9 million students pursuing higher education, 1.3 million students pursuing STEM careers required remediation courses in order to successfully complete college-level STEM courses (Gammon, 2011). The overall percentage of STEM degrees awarded by U.S. universities has remained at approximately 17% of all postsecondary degrees awarded since the 1980s. The decrease in the number of secondary degrees in mathematics, engineering, and physical sciences has been offset by increases in degrees in biology and computer science (Kuenzi, 2008).

Business degrees were roughly equal in number to STEM degrees awarded at the associate and baccalaureate levels. Nearly twice as many master's degrees were pursued in business and education as compared to those in STEM fields. At the doctoral level, degrees awarded for STEM fields comprised approximately one third of all degrees awarded. Federal funding of STEM education programs primarily support graduate and post-doctoral education (Kuenzi, 2008). As of the mid-2000s, a third of STEM doctoral students were foreign students on temporary visas (NSB 10-33, 2010).

The National Assessment of Educational Progress (NAEP) has been assessing elementary and secondary students from public and private schools at grades 4, 8, and 12. Student achievement levels are divided into basic, proficient, and advanced. In 2005, scores indicated that less than one-third of 4th and 8th grade students scored at or above the proficient level in science. Less than one-fifth of 12th grade students scored at or above the proficient level in science. Those percentages have remained fairly similar to performance measures recorded in 1996 (Kuenzi, 2008).

The results of mathematics test between 1990 and 2005 showed continued improvement in scores of 4th and 8th grade students, but the percentage of students performing at the basic level did not change during that period. Approximately 20% of 4th graders and more than 30% of 8th graders scored below the basic level, and only 33% of 4th and 8th grade students performed at the proficient level in math. The results for 12th grade students showed a decrease in the percent of students scoring at the proficient level but they had a higher percentage scoring at the basic level. The percentage of students scoring at or above the proficient level in math has been declining since 2005 (Kuenzi, 2008).

Educational Funding

The current economic crisis is described as the Great Recession and is considered as the worst financial crisis in the United Stated since the Great Depression (Young & Fusarelli, 2011). Reductions in tax revenues for state and local governments combined with increased in demand for publicly funded services have resulted in large budget gaps in many state budgets. Public education has been negatively impacted by government cutbacks which have led to decreased funds available for personnel costs and academic programs (Young & Fusarelli, 2011). These changes are significant as political decisions concerning school funding compete with social issues concerning an aging population. Elderly Americans are more likely to participate in the voting process and exert greater influence on political decisions involving the distribution of limited financial resources which directly impact public school assets (Fusarelli, 2011).

Local property taxes contribute a significant percentage of public school funding. Low income students are more likely to attend neighborhood schools which receive less funding per pupil than schools located in affluent neighborhoods (Museus et al., 2011). Data from the National Assessment of Educational Progress (NAEP) showed that 3% of White eighth graders are in schools where 75% of the students qualify for free or reduced lunch, 34% of eighth grade Hispanics, and 35% of eighth grade Blacks attend such schools. Schools with more resources, as a result of a higher tax base, are able to afford smaller class sizes, instructional materials, laboratories, and technology which positively contribute to student learning and achievement (Museus et al., 2011).

Federal support for high-ability students in K-12 programs has been minimal. The National Association for Gifted Children (NAGC) conducted a survey in 2008-2009 which received input from 45 states. Of those respondents, only 32 states required school districts to provide services for gifted and talented children. Twelve states did not provide funds to support gifted education. Only five states required professional development for teachers in gifted and talented education. These students are more likely to pursue careers in STEM fields with proper guidance and training at the elementary, middle, and high school levels (NSB 10-33, 2010).

A study designed to examine the perception about the influence of scholarships for STEM teachers who agreed to teach in high need schools was conducted. Survey results based on responses by 304 STEM educators suggested that competitive, prestigious scholarships influenced the decisions of top ranking scholarship recipients to enter the teaching profession and serve in high needs schools. Financial incentives were found to be a necessary component of attracting and retaining high quality STEM majors in teaching (Pey-Yan et al., 2010).

Summary

The global economy depends on knowledgeable workers as technology becomes the driving force behind innovations throughout the world. Power players of past generations are being challenged by countries which were unable to compete in eras such as the U.S. industrial revolution. Investment in human capital is differentiating countries which will be competitive in a knowledge based economy from those who will not.

In order for Americans to enjoy the societal benefits, which were possible in past generations as a result of the exemplary educational system, investment in education must once again become a national priority. The status that America enjoyed as a leading innovator and home to the greatest minds in science, technology, engineering, and mathematics is threatened. The investments being made by other countries in their educators and students are preparing the populations to become the leading innovators in the 21st century. The gains which were made in the 50s and 60s created many benefits to all Americans as generations benefited from the educational investment the U.S. made in mathematics and science. The declining performance by American students must be addressed and corrected in order to prepare future generations to continue the legacy which those generations created. Defending our democracy and lifestyle is tied to the development of future generations of STEM innovators. Improving the performance of all students in mathematics and science must become a national priority for security as well as financial reason

CHAPTER 3

METHOD

Introduction

The primary purpose of the study was to examine the impact of a STEM program on 8th graders' academic achievement in mathematics, science, and reading. The study was guided by the following research questions:

1. What is the impact of the STEM program on mathematics achievement among eighth grade students?
2. What is the impact of the STEM program on science achievement among eighth grade students?
3. What is the impact of the STEM program on reading achievement among eight grade students?

Research Design

The study employed an ex-post facto, causal-comparative design. Ex-post facto, Latin for after the fact, includes retrospective studies in which the researcher attempts to determine the cause, or reasons, for known consequences or results (Meltzoff, 2008). In causal-comparative studies, the researcher does not manipulate the independent variable but attempts to identify relationships which may occur between the independent and dependent variables. The researcher compares groups in which the independent variable is present with at least one group in which the independent variable is not present in an attempt to identify differences among the groups based on the dependent variable(s). The researcher speculates about possible causes or effects for the observed variations in historical data outcomes among the groups (Gall, Gall, & Borg, 2007).

A typical STEM program consists of an increased focus on hands-on and project-based learning which includes group assignments. By involving students in solving real world problems, working in collaborative groups, applying critical thinking skills, and developing real solutions, current research in project-based learning suggests that such learning activities may increase student interest in science, technology, engineering, and mathematics (Fortus, Krajcikb, Dershimer, Marx, & Mamlok-Naamand, 2005). The STEM educational programs also involve the integration of knowledge in other subjects (e.g., English, social studies) as students attempt to solve problems and create new knowledge. This process includes interdisciplinary bridging among discrete disciplines which offer students opportunities to make sense of the world in a holistic manner. Rigorous academic concepts coupled with real-world lessons allow students to gain skills which will enable them to compete in STEM fields in a world economy (Tsupros, Kohler, & Hallinen, 2009).

Teacher professional development, collaborative learning, and partnerships with local businesses provide STEM students with additional resources such as field trips that include hands-on applications of lessons, which are designed to encourage underrepresented or disadvantaged groups to pursue higher education in STEM fields (Kuenzi, 2008).

In the study, there was one independent variable, the STEM program, with two levels: 1) STEM program (characteristic-present group) and 2) non-STEM program (comparison group). The outcome measures were the students’ achievement scores on mathematics, science, and reading. The independent variable was not manipulated by the researcher; thus, no causal inferences were drawn.

Subject Selection

The Middle School was located in a lower socio-economic neighborhood in South Texas. The study was delimited to eighth grade students because 1) such students were required to take the TAKS test in mathematics, science, and reading; 2) national mandatory testing for science was required at the fifth, eighth, and eleventh grade levels; and 3) middle schools in the school district in which the study took place offered sixth, seventh, and eighth grade education. The characteristic-present group consisted of 73 eighth grade students in a STEM academic program. An overwhelming majority of the STEM students chose to be in the program due to personal interest or parental encouragement. Requirements for inclusion in the STEM academic group included the submission of student essays and parental signatures on the application form. A maximum of 100 students per middle school grade level could be part of the STEM program based on the grant guidelines. The comparison group consisted of 103 eighth grade students in a non-STEM academic program. Due to the non-probability nature of sampling, external validity was limited to study participants.

Permission to conduct the study was obtained from the Institutional Review Board at Texas A&M University-Corpus Christi and the school district (Appendix A).

Instrumentation

The state of Texas has changed testing programs in the past several decades. The Texas Assessment of Academic Skills (TAAS) test was used from 1990-2002; it was replaced by the Texas Assessment of Knowledge and Skills (TAKS) in 2003. In the 2011-2012 academic school year, the TAKS was replaced by the State of Texas Assessments of Academic Readiness (STAAR).

The TAKS test was designed to measure student's understanding and knowledge of the Texas Essential Knowledge and Skills (TEKS), which were used as guidelines for the statewide curriculum. For the purposes of the study, the 2011 TAKS objective scores in science, mathematics, and reading were used. The proportion of correct answers was used to measure each objective (TEA, 2010).

The eighth grade TAKS mathematics test had six objectives with a total of 50 items, which tested student knowledge of the mathematics TEKS. The mathematics objectives are listed in Table 1.

Table 1

TAKS 8th Grade Mathematics Objectives

Objective	Number of Items Tested
1. Numbers, Operations, and Quantitative Reasoning	10
2. Patterns, Relationships, and Algebraic Reasoning	10
3. Geometry and Spatial Reasoning	7
4. Concepts and Uses of Measurement	5
5. Probability and Statistics	8
6. Mathematical Processes and Tools	10
Total Number of Items	50

The eighth grade TAKS science test had five objectives with a total of 50 items, which tested student knowledge of science TEKS. The science objectives are listed in Table 2.

Table 2

TAKS 8th Grade Science Objectives

Objective	Number of Items Tested
1. Nature of Science	14
2. Living Systems and the Environment	12
3. Structures and Properties of Matter	6
4. Motion, Forces, and Energy	6
5. Earth and Space Systems	12
Total Number of Items	50

The eighth grade TAKS reading test had four objectives with a total of 48 items, which tested student knowledge of reading TEKS. The reading objectives are listed in Table 3.

Table 3

TAKS 8th Grade Reading Objectives

Objective	Number of Items Tested
1. Basic Understanding	12
2. Applying Knowledge of Literary Elements	10
3. Using Strategies to Analyze	10
4. Applying Critical-Thinking Skills	16
Total Number of Items	48

The writers and reviewers for TAKS tests verified that test questions related to each objective measured the appropriate content and were aligned with the test items they had designed to measure TEKS. Construct validity for TAKS test content was shown by the relationship between the tested content and the construct they were designed to measure (TEA, 2010). For the TAKS tests utilizing multiple-choice items, the Kuder-Richardson Formula 20 (KR20) was used to calculate the reliability estimates. Reliability indices for TAKS assessments ranged from .87 to .90 (TEA, 2010).

Data Collection

The data were obtained from the Texas Education Agency (TEA), which included raw scores for each of the TAKS objectives, as well as data on the selected characteristics of the students (i.e., age, gender, ethnicity, socioeconomic status, and special education status). Permission to use the data for the purpose of the study was obtained from the school district where the Middle School was located (Appendix A).

Data Analysis

Data obtained from the TEA were downloaded into the Statistical Package for the Social Sciences (SPSS). The proportion of the total number of test questions answered correctly to the total number of questions in each reporting category was used to measure student achievement in science, mathematics, and reading. Descriptive statistics were used to summarize and organize the data. A t-test for independent samples (Field, 2009) was performed to compare the characteristic-present and comparison groups on the basis of age. A series of chi-square test of independence was performed to compare the two groups on the basis of gender, ethnicity, socioeconomic status, and special education status (Field, 2009).

A series of multivariate analysis of variance (MANOVA) was performed to assess differences between the STEM and non-STEM groups on the basis of the outcome measures. This multivariate statistical technique is used to analyze data that involve more than one dependent variable at a time (Field, 2009). There is a mathematical expression called a vector, which represents each subject's score on more than one response variable. The mean of the vectors for each group is called a centroid. The MANOVA is used to differentiate among groups with respect to their centroids (Stevens, 2009). For the purpose of post hoc analysis, a series of univariate F-test was performed. Mean difference effect sizes were computed to examine the practical significance of the findings. Specifically, Cohen's d ($\frac{2t}{\sqrt{df}}$) was computed and characterized as .2=small, .5=medium, and .8=large (Cohen, 1988).

Group differences on the basis of age and special education status were statistically significant, and the two variables were correlated with the majority of the outcomes measures; thus, they were considered to be confounding variables. Co-variate analysis was deemed necessary. A series of multivariate analysis of co-variance (MANCOVA) was performed to test group differences on the basis of outcome measures adjusted on the basis of age and special education status (Field, 2009). Observed and adjusted mean scores were reported.

CHAPTER 4

RESULTS

The purpose of the ex post facto causal-comparative study was to compare academic achievement in science, mathematics, and reading objective test scores of eighth grade students in a Science, Technology, Engineering, and Mathematics (STEM) program to the academic achievement in science, mathematics, and reading objective test scores of eighth grade students in a non-STEM program. It was hypothesized that the students in the STEM program would outperform the students in the non-STEM program on the basis of the above-mentioned outcome measures. The study was guided by the following questions:

1. What is the impact of the STEM program on mathematics achievement among eighth grade students?
2. What is the impact of the STEM program on science achievement among eighth grade students?
3. What is the impact of the STEM program on reading achievement among eighth grade students?

The data were obtained from the school district and the Texas Education Agency. The data were coded, entered into a computer, and analyzed by using the Statistical Package for the Social Sciences (SPSS).

Achievement in mathematics, science, and reading was measured by the Texas Assessment of Knowledge and Skills (TAKS); the 2010 – 2011 academic school year data were used. The study was delimited to 8th graders and the non-probability sample consisted of 176 students. The characteristic-present group (n = 73) included eighth grade students who had participated in the STEM academic program and the comparison group (n = 103) included eighth grade students who had not participated in the STEM academic program. The two sample sizes were deemed approximately equal as the largest n divided by the smallest n was less than 1.50 (Stevens, 2009).

A Profile of Subjects

The students in the STEM group ranged in age from 13 to 15 years old; students in the non-STEM group ranged in age from 13 to 16 years old. The STEM group (M = 13.56, SD = .58) was younger than the non-STEM group (M = 13.90, SD = .69), and the difference was statistically significant, $t(174) = 3.44$, $p < .01$. The non-STEM group was almost equally represented by both genders, female (49.50%, n = 51) and male (50.50%, n = 52). The STEM group included more females (56.20%, n = 41) than males (43.80%, n = 32). The group differences were not statistically significant, χ^2 (1, N=176) = .51, p = .47. The majority of the students in the STEM program were Hispanic (90.40%, n = 66), followed by White (5.50%, n = 4), and African American (4.1%, n = 3). The non-STEM group had a similar distribution with Hispanics being the majority (89.30%, n = 92), followed by African American (5.80%, n = 6), and White (4.90%, n = 5). For the purpose of data analysis, ethnicity was recoded into Hispanic or non-Hispanic because there were cells with expected frequency less than five; the differences were not statistically significant, χ^2(1, N = 176) = .01, p = 1.00. The majority of the students in both groups were economically disadvantaged, as determined by eligibility for free or reduced lunch; the group differences were not statistically significant, χ^2 (1, N = 176) = 2.50, p = .11. The difference in the number of special education students in the STEM program (4.10%, n = 3) compared to the non-STEM program (22.30%, n = 23) was statistically significant, χ^2 (1, N = 176) = 9.86, *p* = < .01. Gender, ethnicity, and socio-economic status were not correlated with the outcome measures; thus, they were not considered to be confounding variables. Age and special education status were correlated with the majority of the outcome measures; thus, covariate analysis was deemed necessary. Results are summarized in Table 4.

Table 4

A Profile of Subjects

	STEM Group (n = 73)		Non-STEM Group (n = 103)	
Demographic characteristic	F	%	F	%
Gender[a]				
Male	32	43.80	52	50.50
Female	41	56.20	51	49.50
Ethnicity[b]				
Hispanic	66	90.40	92	89.30
Non-Hispanic	7	9.60	11	10.70
Socio-Economic Status[c]				
Disadvantaged	59	80.80	93	90.30
Not disadvantaged	14	19.20	10	9.70
Special Education Status[d]				
Yes	3	4.10	23	22.30
No	70	95.90	80	77.70
Age[e]	M	SD	M	SD
	13.56	.58	13.90	.69

[a] χ^2 (1, N = 176) = .51, *p* = .47
[b] χ^2 (1, N = 176) = .01, *p* = 1.00
[c] χ^2 (1, N = 176) = 2.50, *p* = .11
[d] χ^2 (1, N = 176) = 8.86, *p* < .01
[e] *t* (174) = 3.44, *p* < .01

Outcome Measures

The three sets of outcome measures included TAKS objective scores on mathematics, science, and reading. Mathematics included six objectives: Objective 1:

Numbers, Operations, and Quantitative Reasoning; Objective 2: Patterns, Relationships, and Algebraic Reasoning; Objective 3: Geometry and Spatial Reasoning; Objective 4: Concepts and Uses of Measurement; Objective 5: Probability and Statistics; Objective 6: Mathematical Processes and Tools. Science consisted of five objectives: Objective 1: Nature of Science; Objective 2: Living Systems and the Environment; Objective 3: Structures and Properties of Matter; Objective 4: Motion, Forces, and Energy; Objective 5: Earth and Space Systems. Reading was defined by four objectives: Objective 1: Basic Understanding; Objective 2: Applying Knowledge of Literary Elements; Objective 3: Using Strategies to Analyze; Objective 4: Applying Critical-Thinking Skills.

Mathematics Achievement

Achievement in mathematics was measured by the proportion of correct answers to questions in each of the six objectives. The means and standard deviations are summarized in Table 5.

Table 5

Mathematics Achievement

	STEM Group (n = 73)		Non-STEM Group (n = 103)	
Mathematics Objectives	M*	SD	M*	SD
Objective 1	.68	.17	.60	.22
Objective 2	.67	.20	.51	.23
Objective 3	.70	.21	.59	.23
Objective 4	.47	.26	.42	.25
Objective 5	.68	.17	.60	.21
Objective 6	.67	.21	.55	.21

*Proportion of correct answers

Note: Objective 1: Numbers, Operations, and Quantitative Reasoning
Objective 2: Patterns, Relationships, and Algebraic Reasoning
Objective 3: Geometry and Spatial Reasoning
Objective 4: Concepts and Uses of Measurement
Objective 5: Probability and Statistics
Objective 6: Mathematical Processes and Tools

As can be seen in Table 6, the objective test scores were correlated with each other; thus multivariate analysis of variance (MANOVA) was used to compare the STEM and non-STEM groups on the basis of the group centroids.

Table 6

Correlation Matrix for Mathematics Objective Scores

Factor	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6
Obj1	1.00					
Obj2	.54*	1.00				
Obj3	.38*	.56*	1.00			
Obj4	.31*	.51*	.48*	1.00		
Obj5	.40*	.52*	.46*	.49*	1.00	
Obj6	.46*	.57*	.50*	.41*	.46*	1.00

* $p < .01$

Note: Obj 1: Numbers, Operations, and Quantitative Reasoning
Obj 2: Patterns, Relationships, and Algebraic Reasoning
Obj 3: Geometry and Spatial Reasoning
Obj 4: Concepts and Uses of Measurement
Obj 5: Probability and Statistics
Obj 6: Mathematical Processes and Tools

The MANOVA showed that group differences on the basis of the centroids were statistically significant, $F(6, 169) = 4.61$, $p < .01$. A post hoc analysis showed that with the exception of Objective 4: Concepts and Uses of Measurement, all group differences were statistically significant, favoring the STEM group. In order to examine the practical significance of the findings, mean difference effect sizes were computed. As can be seen in Table 7, effect sizes ranged from .19 to .73. The lowest effect size belonged to the objective which did not differentiate between the two groups statistically.

Table 7

Mean Difference Effect Sizes – Mathematics Achievement

Objective	Mean Difference	*p*	Effect Size*
Objective 1	.09	<.01	.42
Objective 2	.16	<.01	.73
Objective 3	.10	<.01	.46
Objective 4	.05	.21	.19
Objective 5	.08	<.01	.39
Objective 6	.12	<.01	.57

*Effect size, .2 = small, .5 = medium, .8 = large

Note: Objective 1: Numbers, Operations, and Quantitative Reasoning
Objective 2: Patterns, Relationships, and Algebraic Reasoning
Objective 3: Geometry and Spatial Reasoning
Objective 4: Concepts and Uses of Measurement
Objective 5: Probability and Statistics
Objective 6: Mathematical Processes and Tools

Science Achievement

Achievement in science was measured by the proportion of correct answers to questions in each of the five objectives. The means and standard deviations are summarized in Table 8.

Table 8

Science Achievement

	STEM Group (n = 73)		non-STEM Group (n = 103)	
Science Objectives	M*	SD	M*	SD
Objective 1	.79	.15	.63	.20
Objective 2	.74	.18	.60	.21
Objective 3	.60	.25	.57	.24
Objective 4	.64	.22	.54	.22
Objective 5	.69	.20	.56	.22

*Proportion of correct answers

Note: Objective 1: Nature of Science
Objective 2: Living Systems and the Environment
Objective 3: Structures and Properties of Matter
Objective 4: Motion, Forces, and Energy
Objective 5: Earth and Space Systems

The objective test scores were correlated with each other (Table 9); thus, MANOVA was used to compare the STEM and non-STEM groups on the basis of the group centroids.

Table 9

Correlation Matrix for Science Scores

Factor	Obj1	Obj2	Obj3	Obj4	Obj5
Obj1	1.00				
Obj2	.64*	1.00			
Obj3	.46*	.43*	1.00		
Obj4	.52*	.54*	.47*	1.00	
Obj5	.66*	.65*	.50*	.61*	1.00

* $p < .01$

Note: Objective 1: Nature of Science
Objective 2: Living Systems and the Environment
Objective 3: Structures and Properties of Matter
Objective 4: Motion, Forces, and Energy
Objective 5: Earth and Space Systems

The MANOVA showed that the group differences on the basis of the centroids were statistically significant, $F(5, 170) = 8.36$, $p < .01$, favoring the STEM group. A post hoc analysis showed that with the exception of Objective 3: Structures and Properties of Matter, all group differences were statistically significant in favor of the STEM group. Mean difference effect sizes were computed to examine the practical significance of the findings. As can be seen in Table 10, effect sizes ranged from .16 to .90. Objective 3 showed the smallest effect size.

Table 10

Mean Difference Effect Sizes – Science Achievement

Objective	Mean Difference	p	Effect Size*
Objective 1	.16	<.01	.90
Objective 2	.14	<.01	.68
Objective 3	.04	.30	.16
Objective 4	.09	<.01	.43
Objective 5	.14	<.01	.65

*Effect size, .2 = small, .5 = medium, .8 = large

Note: Objective 1: Nature of Science
Objective 2: Living Systems and the Environment
Objective 3: Structures and Properties of Matter
Objective 4: Motion, Forces, and Energy
Objective 5: Earth and Space Systems

Reading Achievement

Achievement in reading was measured by the proportion of correct answers to questions in each of the four objectives. The means and standard deviations are summarized in Table 11.

Table 11

Reading Achievement

	STEM Group (n = 73)		non-STEM Group (n = 103)	
Reading Objectives	M*	SD	M*	SD
Objective 1	.90	.10	.80	.19
Objective 2	.88	.12	.79	.18
Objective 3	.90	.12	.77	.20
Objective 4	.87	.12	.76	.20

*Proportion of correct answers

Note: Objective 1: Basic Understanding
Objective 2: Applying Knowledge of Literary Elements
Objective 3: Using Strategies to Analyze
Objective 4: Applying Critical-Thinking Skills

As can be seen in Table 12, the objective test scores were correlated with each other and MANOVA was used to compare the STEM and non-STEM groups on the basis of the group centroids.

Table 12

Correlation Matrix for Reading Scores

Factor	Obj1	Obj2	Obj3	Obj4
Obj1	1.00			
Obj2	.60*	1.00		
Obj3	.74*	.61*	1.00	
Obj4	.68*	.60*	.72*	1.00

* *p* < .01

Note: Objective 1: Basic Understanding
Objective 2: Applying Knowledge of Literary Elements
Objective 3: Using Strategies to Analyze
Objective 4: Applying Critical-Thinking Skills

The MANOVA showed that the group differences on the basis of the centroids were statistically significant**,** $F(4, 171) = 6.42$, $p < .01$**.** All group comparisons were statistically significant, favoring the STEM group, based on a post hoc analysis. In order to examine the practical significance of the findings, mean difference effect sizes were computed. As can be seen in Table 13, effect sizes ranged from .59 to .74.

Table 13

Mean Difference Effect Sizes – Reading Achievement

Objective	Mean Difference	*p*	Effect Size*
Objective 1	.10	<.01	.63
Objective 2	.09	<.01	.59
Objective 3	.13	<.01	.74
Objective 4	.11	<.01	.63

*Effect size, .2 = small, .5 = medium, .8 = large

Note: Objective 1: Basic Understanding
Objective 2: Applying Knowledge of Literary Elements
Objective 3: Using Strategies to Analyze
Objective 4: Applying Critical-Thinking Skills

Covariate Analysis

As reported earlier, differences between the STEM and non-STEM groups on the basis of age and special education status were statistically significant. The majority of the bivariate associations between individual objectives scores and these two variables were statistically significant (Table 14).

Table 14

Bivariate Correlations Between Outcome Measures and Covariates

Objective	Age	Sp Ed Status
Math Objective 1	-.17*	-.39***
Math Objective 2	-.17*	-.28***
Math Objective 3	-.08	-.22**
Math Objective 4	-.08	-.10
Math Objective 5	-.18*	-.18*
Math Objective 6	-.21**	-.25**
Science Objective 1	-.27***	-.24**
Science Objective 2	-.15*	-.11**
Science Objective 3	-.05	-.15*
Science Objective 4	-.12	-.10
Science Objective 5	-.13	-.26***
Reading Objective 1	-.29***	-.36***
Reading Objective 2	-.20**	-.45***
Reading Objective 3	-.26**	-.40***
Reading Objective 4	-.23**	-.40***

* $p < .05$, ** $p < .01$, *** $p < .001$

Math Objective 1: Numbers, Operations, and Quantitative Reasoning
Math Objective 2: Patterns, Relationships, and Algebraic Reasoning
Math Objective 3: Geometry and Spatial Reasoning
Math Objective 4: Concepts and Uses of Measurement
Math Objective 5: Probability and Statistics
Math Objective 6: Mathematical Processes and Tools
Science Objective 1: Nature of Science
Science Objective 2: Living Systems and the Environment
Science Objective 3: Structures and Properties of Matter
Science Objective 4: Motion, Forces, and Energy
Science Objective 5: Earth and Space Systems
Reading Objective 1: Basic Understanding
Reading Objective 2: Applying Knowledge of Literary Elements
Reading Objective 3: Using Strategies to Analyze
Reading Objective 4: Applying Critical-Thinking Skills

Age and special education status were treated as covariates and a series of Multivariate Analysis of Co-variate (MANCOVA) was performed to compare the two groups on the basis of the centroids adjusted for the two confounding variables. The observed and adjusted means for mathematics, science, and reading objectives are reported in Table 15

Table 15

Observed and Adjusted Mean Scores for all Objectives

	STEM Group (n = 73)		Non-STEM Group (n = 103)	
Objectives	Observed Mean*	Adjusted Mean*	Observed Mean*	Adjusted Mean*
Math Objective 1	.68	.66	.60	.62
Math Objective 2	.67	.65	.51	.52
Math Objective 3	.70	.69	.59	.60
Math Objective 4	.47	.47	.42	.43
Math Objective 5	.68	.67	.60	.61
Math Objective 6	.67	.65	.55	.57
Science Objective 1	.79	.78	.63	.64
Science Objective 2	.74	.74	.60	.61
Science Objective 3	.60	.60	.57	.58
Science Objective 4	.64	.63	.54	.55
Science Objective 5	.69	.68	.56	.57
Reading Objective 1	.90	.88	.80	.82
Reading Objective 2	.88	.86	.79	.81
Reading Objective 3	.90	.88	.77	.79
Reading Objective 4	.87	.85	.76	.78

*Proportion of correct answers

Math Objective 1: Numbers, Operations, and Quantitative Reasoning, Math Objective 2: Patterns, Relationships, and Algebraic Reasoning, Math Objective 3: Geometry and Spatial Reasoning, Math Objective 4: Concepts and Uses of Measurement, Math Objective 5: Probability and Statistics, Math Objective 6: Mathematical Processes and Tools

Science Objective 1: Nature of Science, Science Objective 2: Living Systems and the Environment, Science Objective 3: Structures and Properties of Matter, Science Objective 4: Motion, Forces, and Energy, Science Objective 5: Earth and Space Systems

Reading Objective 1: Basic Understanding, Reading Objective 2: Applying Knowledge of Literary Elements, Reading Objective 3: Using Strategies to Analyze, Reading Objective 4: Applying Critical-Thinking Skills

With respect to achievement in mathematics, MANCOVA showed that group differences remained statistically significant, favoring the STEM group, $F(6, 167) = 2.94$, $p < .01$. As reported earlier, post hoc analysis for MANOVA had shown that with the exception of Objective 4: Concepts and Uses of Measurement, all group differences were statistically significant. The post hoc analysis for MANCOVA showed that in addition to Objective 4, group differences on the basis of adjusted scores for Objective 1: Numbers, Operations, and Quantitative Reasoning and Objective 5: Probability and Statistics were not statistically significant. With respect to achievement in science, MANCOVA showed that group differences remained statistically significant, favoring the STEM group, $F(5, 168) = 5.96$, $p < .01$, and the post hoc results were the same as those obtained by MANOVA. With respect to achievement in reading, MANCOVA showed that group differences remained statistically significant, favoring the STEM group, $F(4, 169) = 3.07$, $p < .05$, and the post hoc results were the same as those obtained by MANOVA.

Summary

It was hypothesized that the eighth grade students in the STEM program would outperform the eighth grade students in the non-STEM program on the basis of academic achievement in mathematics, science, and reading, as measured by the Texas Assessment of Knowledge and Skills (TAKS) 2010 – 2011 academic school year data. Multivariate and univariate analysis of the data showed that the STEM group performed at a higher achievement level on the majority of the tested objectives than did the non-STEM program on the basis of observed and adjusted scores for the outcome measures.

With respect to achievement in mathematics, the STEM group outperformed the non-STEM group on the basis of observed and adjusted test scores for Objective 2:

Patterns, Relationships, and Algebraic Reasoning, Objective 3: Geometry and Spatial Reasoning, and Objective 6: Mathematical Processes and Tools. The observed and adjusted test scores for Objective 4: Concepts and Uses of Measurement showed no statistically significant group differences. Although group differences on the basis of observed test scores for Objective 1: Numbers, Operations, and Quantitative Reasoning and Objective 5: Probability and Statistics were statistically significant, adjusted test scores showed no statistically significant differences.

With respect to achievement in science, the STEM group outperformed the non-STEM group on the basis of observed and adjusted test scores for Objective 1: Nature of Science, Objective 2: Living Systems and the Environment, Objective 4: Motion, Forces, and Energy, and Objective 5: Earth and Space Systems. Objective 3: Structures and Properties of Matter showed no statistically significant differences between the two groups on the basis of either the observed or the adjusted test scores.

With respect to achievement in reading, the STEM group outperformed the non-STEM group on the basis of all observed and adjusted test scores for all objectives. The objectives were Objective 1: Basic Understanding, Objective 2: Applying Knowledge of Literary Elements, Objective 3: Using Strategies to Analyze, and Objective 4: Applying Critical-Thinking Skills.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND DISCUSSION

Introduction

"A world-class education is the single most important factor in determining not just whether our kids can compete for the best jobs but whether America can out-compete countries around the world. America's business leaders understand that when it comes to education, we need to up our game. That's why we're working together to put an outstanding education within reach for every child."

-President Barack Obama, July 18, 2011

Prior to the 1940s, access to higher education was limited to affluent or academically gifted students (Cohen & Kisker, 2010). The American G.I. Bill and the launch of Sputnik by the Soviet Union were the impetus for identifying and educating the most intellectually gifted Americans from all walks of life through investments in science, technology, engineering, and mathematics (STEM) education. These investments in education led to innovations which made scientific innovation synonymous with the United States (NSB 07-114, 2007).

The great economic gains made in the United States from the early 1940s through the 1970s have been attributed to educational gains in STEM fields, which contributed to the creation of a middle class through American innovations impacting societal changes (Young & Fusarelli, 2011).

Investment in education decreased significantly by the early 1980s, as America experienced a double-dip recession. Current economic indicators suggest America is experiencing the greatest economic downturn since the Great Depression based on the duration and recovery rates of prior economic downturns (Young & Fusarelli, 2011). The U.S. policies and world events have led to the current recession, with a slow recovery beginning in late 2009, which has contributed to significant changes in educational funding (Young & Fusarelli, 2011). Residential segregation by income has resulted in greater disparity between public resources, such as schools and teachers, available to affluent residential areas as compared to low and middle-income residential areas (Reardon & Bischoff, 2011).

The gap between the affluent and the poor in the U.S. has widened and the middle class is threatened as access to higher education, which President Lyndon Johnson referred to as the great equalizer, becomes more expensive (Young & Fusarelli, 2012). Technological advances and demographic changes, which have occurred at an accelerated rate since the 1980s, are currently challenging America's dominance in STEM fields (Aud et al., 2012).

President Barak Obama described the American dream as defined by the dreams of a strong middle class during campaign speeches throughout the summer of 2012. As part of his speech in Pittsburg, Pennsylvania, the President described higher education as an economic necessity rather than a luxury (The White House, 2012).

The decrease in academic achievement of U.S. students, particularly among minority students, as measured by test scores on the Trends in International Mathematics and Science Study (TIMSS) and standardized tests, has been a cause of great concern. Measures such as NCLB, which was passed in 2001 and reauthorized in 2007, have been used to assess student achievement and hold states, school districts, and individual schools accountable for their results. In this study, it was hypothesized that the STEM program was effective in increasing student achievement on mathematics, science, and reading. The research questions guiding the study were:

1. What is the impact of the STEM program on mathematics achievement among eighth grade students?
2. What is the impact of the STEM program on science achievement among eighth grade students?
3. What is the impact of the STEM program on reading achievement among eighth grade students?

Summary of Results

The characteristic-present group consisted of 73 eighth grade students in a STEM academic program. The comparison group consisted of 103 eighth grade students in a non-STEM academic program. Analysis of quantitative data revealed that there were statistically significant differences between eighth grade students in a STEM academic program and eighth grade students in a non-STEM academic program in mathematics, science, and reading academic achievement, favoring the STEM sample.

The STEM group (M = 13.56, SD = .58) was slightly younger than the non-STEM group (M = 13.90, SD = .69). The non-STEM group was almost equally represented by both genders, female (49.50%, n = 51) and male (50.50%, n = 52). The STEM group included more females (56.20%, n = 41) than males (43.80%, n = 32). The majority of the students in the STEM program were Hispanic (90.40%, n = 66), followed by white (5.50%, n = 4), and African American (4.1%, n = 3). The non-STEM group had a similar distribution with Hispanics being the majority (89.30%, n = 92), followed by African American (5.80%, n = 6), and White (4.90%, n = 5).

Achievement in mathematics was measured by the proportion of correct answers to questions in each of the six objectives. A Multivariate Analysis of Variance (MANOVA) showed that group differences on the basis of the centroids were statistically significant, $F(6, 169) = 4.61$, $p < .01$. A post hoc analysis showed that with the exception of Objective 4: Concepts and Uses of Measurement, all group differences were statistically significant, favoring the STEM group.

Achievement in science was measured by the proportion of correct answers to questions in each of the five objectives. The MANOVA showed that the group differences on the basis of the centroids were statistically significant, $F(5, 170) = 8.36$, $p < .01$, favoring the STEM group. A post hoc analysis showed that with the exception of Objective 3: Structures and Properties of Matter, all group differences were statistically significant in favor of the STEM group.

Achievement in reading was measured by the proportion of correct answers to questions in each of the four objectives. The MANOVA showed that the group differences on the basis of the centroids were statistically significant, $F(4, 171) = 6.42$, $p < .01$. All group comparisons were statistically significant, favoring the STEM group.

In short, 1) the STEM group outperformed the non-STEM group on all mathematics objectives with the exception of the concepts and uses of measurement objective; 2) with the exception of the structures and properties of matter objective, the STEM group outperformed the non-STEM group in all science objectives; and 3) the STEM group outperformed the non-STEM group in all four reading objectives.

Conclusions

The reader is cautioned that due to the non-experimental nature of the study, no causal inferences may be drawn. Based on the results, the study's hypothesis was found tenable. It was concluded that participation in a STEM academic program positively impacted eighth grade students' academic achievement in mathematics, science, and reading.

Discussion

National and state efforts to improve student academic achievement have incorporated various approaches. The purpose of NCLB was to increase the academic achievement of all children and included negative financial consequences to schools and districts which did not meet expectations. Grants providing funding for educational programs such as STEM became available as efforts to identify approaches which could positively impact student achievement intensified.

The use of project-based and hands-on learning, which is prevalent in STEM programs, requires significant investments of time and training for both educators and students. Improving academic achievement is critical for the nation as a whole, and federal funding is tied directly to attainment of acceptable academic achievement levels. Many research studies to validate STEM programs and their effectiveness have focused on high school or higher education programs. The study was conducted because there was a need to evaluate the effectiveness of a STEM program at a middle school level on student achievement on standardized assessments.

Traditional training methods and the NCLB have come under greater scrutiny as it becomes apparent that the academic achievement of most students will not meet federal expectations. The main mandate of the NCLB, signed into law by former president George W. Bush in 2002, stipulated that 100% of elementary and secondary students would be proficient in mathematics and reading by 2014. In 2011, Secretary of Education, Arne Duncan, projected that more than 80% of schools would be unable to achieve 100% proficiency and would risk losing federal funding as a result. Mr. Duncan speculated that many states would have a 90% failure rate based on NCLB testing standards (Berry & Herrington, 2011).

Many states have submitted waivers for opting out of the NCLB and political pressure is mounting to find new ways to hold states accountable for student achievement. Some of the requirements of waivers include measuring accountability standards by showing improvement in test scores by comparing year-to-year to show improvement. Other measures of accountability emphasize college and career readiness standards instead of the proficiency standards established through NCLB (Berry & Herrington, 2011). Teacher preparation and performance standards tied to student academic achievement are being carefully analyzed by many districts.

Technology has made monitoring and comparing student achievement between countries, states, and individual districts possible in a timely basis. Reports such as *The Condition of Education* use indicators including school characteristics, climate, finance, assessments, student efforts, and persistence to measure student progress in the United States of America (Aud et al., 2012). School administrators, teachers, financial resources, and student assessments are used to evaluate progress through the education system. Indicators of student achievement based on performance on assessments in mathematics, reading, science, and other academic subject areas are used to examine the context of learning in U.S. schools (Aud et al., 2012).

Finding ways to improve student achievement via programs such as STEM may impact state and school district funding in numerous ways. In addition to funding issues for the schools, the ability to provide an educated workforce is a key indicator in attracting business investment in specific areas. Having an educated workforce includes a higher tax base to fund further educational investment (Reardon & Bischoff, 2011).

Many states are attempting to identify ways to encourage institutions of higher learning to encourage degrees in STEM fields. For example, California's attempt to identify the best and the brightest is reflected in the California State Summer School for Mathematics and Science program (COSMOS), which began in 1998, and is currently offered at four University of California campuses in Irvine, San Diego, Davis, and Santa Cruz. The COSMOS is a summer program that attempts to identify and recruit highly talented and motivated students within the state and expose them to STEM activities to further their interests and skills in such fields. The students participate in hands-on labs and field activities in addition to working on a research project and attending lectures and discussions. The students work in groups, referred to as clusters, which vary from 18 to 24 students. The students attend courses taught by University of California faculty and researchers with a typical staff to student ratio of 5:1. The Students can participate only once due to the high demand for this program and financial assistance is available for students who are unable to pay for the program (Goldstein, 2008).

The Texas Higher Education Agency is considering changing its funding model to include merit-based funding linked to graduation rates and awarded degrees. The number of degrees awarded in STEM fields and teachers in those subjects could impact 10% of undergraduate funding. In a period of decreased funding in education, Texas is attempting to increase funding linked to a business model based on outcomes that are needed to fulfill the STEM skills demands of businesses (Meyers, 2012).

The STEM careers offering higher paying job opportunities attract an educated workforce, which will support other businesses to meet the societal needs of communities (Reardon & Bischoff, 2011). Encouraging students' interest in these careers at the middle school level is facilitated through STEM programs which helps them develop skills which are critical for success in such fields (Reardon & Bischoff, 2011).

The goal of the study was to provide evidence that participation in a STEM academic program positively impacts student achievement on state assessments in mathematics, science, and reading. Reading was included in the study because it is shown that it impacts student achievement in other content areas, particularly science and mathematics. Poor performance in reading has been linked to lower academic progress in school (Perie, Grigg, & Donahue, 2005). Part of the process of understanding and learning to think mathematically is related to read mathematically, particularly understanding reading passages in textbooks and standardized tests (Schoenfeld, 2008). Science knowledge and reading skills were found to be significant predictors of science achievement scores (O'Reilly & McNamara, 2007).

The study's STEM group participated in grant-funded field trips that included cooperative learning as students experienced hands-on applications of scientific and mathematics knowledge gained in the classroom. For example, trips dedicated to the acquisition, classification, and analysis of oceanic samples, as well as applying scientific methods standards. Group learning, a greater number of hands-on experiments in the classroom, interdisciplinary assignments (science and mathematics), and project-based learning activities allow for a deeper understanding of science and mathematics concepts for the STEM students. Many higher education engineering and science programs require cooperative learning and project-based learning as part of their curriculum (Smith, Sheppard, Johnson, & Johnson, 2005).

Challenging students to apply mathematics skills in group projects and competitions is an integral part of STEM mathematics classes. Sandra S. Snyder, in her study entitled, *Cooperative Learning Groups in the Middle School Mathematics Classroom,* found that problem-solving and communication skills improve significantly with the inclusion of cooperative learning groups. Her research found that cooperative learning affected students' attitudes toward mathematics and improved their oral and written communication skills (Snyder, 2006). Students who participate in cooperative learning acquire skills which will serve them well in higher education and as they enter the workforce, particularly in STEM fields (Smith et al., 2005). The results of the study demonstrated that the STEM students outperformed the non-STEM students in all mathematics objectives with the exception of Objective 4: Concepts and Uses of Measurement. Students in both groups had low achievement scores in Objective 4; the STEM group had a mean score of .47, while the non-STEM group had a mean score of .42. Could this suggest that "Concepts and Uses of Measurement" were not adequately taught in either the STEM or the non-STEM classes? If so, contributing factors may include teacher preparation, students' lack of comfort with metric units of measurement used in testing mathematics and science, length of exposure, and practice with concepts and usages of measurement.

The STEM students outperformed the non-STEM students in all science objectives with the exception of Objective 3: Structures and Properties of Matter. The students in the STEM group had a mean score of .60, while the students in the non-STEM group had a mean score of .57, and the effect size was small, .16. This objective includes concepts that require abstract thinking. Developmental studies suggest that abstract terms and thinking are not mastered until adolescence. While there is a significant gain in abstract thinking for children by age 12, repeated exposure is required by most students in order to understand such concepts (Caramelli, Setti, & Maurizzi, 2004). Repeated exposure to this objective's concepts would be beneficial to all students.

The largest effect size, .90, was found in Objective 1: Nature of Science. The STEM group had a mean score of .79, while the non-STEM group had a mean score of .63. The large effect size is reflected in the large difference in achievement between the two groups for this objective. The hands-on activities, cooperative learning, and project-based learning, which the STEM students were exposed to, may have contributed to their greater understanding of the nature of science.

With respect to reading objectives, all group comparisons were statistically significant, favoring the STEM group. The ability to read and analyze questions is critical to student's academic achievement. The smallest effect size, .59, was for Objective 2: Applying Knowledge of Literary Elements. The STEM group had a mean score of .88, while the non-STEM group had a mean score of .79. The largest effect size, .74, was for Objective 3: Using Strategies to Analyze. The STEM group had a mean score of .90, while the non-STEM group had a mean score of .77. The non-STEM group had a higher number of special education students who might have been unable to read at an eighth grade level. The STEM students were exposed to more activities requiring analysis and interpretation of data than did the non-STEM group which might have contributed to their higher Objective 3 scores.

The MANOVA and MANCOVA results were similar with two exceptions. After adjusting the mathematics achievement scores on the basis of age and education, in addition to Objective 4: Concepts and Uses of Measurement, differences between the STEM and non-STEM groups on the basis of Objective 1: Numbers, Operations, and Quantitative Reasoning and Objective 5: Probability and Statistics were not statistically significant. The lack of statistical significance could have been due to similar difficulties encountered by both groups in applying higher level mathematics concepts to questions addressing these objectives. The ability to successfully apply quantitative reasoning and problem-solving techniques involving probability and statistics requires repeated exposure and practice for many students. Research by Lisa Kasmer and Ok-Kyeong Kim has shown that prediction has the potential to enhance mathematics understanding and reasoning in a middle school context. Students who were exposed to prediction questions on a daily basis were found to have improved mathematical understanding and reasoning skills (Kasmer & Kim, 2011). Exposing eighth grade students to prediction questions on a consistent basis would be beneficial for both groups.

Implications

The jobs of the future, which will allow the middle class and all Americans to prosper, are concentrated in fields that involve STEM skills. According to the U.S.

Bureau of National Statistics, STEM fields provided occupations which allowed workers to earn about 70% more than the national average in 2005 (Terrell, 2007). In May 2009, data from the Occupational Employment Statistics program showed that only 4 out of the 97 STEM occupations had mean wages below the U.S. average. The average annual wage for all STEM occupations based was $77,880, compared to the U.S. average of $43,460 (Cower, Jones, & Watson, 2011). American students who are unprepared to meet the criteria required for STEM occupations will be unable to compete for those high-paying jobs at home and abroad.

Finding ways to increase student achievement to meet the educational requirements of STEM careers is crucial for continuing America’s standing as a leader in such fields. Programs which increase interest in STEM courses in middle school, including project-based and hands-on learning, influence the recruitment and retention of students in high-level science and mathematics courses in high school. High school graduates who participate in rigorous college preparatory courses are more likely to succeed in completing STEM coursework in higher education (Stein & Matthews, 2009). If American students are unprepared to meet the demands of employers providing STEM careers, highly qualified applicants from other countries will be ready to fill the void.

Approximately 90% of the students included in the study were Hispanic, and there were no significant gender gaps in either the STEM or the non-STEM group. In the United States, African-Americans, Hispanics, and women are seriously underrepresented in STEM fields. Participation in high growth, high wage positions projected for future jobs require STEM skills and training which must be encouraged, particularly among minority groups, in order for the U.S. to meet employer needs with local labor forces.

Recommendations for Further Research

Incorporating a qualitative component into future research studies may provide teacher and student perspectives regarding the pros and cons of participating in a STEM program. Identifying successful teaching techniques could provide information regarding characteristics of highly successful teachers. Student perspectives could provide insight into what motivates and challenges them in an academic setting. Decreased state and federal funding increases the benefit of obtaining grant funding such as those offered for STEM curriculum and related staff. A longitudinal study to track progress of students who participated in a STEM academic program in middle school through high school and higher education programs could provide valuable feedback for obtaining grant funding. Including an analysis of STEM graduates and the number of remedial courses they required may provide useful information for curriculum development at secondary and higher education levels.

Identifying and developing techniques which improve academic achievement, especially among Hispanic students, could provide useful information. Determining how programs, such as STEM, which engage students through hands-on learning may improve academic achievement among students with deficient reading skills may lead to curriculum changes. Qualitative research investigating cultural beliefs and value systems among Hispanics may provide insight into why STEM fields attract such limited numbers of Latino students.

Characteristics of highly effective PBL teachers could be identified through studies in order to create guidelines for teacher development, particularly for those dealing with minority and at-risk students. Effective STEM programs employ PBL techniques which must be mastered by teachers in order to maximize student learning opportunities. Districts must capitalize on grant funding available for research and training involving PBL strategies aimed at improving academic achievement and developing STEM skills among all students. Research investigating how non-traditional teaching strategies such as PBL impact minorities can provide justification for the investment of time and resources required to successfully implement programs to prepare students for success in a knowledge-based economy.

REFERENCES

Aud, S., Hussar, W., Johnson, F., Kena, G., Roth, E., Manning, E., Wang, X., & Zhang, J. (2012). *The Condition of Education 2012.* (NCES 2012-045). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Aud, S., Hussar, W., Planty, M, & Snyder, T. (2010). *The Condition of Education 2010.* (NCES 2010-028). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Avery, S., Chambliss, D., Truiett, R., & Stotts, J. L. (2010). Texas Science, Technology, Engineering, and Mathematics Academies (pp. 1-40): Texas High School Project: Austin, TX.

Baseya, J. M., & Francis, C. D. (2011). Design of inquiry-oriented science labs: Impacts on students' attitudes. *Research in Science & Technological Education, 29*(3), 241-255.

Berry, K. S., & Herrington, C. D. (2011). States and their struggles with NCLB: Does the Obama blueprint get it right? *Peabody Journal of Education, 86*(3), 272-290.

Bicknell-Holmes, T., & Hoffman, P. S. (2000). Elicit, engage, experience, and explore: Discovery learning in library instruction. *Reference Services Review, 28*(4), 313-322.

Brookings Institution. (2010). *State of metropolitan America on the front lines of demographic transformation.* Washington, DC: The Brookings Institution Metropolitan Policy Program.

Bruner, J. (1963). *The Process of Education*. Cambridge, MA: Harvard University Press.

Campbell, J. R., Hombo, C. M., & Mazzeo, J. (2000). *NAEP 1999 trends in academic progress: Three decades of student performance.* (NCES 2000-469). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Caramelli, N., Setti, A., & Maurizzi, D. D. (2004). Concrete and abstract concepts in school age children. *Psychology of Language and Communication, 8*(2), 17-32.

Castronova, J. (2002). Discovery learning for the 21st century: What is it and how does it compare to traditional learning effectiveness in the 21st century? *Action Research Exchange, 1*(1). Valdosta, GA: Valdosta State University, Department of Curriculum & Instructional Technology.

Cohen, J. (1988). *Statistical power analysis for the social sciences*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohen, A. M., & Kisker, C. B. (2010). *The shaping of American higher education: Emergence and growth of the contemporary system.* San Francisco, CA: Jossey-Bass.

Cower, B., Jones, J. I., & Watson, A. (2011, May). Science, technology, engineering, and mathematics (STEM) occupations: A visual essay. *Monthly Labor Review,* 3-15.

Museus, S., Palmer, R., Davis, R., & Maramba, D. (2011). Racial and ethnic minority success in STEM education. *ASHE Higher Education Report, 36*(6), 27-52.

Field, A. (2009). *Discovering statistics using SPSS*. Los Angeles, CA: Sage.

Flory, S. L., Ingram, E. L., Heidinger, B. J., & Tintjer, T. (2005). Hands-on in the non-laboratory classroom. *The American Biology Teacher, 67*(9), 542-547.

Fontenot, D., Chandler, J. R., Talkmitt, S., & Sullivan, K. (2007). *The Texas High School Initiative aims at STEM education reform: Texas Tech University T-STEM Center – putting the "E" in k-12 STEM education.* Paper presented at the 37th ASEE/IEEE Frontiers in Education Conference, Milwaukee, WI.

Fortus, D., Krajcik, J., Dershimer, R., Marx, R., & Mamlok-Naaman, R. (2005). Design-based science and real world problem-solving. *International Journal of Science Education, 27*(7), 855-879.

Fry, R. (2007). *The changing racial and ethnic composition of U.S. public schools.* Washington, DC: Pew Hispanic Center.

Fry, R., & Gonzales, F. (2008). *One-in-five and growing fast: A profile of Hispanic public school students*. Washington, DC: Pew Hispanic Center.

Fusarelli, L. D. (2011). School reform in a vacuum: Demographic change, social policy, and the future of children. *Peabody Journal of Education, 86*(3), 215-35.

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). White Plains, NY: Longman.

Gammon, M. (2011). *Next generation learning challenges seeks promising technology tools that can help U.S. students get ready for college*. Seattle, WA: Bill & Melinda Gates Foundation.

Gardner, D. P., & Larsen, Y. W. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: Department of Education, National Commission on Excellence in Education.

Goldstein, D. (2008). *The evaluation of COSMOS (2000-2008): Developing future scientists, engineers, and mathematicians*. Berkeley, CA: University of California, Center for Research Evaluation and Assessment.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth and eighth grade students in an international context*. (NCES 2009-001). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Goodnough, K. (2006). Enhancing pedagogical content knowledge through self-study: An exploration of problems-based learning. *Teaching in Higher Education, 11*(3), 301-318.

Gordon, R., Kane, T. J., & Staiger, D. O. (2006). *Identifying effective teachers using performance on the job*. Washington, DC: The Brookings Institution.

Greene, J. P., Ph.D., & Winters, M. (2005). *Public high school graduation and college-readiness rates: 1991-2002*. Washington, DC: U.S. Department of Education.

Heppner, F. H., Kouttab, K. R., & Croasdale, W. (2006, September). Inquiry: Does it favor the prepared mind? *American Biology Teacher,* 390-392.

Hill, D. (2004, October). The mathematics pathway for all children. *Teaching Children Mathematics, 11*(3), 127-133.

Houtenville, A. J., & Conway, K. S. (2008). Parental effort, school resources, and student achievement. *Journal of Human Resources*, *43*(2), 437-453.

Kane, T. J., & Cantrell, S. (2009). *Initial findings from the measures of effective teaching (MET) project*. Seattle, WA: Bill & Melinda Gates Foundation.

Kasmer, L., & Kim, O. (2011). Using prediction to promote mathematical understanding and reasoning. *School Science & Mathematics*, *111*(1), 20-33.

Kuenzi, J. J. (2008). *Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action.* (RL33434). Washington, DC: National Council for Science and the Environment.

Luera, G., Killu, K., & O'Hagen, J. (2003). Linking math, science, and inquiry-based learning: An example from a mini-unit on volume. *School Science and Mathematics, 103*(4), 194-207.

Mathis, W. J. (2011). International test scores, educational policy, and the American Dream. *ENCOUNTER: Education for Meaning and Social Justice, 24*(1), 31-33.

Meltzoff, J. (2008). *Critical thinking about research: Psychology and related fields.* Washington, DC: American Psychological Association.

Memory, D. M., Yoder, C. Y., Bolinger, K. B., & Wilson, J. W. (2004, July/August). Creating thinking and inquiry tasks that reflect the concerns and interests of of adolescents. *The Social Studies,* 147-154.

Meyers, R. (2012, August 2). Higher Education Agency: New funding model may be merit-based. *Corpus Christi Caller Times,* pp. 1A, 7A

Nathan, M. J., Tran, N. A., Atwood, A. P., and Phelps, L. A. (2010). Beliefs and expectations about engineering preparation exhibited by high school STEM teachers. *Journal of Engineering Education, 99*(4), 409-426.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning.* Washington, D.C.: National Academy Press.

National Science Board. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system.* (NSB-07-114). Arlington, VA: National Science Foundation.

National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's capitol*. (NSB-10-33). Arlington, VA: National Science Foundation.

National Science Board. (2012). *Science and Engineering Indicators 2012.* (NSB-12-01). Arlington, VA: National Science Foundation.

O'Reilly, T., & McNamara, D. S. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional "high stakes" measures of high school students' science achievement. *American Educational Research Journal, 44*, 161-196.

Patton, M. Q. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage.

Perie, M., Grigg, W. S., & Donahue, P. L. (2005). *The nation's report card: Reading 2005*. (NCES 2006-451). Washington, DC: U.S. Department of Education National Center for Education Statistics.

Pey-Yan, L., Desjardins, C., & Lawrenz, F. (2010). Influence of Scholarships on STEM Teachers: Cluster Analysis and Characteristics. *School Science & Mathematics*, *110*(3), 128-143. doi:10.1111/j.1949-8594.2010.00016.x

Ravitz, J. (2010). Beyond changing culture in small high schools: Reform models and changing instruction with project-based learning. *Peabody Journal of Education*, *85*(3), 290-312.

Reardon, S. F., & Bischoff, K. (2011). Income inequality and income segregation. *American Journal of Sociology, 116*(4), 1092-1153

Reigle-Crumb, C., & Callahan, R. M. (2009). Exploring the academic benefits of friendship ties for Latino boys and girls. *Social Science Quarterly, 90*(3), 611-631.

Reigle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education*, *95*(3), 458-476.

Schoenfeld, A. H. (Ed.). (2008). A study of teaching: Multiple lenses, multiple views. *Journal for Research in Mathematics, Education Monograph No. 14,* 45-96. Reston, VA: National Council of Teachers of Mathematics.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education, 94*(1), 87-102.

Snyder, S. S. (2006). Cooperative learning groups in the middle-school mathematics classroom. *Action Research Projects.* Paper 30. Retrieved from http://digitalcommons.unl.edu/mathmidactionresearch/30

Stevens, J. P. (2009). *Applied multivariate statistics for the social sciences.* New York, NY: Routhledge.

Stine, D. D., & Matthews, C. M. (2009). *The U.S. science and technology workforce.* Washington, DC: Congressional Research Service.

SRI International. (2011). *Evaluation of the Texas High School Project: Third Comprehensive Annual Report Executive Summary*. (P18092). Menlo Park, CA: SRI International Center for Education Policy.

TEA. (2009-2010). Academic Excellence Indicator System. Austin, TX: Texas Education Agency.

TEA. (2010). Technical Digest. Austin, TX: Texas Education Agency.

Terrell, N. (2007, Spring). STEM occupation. *Occupational Outlook Quarterly*, 26-33. Retrieved from http://www.bls.gov/opub/ooq/2007/spring/art04.pdf

The Inquiry Synthesis Project. (2006). *Technical report 2: Conceptualizing inquiry science instruction*. Washington, DC: Center for Science Education, Education Development Center, Inc. (EDC).

The White House, Office of the Press Secretary. (2012*). Taking out Stafford Loans to help pay for college***?*** *Thanks to young people all over the country who made their voices heard, interest rates on student loans will not double this summer* (Press release). Retrieved from http://www.whitehouse.gov/dontdouble-my-rates.

Tracy, D. M. (2003). Linking math, science, and inquiry-based learning: An example from a mini-unit on volume. *School Science & Mathematics, 103*(4), 94-108.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM education: A project to identify the missing components*, Intermediate Unit 1 and Carnegie Mellon, Pennsylvania.

Warde, W. F., & Novak, G. (1960). John Dewey's theories of education. *International Socialist Review*, *21*(1), 1-12.

Young, T. V., & Fusarelli, B. C. (2011). The politics of education and equity in turbulent times: An introduction. *Peabody Journal of Education, 86*(3), 211-214.

APPENDICES

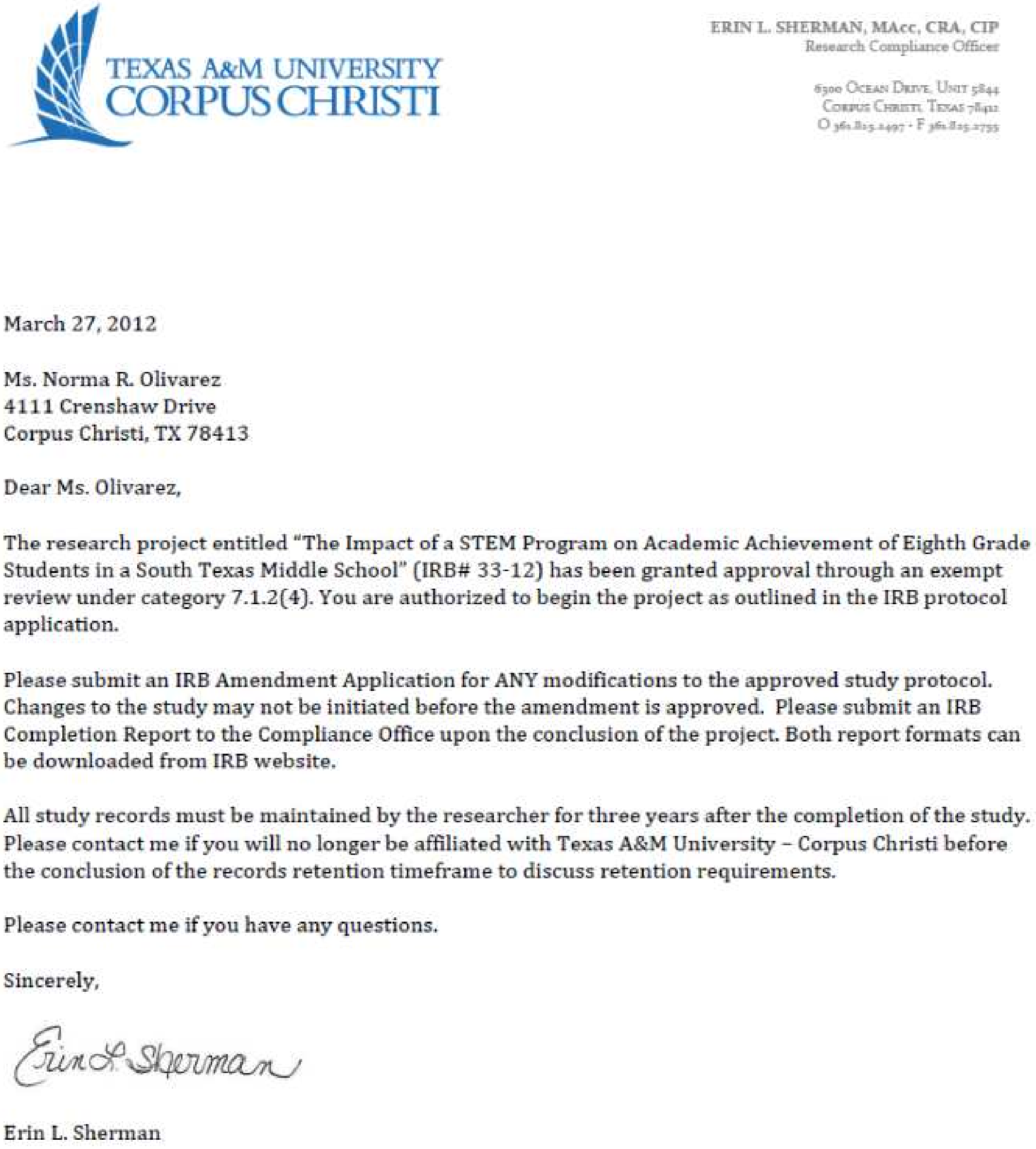
APPENDIX A: IRB Approval Letter

APPENDIX B: Outside Research Evaluation and Approval Form

APPENDIX C: Campus Approval Form

APPENDIX A

IRB Approval Letter



TEXAS A&M UNIVERSITY
CORPUS CHRISTI

ERIN L. SHERMAN, MAcc, CRA, CIP
Research Compliance Officer

6300 Ocean Drive, Unit 5844
Corpus Christi, Texas 78412
O 361.825.2497 • F 361.825.2755

March 27, 2012

Ms. Norma R. Olivarez
4111 Crenshaw Drive
Corpus Christi, TX 78413

Dear Ms. Olivarez,

The research project entitled "The Impact of a STEM Program on Academic Achievement of Eighth Grade Students in a South Texas Middle School" (IRB# 33-12) has been granted approval through an exempt review under category 7.1.2(4). You are authorized to begin the project as outlined in the IRB protocol application.

Please submit an IRB Amendment Application for ANY modifications to the approved study protocol. Changes to the study may not be initiated before the amendment is approved. Please submit an IRB Completion Report to the Compliance Office upon the conclusion of the project. Both report formats can be downloaded from IRB website.

All study records must be maintained by the researcher for three years after the completion of the study. Please contact me if you will no longer be affiliated with Texas A&M University – Corpus Christi before the conclusion of the records retention timeframe to discuss retention requirements.

Please contact me if you have any questions.

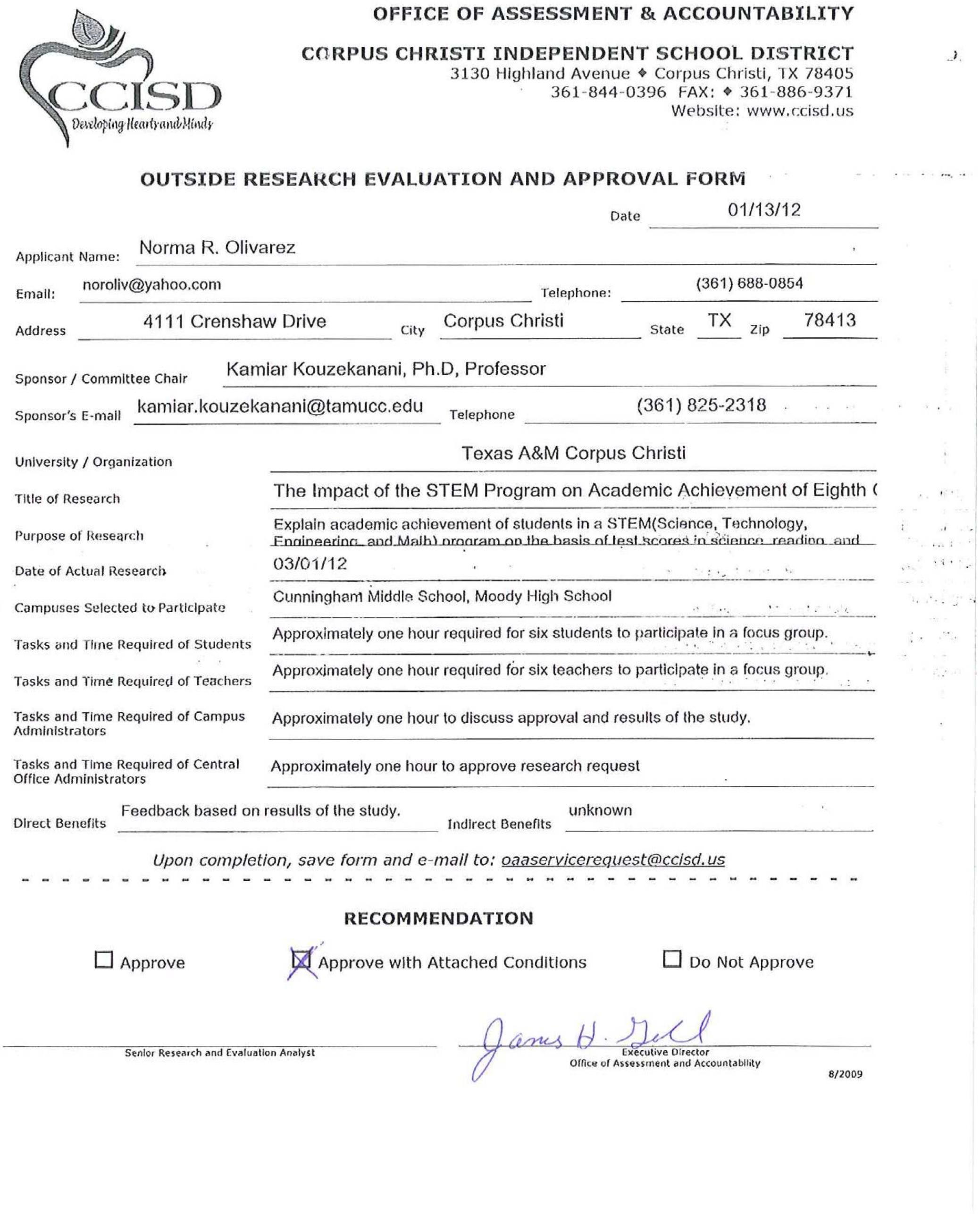
Sincerely,

Erin L. Sherman

Erin L. Sherman

APPENDIX B

Outside Research Evaluation and Approval Form



OFFICE OF ASSESSMENT & ACCOUNTABILITY

CORPUS CHRISTI INDEPENDENT SCHOOL DISTRICT
3130 Highland Avenue ◆ Corpus Christi, TX 78405
361-844-0396 FAX: ◆ 361-886-9371
Website: www.ccisd.us

CCISD
Developing Hearts and Minds

OUTSIDE RESEARCH EVALUATION AND APPROVAL FORM

Date 01/13/12

Applicant Name: Norma R. Olivarez

Email: noroliv@yahoo.com Telephone: (361) 688-0854

Address 4111 Crenshaw Drive City Corpus Christi State TX Zip 78413

Sponsor / Committee Chair Kamiar Kouzekanani, Ph.D, Professor

Sponsor's E-mail kamiar.kouzekanani@tamucc.edu Telephone (361) 825-2318

University / Organization Texas A&M Corpus Christi

Title of Research The Impact of the STEM Program on Academic Achievement of Eighth (

Purpose of Research Explain academic achievement of students in a STEM(Science, Technology, Engineering, and Math) program on the basis of test scores in science, reading, and

Date of Actual Research 03/01/12

Campuses Selected to Participate Cunningham Middle School, Moody High School

Tasks and Time Required of Students Approximately one hour required for six students to participate in a focus group.

Tasks and Time Required of Teachers Approximately one hour required for six teachers to participate in a focus group.

Tasks and Time Required of Campus Administrators Approximately one hour to discuss approval and results of the study.

Tasks and Time Required of Central Office Administrators Approximately one hour to approve research request

Direct Benefits Feedback based on results of the study. Indirect Benefits unknown

Upon completion, save form and e-mail to: oaaservicerequest@ccisd.us

RECOMMENDATION

☐ Approve ☒ Approve with Attached Conditions ☐ Do Not Approve

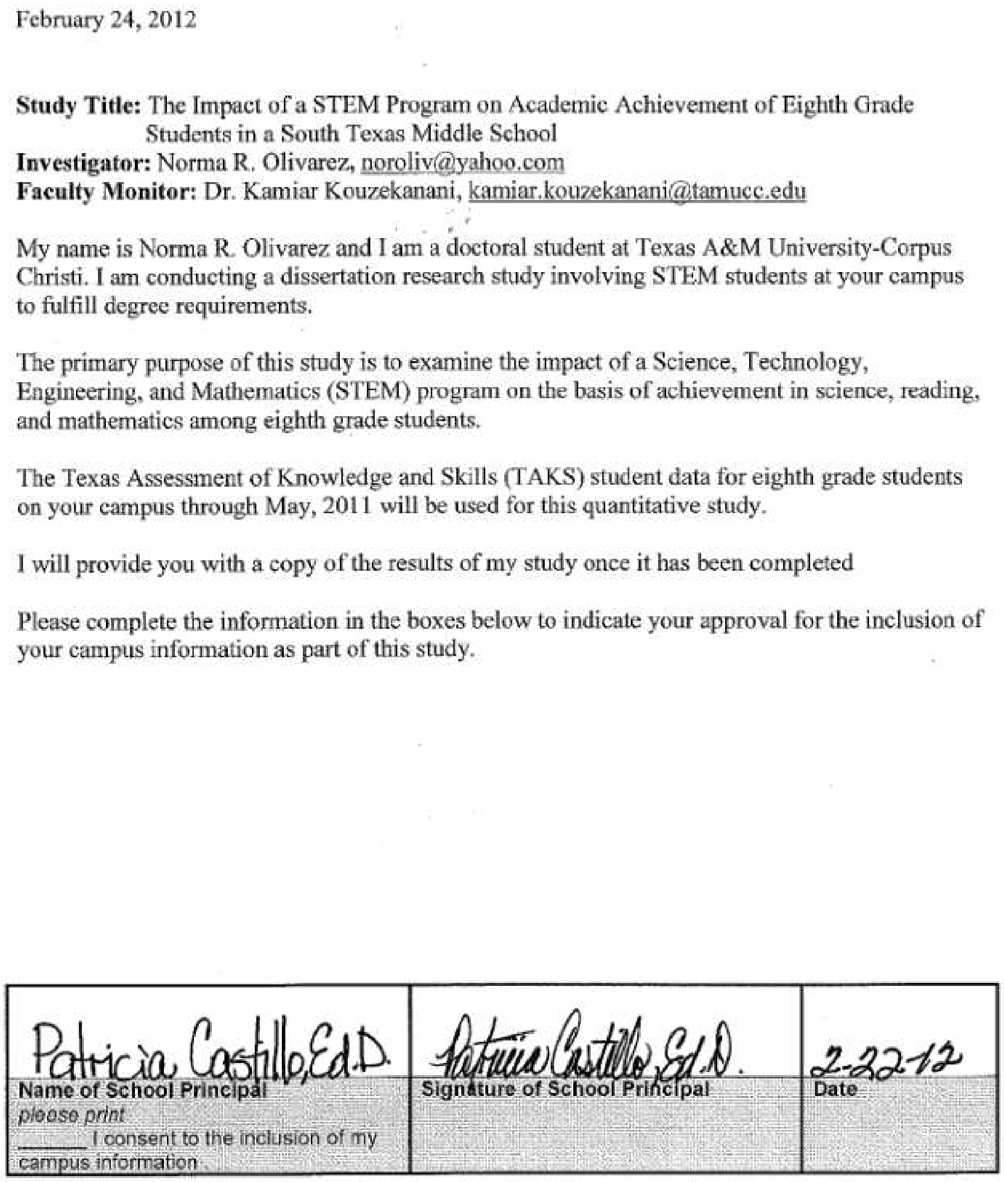
Senior Research and Evaluation Analyst

James H. Gold
Executive Director
Office of Assessment and Accountability

8/2009

APPENDIX C

Campus Approval Form



February 24, 2012

Study Title: The Impact of a STEM Program on Academic Achievement of Eighth Grade Students in a South Texas Middle School
Investigator: Norma R. Olivarez, noroliv@yahoo.com
Faculty Monitor: Dr. Kamiar Kouzekanani, kamiar.kouzekanani@tamucc.edu

My name is Norma R. Olivarez and I am a doctoral student at Texas A&M University-Corpus Christi. I am conducting a dissertation research study involving STEM students at your campus to fulfill degree requirements.

The primary purpose of this study is to examine the impact of a Science, Technology, Engineering, and Mathematics (STEM) program on the basis of achievement in science, reading, and mathematics among eighth grade students.

The Texas Assessment of Knowledge and Skills (TAKS) student data for eighth grade students on your campus through May, 2011 will be used for this quantitative study.

I will provide you with a copy of the results of my study once it has been completed

Please complete the information in the boxes below to indicate your approval for the inclusion of your campus information as part of this study.

Patricia Castillo, Ed.D.	Patricia Castillo, Ed.D.	2-22-12
Name of School Principal *please print* ______ I consent to the inclusion of my campus information	**Signature of School Principal**	**Date**