A Study on The Effectiveness of a Pilot Inquiry-Based Middle School Science Program on Non-Cognitive Outcomes and Academic Achievement

Rui Meira Dionisio
roy.dionisio@student.shu.edu

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A Study on The Effectiveness of a Pilot Inquiry-Based Middle School Science Program on Non-Cognitive Outcomes and Academic Achievement

by

Rui Meira Dionisio

Submitted in Partial Fulfillment of the Requirements for the Degree
Doctor of Education Leadership, Management, and Policy
Seton Hall University
2017

SETON HALL UNIVERSITY
College of Education and Human Services
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SETON HALL UNIVERSITY
COLLEGE OF EDUCATION AND HUMAN SERVICES
OFFICE OF GRADUATE STUDIES

APPROVAL FOR SUCCESSFUL DEFENSE

Rui Dionisio, has successfully defended and made the required modifications to the text

DISSERTATION COMMITTEE
(please sign and date beside your name)

Mentor:
Dr. Elaine Walker  

Committee Member:
Dr. Daniel Gutmore

Committee Member:
Dr. Daniel Fishbein  

Committee Member:
Dr. James McLaughlin

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Acknowledgments

This project was the result of the concerted efforts of many dedicated and passionate individuals. We continue to strive to create spaces where our students may develop an insatiable curiosity and motivation to learn each and every day. I consider myself incredibly fortunate to have worked with an outstanding group of educators whose knowledge, dedication, and efforts made this project possible. I am blessed to have known you.

Thank you to my mentor, Dr. Elaine Walker, for your knowledge, patience, and encouragement. You helped me navigate this journey and I am extremely appreciative of your guidance. A special thank you to the members of my doctoral committee, Dr. Daniel Gutmore, Dr. Daniel Fishbein, and Dr. James McLaughlin. Thank you for your time and insightful feedback. Your recommendations and support enabled me to reflect and improve this work.

To my mother, who instilled in me as a young child the importance of hard work, and to my father, who I know has always watched over me from heaven above. To Uncle Joe, for your foresight in guiding me to become an educator and for reminding me to always be proud of what I have already achieved. You have left an indelible mark on my life. For that, I am eternally grateful. To my wife, Diane. You always inspire me by your passion and desire to help others. Thank you for believing in and encouraging me. I am in awe of you. To our three beautiful children, Olivia, Skye, and Christian. I love you more than words can express. May you always find purpose in life and make a positive impact on the lives of others the way you have made a difference in my life.
I am what I am at the hand of my God in whom I have complete faith. “Trust in the LORD with all thine heart; and lean not on thine own understanding. In all thy ways acknowledge him, and he shall direct thy paths” (Proverbs 3:5-6).
Dedication

To my wife Diane, my everything, for all of your love, patience, encouragement, sacrifice, and unending support. I couldn’t have done it without you. This work belongs to both of us.

I love you.
Abstract

The randomized research study assessed the effect of an inquiry-based science (IBS) program on non-cognitive outcomes and academic achievement. The study was the result of a grant that was awarded by Professional Resources in Science and Mathematics (PRISM), a program affiliated with Montclair State University in conjunction with Bristol-Myers Squibb, and part of the New Jersey Statewide Systemic Initiative (NJSSI). The NJSSI is a partnership of schools, districts, colleges and universities, science centers, businesses, and museums dedicated to improving the teaching and learning of science, mathematics, and technology in New Jersey. The quantitative research study utilized an IBS instructional program titled Science and Technology Concepts for Middle Schools (STC/MS) and was implemented in two middle schools within the same suburban school district. This study examined the effect of IBS classrooms on learning outcomes specifically related to gender and special education.

Evaluation of student learning outcomes was conducted through the administration of three instruments: the Academic Self-Concept (ASC) scale, unit assessments, and NJASK 8 Science. The ASC scale and unit assessments were administered as a pretest and posttest in IBS classrooms. NJASK 8 Science scale scores were obtained through reporting of student performance data from the New Jersey Department of Education to the district. The quantitative analysis in this study provided evidence that IBS classrooms had a positive effect on academic achievement. Overall, students in IBS classrooms performed better than students in traditional classrooms on unit assessments. Additionally, male students and special education students in IBS classrooms outperformed students in traditional classrooms on unit assessments.
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CHAPTER I: INTRODUCTION

Introduction

Senator John Glenn, Chairman of the National Commission on Mathematics and Science Teaching for the 21st Century, said:

Our children are losing the ability to respond not just to the challenges already presented by the 21st century but to its potential as well. We are failing to capture the interest of our youth for scientific and mathematical ideas. We are not instructing them to the level of competence they will need to live their lives and work at their jobs productively. Perhaps worst of all, we are not challenging their imaginations deeply enough. (United States Department of Education [USDOE], 2000, p. 4)

Statement of the Problem

An understanding of scientific principles plays a significant role in the lives of all people, but most U.S. citizens are not scientifically literate (American Association for the Advancement of Science [AAAS], 1989). Science may be taught through a variety of instructional approaches, including but not limited to traditional, didactic instruction and a hands-on, inquiry-based approach. Teachers may incorporate different methods in an effort to foster critical thinking and create a learning environment where students may apply knowledge to solve problems. But findings from the Trends in Mathematics and Science Study (TIMSS) showed mixed results for U.S. students compared to their international peers. At the fourth grade level, U.S. students appeared to be falling behind in science, while students at the eighth grade level had made only modest gains (Lemke & Gonzales, 2006; USDOE, 2006). Results from TIMSS (2012) showed no measurable difference between the U.S. average science score at grade 4 in 1995 (542) and in
2011 (544). Additionally, there was no statistically significant difference between the U.S. average score in 2007 (520) and in 2011 (525) on the eighth grade assessment (USDOE, 2006). There were no measurable differences between science scores in 2015 and 1995 (Martin, 2016).

Scientific literacy is defined as the ability to apply scientific knowledge and skills to everyday situations and is a major goal of many science organizations (AAAS, 1989; National Research Council [NRC], 1996, 2000; National Science Teachers Association [NSTA], 2003). Acquisition of scientific skills is critical if the United States expects to be competitive in a global economy. Science literacy is an integral component of preparing U.S. students to compete in a global market. The advancement of science education is grounded in research-based instructional practices that favor context-dependent critical thinking skills and processes. According to Bruner (1960):

- **Our schools may be wasting precious years by postponing the teaching of many important subjects on the ground that they are too difficult… the foundations of any subject may be taught to anybody at any age in some form. The teaching and learning of structure, rather than simply the mastery of facts and techniques, is at the center of the problem of transfer. (p. 12)**

Several studies have been conducted which indicate that most teachers in science classrooms are still using traditional, didactic methods (Harms & Yager, 1981; Seymour, 2002; Unal & Akpinar, 2006). Traditional instructional methods fail to personalize learning for each student because they do not foster a learning environment where the teacher may engage learners’ prior knowledge, individuals’ prior experiences, and student preconceptions about science. A lack of student involvement in a lesson contributes to decreased interest and
motivation. As a result, U.S. students continue to underperform in science in relation to students in other nations (Martin et al., 2004; Parker & Gerber, 2000; Roth et al., 2006; Stigler & Hiebert, 1999).

Research findings on the effectiveness of IBS instruction are mixed and have revealed contradictory results. However, the body of research leans toward positive effects for learning outcomes incorporating inquiry instruction. The discrepancies in the research may be a result of varying definitions for inquiry as a method of instruction. Additionally, researchers often utilize multiple methods of measuring student learning outcomes that may have an impact on research findings and comparisons.

Gender differences abound in a review of numerous science achievement data studies. Males performed better than females at the 4th, 8th, and 12th grade levels in science, with statistical significance at the fourth and eighth grades (TIMSS, 2016). The gender achievement gap has become more prevalent as students get older, with males dominating different fields of science (U.S. Department of Commerce, 2013). It is important to note women comprise 48% of the total workforce in the United States (U.S. Department of Commerce, 2013). However, females only account for 26% of science, technology, engineering, and math (STEM) jobs and unfortunately this statistic has not changed since 2000 (U.S. Department of Commerce, 2013). These statistics reveal an underrepresentation of females in science-based careers. Policy makers and educators can develop ways to increase engagement.

Bay et al. (1992) conducted a study which compared inquiry versus traditional teaching methods. In that study, inquiry-based instruction consisted of discovery learning where general education and special education students actively engaged in learning (Bay, Staver, Bryan, &
Hale, 1992). Findings from this study indicated special education students in the inquiry classroom performed better than special education students in the traditional classroom. However, few research studies exist in the discipline of science where the academic performance of students with learning disabilities is treated as an outcome (Nietupski, Hamre-Nietupski, Curtain, & Shrikanth, 1997).

The present study seeks to address some of the apparent gaps in the literature. In so doing, the study clearly defines IBS instruction and distinguishes the difference between IBS and traditional science instruction. It seeks to determine through a random design whether differences exist in outcomes between students in IBS classrooms and students in traditional science classrooms. The two outcomes of interest are non-cognitive and academic outcomes. Moreover, the study examines the moderating effects gender and special education have on these outcomes.

**Purpose of the Study**

The development of the National Science Education Standards (NSES) was established by the NRC as a set of guidelines for primary and secondary science education in the United States in 1996. These principles provide a set of goals for teachers to establish for students and for school administrators to utilize as they support teachers with professional development. The NSES is clear that all students should be actively engaged in science instruction and the improvement of science education is part of a systemic education reform (NSES, 1996). The Standards described in the NSES are also described in the American Association for the AAAS document Benchmarks for Scientific Literacy (AAAS, 1993).
The NSES has delineated commitments to science education for all students to compete in a global market and to providing opportunities to fill voids in a growing field of employment in STEM. Results from national and international assessments such as the National Association for Education Progress (NAEP), TIMSS, and the Programme for International Student Assessment (PISA) provide us with a clear understanding of the urgency and magnitude of the state of our current student achievement and the potential future of our economy. Wilke and Straits (2005) have suggested that one strategy to address the achievement gap is to further engage students as active learners. In this way, students will be able to apply and transfer that which they have learned to new, authentic situations in the real world. It is important to keep in mind that student prior knowledge and background experiences are important parts of the learning process. Students’ background experiences, beyond what they learn in school, play a key role in forming their knowledge and understanding of the world around them (Unal & Akpinar, 2006).

The NSES has been key in reform efforts to achieve the goal of developing scientific literacy through the use of inquiry grounded in a constructivist approach (Haney, Lumpe, Czerniak, & Egan, 2002; NRC, 1996). The NSES espouses the concept that IBS instruction is critical to ensure that students attain the highest level of academic achievement and become scientifically literate citizens. IBS represents an evolution from didactic or traditional instructional methods of teaching science with a focus on process over behavioral memorization of a body of facts (Dewey, 1910a, 1910b, 1959; NRC, 1996b; Schwab, 1958, 1960, 1962, 1966). The NSES (1996) states that inquiry-based learning is an active learning process where “learning science is something students do, not something that is done to them” (p. 20). The NSES
provides us with inquiry defined as asking questions and attempting to answer them through investigations involving experimentation and data collection, logical analysis, and searching for information from existing sources (1996). George DeBoer (1997) suggests inquiry is carried out on “researchable questions of genuine interest to students in the context of the content” (p. 5). Duschl establishes inquiry defined as the student development of concepts and the importance of being cognizant of the student’s prior knowledge (2003). Furthermore, inquiry learning requires the integration of knowledge across different areas of science (Duschl, 2003).

The purpose of this quantitative study was to determine to what extent IBS instruction has an effect on non-cognitive outcomes and academic achievement in a middle school setting. Effective educational leadership is critical to student achievement in schools. A major role of the school administrator is to improve learning outcomes. Administrators are charged with preparing graduates with a foundation and skill set so students can adapt to a rapidly evolving society with the acquisition of skills for jobs that do not yet exist. Knowing and understanding the impact of positive levels of student attitudes, interests, and perceived self-efficacy in science could help school leaders assess and implement programs for their current educational practices.

Research has shown that IBS instruction has positive effects on students’ science achievement, cognitive development, laboratory skills, and science process skills compared to traditional teaching approaches (Gibson & Chase, 2002; Tuan, Chin, & Tsai, 2004; Cartier & Stewart, 2000; Russell & French, 2002; Talton & Simpson, 1987). “It has been found that students using an inquiry based approach score higher on standardized assessments, improve their science process skills, and have more positive attitudes toward science” (Gibson & Chase, 2002, p. 694). Inquiry advocates have pursued the paradigm shift away from traditional
memorization of facts toward inquiry-based learning where students seek answers to their own questions (Gibson & Chase, 2002). According to the NRC (1999):

It is important to stress that a coherent program should be accessible to all students. While the curriculum should be designed so that each learning activity builds on previous activities, instruction should be guided by decisions that allow every student, regardless of past experience, to participate in intellectually stimulating ways and to demonstrate continual progress. If the curriculum has been designed with rich, engaging tasks, appropriate instructional decisions can be made to assist all students in attaining significant cognitive growth. (1999, p. 12)

**Research Questions**

This random design study will be guided by three main research questions:

1. What is the impact of IBS classrooms on non-cognitive outcomes (academic self-concept) and academic achievement (unit assessments and NJASK 8 Science) compared to students who learn in traditional classrooms?
2. To what extent does gender moderate these relationships?
3. Do IBS classrooms have an effect on learning outcomes for special education students?

**Hypotheses**

The following null hypotheses correspond with the research questions in this study:

Null Hypothesis 1: Middle school students who participate in IBS classrooms will not achieve a statistically significant difference in their non-cognitive outcomes and academic performance when compared to students in traditional classrooms.
Null Hypothesis 2: Gender does not have a statistically significant moderating effect on non-cognitive outcomes and academic achievement for middle school students in IBS classrooms compared to traditional classrooms.

Null Hypothesis 3: There is no statistically significant difference for middle school special education students with respect to non-cognitive outcomes and academic achievement in IBS classrooms compared to traditional classrooms.

**Significance of the Study**

Effective educational leadership is critical to student achievement in schools. A major role of the school administrator is to improve learning outcomes. The Interstate School Leaders Licensure Consortium (ISLLC) Standards represent the broad themes that educational leaders address in order to promote the success of all students (ISLLC, 2008). Effective school leaders are expected to promote qualities and implement programs for improved teaching practices that positively influence student outcomes. The ISLLC Standards establish clear expectations on how school leaders may improve teaching and learning. This study aims to provide school leaders with research and policy recommendations for practicing administrators to improve teaching, enhance learning, and attain positive student academic outcomes.

The findings of this study are likely to be significant because they may add to the body of knowledge encompassing inquiry-based instruction in middle school science and the effect it has on academic self-concept and academic achievement. Results from this study may generate interest in educational leadership practices and their importance as they relate to the development, implementation, and use of IBS teaching practices, if found to be significant. This study also maintains an evaluative component where school and district leaders may use the
findings of this research to inform their decisions as to whether allocation of financial resources is worth an investment in an IBS program when compared to results from a traditional classroom setting. Furthermore, this study may shed light on instructional methodology anchored in a constructivist approach in the development of critical thinking skills with a focus on scientific process for learners. Results of this study may provide evidence to determine to what extent IBS instruction has an effect on student engagement and achievement.

**Design and Methods of the Study**

The effects of IBS instruction on non-cognitive outcomes and academic performance were examined through a random control design. Middle school students in grades 6-8 were randomly assigned to one of two groups (experimental group and control group) at each grade level. Both groups at each grade level were administered a pretest to assess academic self-concept and science content knowledge. After the administration of the pretest, each experimental group received IBS instruction while the control groups received traditional science instruction. Upon conclusion of instruction, both groups were administered a posttest to assess academic self-concept and science content knowledge.

Students in the experimental group learned science through inquiry by the administration of STC-MS investigation kits. For the purpose of this study, quantitative research methods were utilized. Student achievement data were analyzed from the NJASK 8 Science assessments administered in May, 2010, May, 2011, and May, 2012. The NJASK 8 Science assessment was the only middle school state assessment that measured science knowledge and skills. This program was also administered in the 2009-2010 academic year.
Limitations of the Study

First, this study examined a site-specific group of science teachers within one science department in one suburban school district. The results and findings from one district may not apply to other content area departments in other school districts. Therefore, this study is limited with respect to the transfer of results to other districts because the study only occurred in one district. Second, the use of NJASK test scores and the district developed unit assessments, developed with NAEP and NJASK test bank questions, are criterion-referenced and only provide a view through one lens into academic achievement. Criterion-referenced assessments are not the only measure of student learning. Third, a limitation of this study was the fact that the use of the NJASK covered a breadth of skills and content knowledge, whereas the intervention in this research was a specific unit of study. The results of the intervention could be more significant but may not be measureable since the NJASK was not able to isolate the learning outcomes specific to this intervention. Fourth, although the administration of the instructional program and assessments occurred within the cohort in 2009-2010, the administration of the NJASK 8 Science assessment occurred with different grade-level groups of students each year over a 3-year period: NJASK 8 Science administration for eighth graders in Spring, 2010, NJASK 8 Science administration for seventh graders in Spring, 2011, and NJASK 8 Science administration for sixth graders in Spring, 2012. Fifth, teachers in the experimental group participated in professional development provided by PRISM and the NSRC. Teachers in the experimental group were required to engage students in IBS instruction through STC/MS investigation laboratory units of study. All teachers were aware of whether they were assigned to the experimental or control groups. Finally, teacher fidelity of implementation may be a limitation in
this study (Berman & McLaughlin, 1976; Biglan & Taylor, 2000; Freeman, 1977; Fullan, 2001; Hord, Rutherford, Huling-Austin, & Hall, 1987; Lipsey, 1999; Mihalic, 2002; NRC, 2004; Patton, 1978; Scheirer & Rezmovic, 1983; USDOE, 2006).

**Definition of Terms**

*Achievement* - An academic accomplishment or advancement measured quantitatively in the areas of student motivation, student interest level, student confidence level, and content understanding (Chinni, 1996).

*American Association for the Advancement of Science (AAAS)* - An international nonprofit organization dedicated to advancing science around the world.

*Adequate Yearly Progress (AYP)* - A statewide accountability system mandated by the federal government through the No Child Left Behind Act (NCLB) of 2001 requiring each state to ensure that all schools make adequate yearly progress.

*Assessment* - An instrument used by an educator to evaluate evidence of a student’s learning (Chinni, 1996).

*Benchmarks for Scientific Literacy* - The Project 2061 declaration that delineates the knowledge and skills students should attain in science, mathematics, and technology by the end of grades 2, 5, 8, and 12 (AAAS, 1993).

*Carolina Curriculum Programs for Science and Math* - The professional development department of Carolina Biological Supply Company that provides professional learning for teachers on the STC-MS IBS kits.

*Constructivism* - A learning theory where students are encouraged to construct their own knowledge instead of being recipients from other sources (Kanselaar, De Jong, Andriessen &
Goodyear, 2000). Constructivism exists when learning and development are a collaborative process and children interact with the social environment and internalize the experience for learning to occur (Vygotsky, 1978).

**Didactic Instruction** - The transmission of a body of knowledge from a teacher to students. Didactic instruction is described as traditional instruction where students are passive recipients of facts through the use of lectures, note-taking, memorization, and cookbook laboratory experiments. Instruction is transferred to an entire class as a whole and little attention is paid to individual student prior experiences or preconceptions. Furthermore, learners are not awarded opportunities to experiment with different approaches to identify solutions to problems, but rather use textbooks for drill and practice (Smerdon, Burkam, and Lee, 1999).

**Discovery Learning** - Learning alternative to memorization of facts focused on experiences and contexts that make the student willing and able to learn (readiness), include teaching structured so it can be easily grasped by students (spiral organization), and where instruction should be designed to facilitate extrapolation and/or fill in the gaps (going beyond the information given) (Bruner, 1966).

**District Factor Group (DFG)** - System developed by the New Jersey Department of Education (NJDOE) in 1975 in order to compare student performance on statewide assessments across school districts with similar demographics based on socioeconomic status. Eight DFGs exist ranging from A (lowest SES group) to J (highest SES group).

**Hands-On Learning** - Students are directly engaged in learning with materials and opportunities to investigate a problem rather than receive knowledge through lecture or reading. According to Rankin, hands-on learning is distinguished by the:
amount of flexibility a teacher allows in order for children to develop individual curiosity and ways to solve problems. This is different from a situation in which a teacher poses a question and then directs all the students to take the same pathway to find a common solution. (2000, p. 35)

Inquiry-Based Instruction - The NSES defines inquiry-based instruction as engaging students in: making observations; posing questions; reviewing experimental evidence; using tools to gather, analyze, and interpret data; proposing solutions and explanations; making predictions; communicating results; identifying assumptions; using critical and logical thinking; considering alternative explanations; processing information; communicating with groups; coaching; student actions; facilitating student thinking; modeling the learning process; and the flexible use of materials (NRC, 1996).

Leadership and Assistance for Science Education Reform (LASER) - A public/private partnership in Washington State committed to a shared vision of effective teaching and learning through a network of committed individuals and organizations. LASER has aligned with the NRC and works with school districts to improve instructional practice with a focus on increasing student learning and achievement.

National Assessment of Education Progress (NAEP) - According to Schrag (1997), the NAEP is better known as the Nation’s Report Card. This national assessment is regarded as one of the most reliable measures for academic achievement for what students know in specific subjects with relation to the impact of changes in demographics, ethnic populations, and socioeconomic factors on student achievement. The NAEP is administered across the nation and
serves as a common metric for all states. The NAEP science assessment measures student knowledge in Earth Science, Life Science, and Physical Science.

*National Science Education Standards (NSES)* - The set of knowledge and skills students all students should understand and be able to do in science.

*National Science Teachers Association (NSTA)* - An organization comprised of science educators that provides advocacy on educational issues and professional development opportunities for educators.

*National Research Council (NRC)* - A nonprofit institution devoted to establishing public policy, informing public opinion, and promoting the fields of science, engineering, technology, and health.

*National Science Resources Center (NSRC)* - The NSRC, established by the Smithsonian Institution and the National Academies, is committed to improving teaching and learning in science.

*Next Generation Science Standards (NGSS)* - Set of standards that identify what students should know and be able to do with respect to three distinct and equally important dimensions of learning science: practices, crosscutting concepts, and core ideas (NGSS, 2013).

*Professional Resources in Science and Mathematics (PRISM)* - An organization located at Montclair State University in New Jersey at the Bristol-Myers Squibb Center for Science Teaching and Learning. PRISM is a program that serves school districts to improve science and mathematics teaching. PRISM scientists, educators, and classroom teachers are content area specialists in curriculum, professional development, and pedagogy who emphasize inquiry-based and constructivist teaching.
Programme for International Student Assessment (PISA) - An international assessment that assesses students at the age of 15 in reading, mathematics, and science.

Science and Technology Concepts for Middle Schools (STC/MS) - An inquiry-based middle school science curriculum developed by the NSRC.

Science Literacy - AAAS defines science literacy as developing a familiarity and respect for the natural world, understanding basic scientific principles, maintaining the capacity for scientific thinking, and the ability to apply scientific knowledge (AAAS, 1989).

The National Academies - This organization convenes committees of experts in all areas of science and technology to address critical national issues and provides advice to the federal government and the public.

Trends in International Mathematics and Science Study (TIMSS) - This research tool provides reliable and timely data every 4 years to evaluate mathematics and science achievement of U.S. fourth and eighth grade students compared to student achievement results in other countries. TIMSS data have been collected since 1995 and were recently collected in 2015.
CHAPTER II: REVIEW OF LITERATURE

Introduction

This chapter provides an overview of the relevant literature as it relates to the conceptual framework and inquiry-based methodologies. The literature review coordinates research study findings of IBS teaching and learning in an effort to create an argument for the significance of this study. The quantitative study seeks to determine to what extent inquiry-based learning impacts student interest level in science. The study also analyzes the effect of IBS classrooms on academic achievement. The review of the literature begins with the history of science reform and the current state of science education. The chapter then presents the theoretical frameworks upon which this study was built by examining constructivism and inquiry instruction. The third part of this chapter focuses on inquiry and its effect on achievement and academic self-concept, as well as the moderating effects of gender and special education on IBS. The chapter concludes with a brief summary of the literature review.

This study includes science education research, including but not limited to scientific journals and research studies, examining both academic self-concept and student achievement. The goal for this review of education literature is to address the following questions: a) What is the impact of IBS classrooms on non-cognitive outcomes (academic self-concept) and academic outcomes (unit assessments and NJASK 8 Science) compared to students who in traditional classrooms? b) To what extent does gender moderate these relationships? and c) Do IBS classrooms have an effect on learning outcomes for special education students? This study evaluates the effectiveness of IBS classrooms and their ability to improve non-cognitive
outcomes and academic achievement, specifically as relates to gender and students with disabilities.

**History of Science Reform**

There may not exist a visual representation more alarming than that from the documentary *A Private Universe*. *A Private Universe* was produced by the Harvard-Smithsonian Center for Astrophysics in 1987 and funded by the NSF and Annenberg/CPB. This persuasive documentary proves through firsthand accounts that even recent Harvard and MIT graduates do not understand the most basic scientific ideas taught in grade school and these concepts are unlearned outside of the classroom.

Senator John Glenn led the Glenn Commission in 2000 and became a champion for math and science reform so the United States may remain a global leader. Glenn stated:

It is abundantly clear from the evidence already at hand that we are not doing the job that we should do – or can do – in teaching our children to understand and use ideas from these fields. Our children are falling behind; they are simply not "world-class learners" when it comes to mathematics and science (USDOE, 2000, p. 4).

The National Science Board, the governing board of the National Science Foundation, and policy advisors to the President and Congress found that the U.S. graduation rate in 2012 was 79%, demonstrating no improvement since 2006 and ranking 22nd among Organization for Economic Cooperation and Development (OECD) nations for graduation rate (NSB, 2016).

Thomas Friedman, author of *The World is Flat* (2005), highlights that Asian universities produce eight times as many bachelor's degrees in the engineering field than do U.S. universities. As of 2012, U.S. graduates with an engineering degree accounted for 5%. Since 2000, the number of
engineering degrees has modestly increased by 100,000 in the United States (NSB, 2016). Alternatively, the number of engineering degrees has surged by one million within the same timeframe. These statistics are staggering, especially as the number of jobs requiring science and engineering skills in the U.S. labor force is growing by almost 5% per year (Friedman, 2005). A report from the National Assessment Governing Board concludes that 63% of life science and aerospace firms report shortages of qualified workers (Sellman, 2004). Among STEM doctorate holders in the labor force, 40% are age 50 or older (NSF, 2008).

Various points in American history have precipitated an awakening for increased focus on reform, especially improvement in student achievement as it relates to science. The emphasis on public education in America today is one of the mostly intensely debated issues and lies at the center of public policy discussions. In 1957, Sputnik triggered an increased national focus on science education and propelled the United States into an educational race of global competition (Rutherford, 1997). As a result, the 1960s brought about the space race as a period in time that created an increased awareness and emphasis on math and science instruction in U.S. schools. John F. Kennedy, 35th President of the United States, made the following statement in a speech at Rice University in September 1962:

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.
Political attention to the goal of advancing science and technological advancement ultimately resulted in the Apollo moon landing in 1969 along with a renewed commitment to science education. Government funding and national attention provided financial resources to a variety of institutions and organizations that initiated the study of research-based best practices in order to establish developmentally appropriate curriculum.

*A Nation at Risk* (1983), published by the USDOE National Commission on Excellence in Education, is known as the landmark report that casted doubt on public education and contributed to an existing and growing belief that the American educational system was failing to meet the national need for a competitive workforce. This period in history was one that initiated an outcry among political leaders and led to further local, state, and federal reform efforts. The rigor and viability of our schools came under public scrutiny and was persistently questioned by the American public (Marzano, 2003). In 1989, *Science for All Americans (SFAA)* was published by the AAAS. *SFAA* presents a vision of science literacy goals for all students for grades K-12. An expert panel of scientists, mathematicians, and technologists set out to identify the fundamental ideas and critical attributes necessary for attainment of scientific literacy. *SFAA* lays out a coherent set of goals with recommendations about what students should and could be able to do in science, mathematics, and technology by the time they graduate from high school (AAAS, 1993). The prescribed philosophy presented by AAAS is one of less is more. It is of utmost importance for educators to restructure how they teach by reducing the volume of fragmented facts being taught. Teachers should shift away from a coverage approach and reorganize instructional design to primary concepts, or big ideas, through a conceptual, thematic methodology (Brooks, 1999).
The 1990s generated a continuous push for science education reform (AAAS, 1989, 1993; NRC, 1996, 2000, 2002). One of the major themes highlighted in the recommendations calls for improving scientific literacy by increasing foundational knowledge in an effort to prepare students to make informed decisions (AAAS, 1989). *Benchmarks for Science Literacy: Project 2061* (1993) was published as a companion report to *SFAA* and maps out what students should be able to accomplish at specific benchmarks as reasonable grade-level appropriate progress. These two publications can help support reform in science, mathematics, and technology education (AAAS, 1993). The NSES, published in 1996 by the NRC, is a set of goals for achievement appropriate for all members of the science education community. The NSES encompass standards for teaching, professional development, assessment, content, education programs, and systems. The National Science Standards (NRC, 1996b) call for a major shift in pedagogical approach to teaching science, prompting studies on student achievement. The NSES initiated a call to action wherein the first sentence of their call established an increasingly important, yet broad, goal: “The nation has established as a goal that all students should achieve scientific literacy” (NRC, 1996b, p. ix). The document then sets out the following goals for students:

- to experience the richness and excitement of knowing about and understanding the natural world;
- to use appropriate scientific processes and principles in making personal decisions;
- to engage intelligently in public discourse and debate about matters of scientific and technological concern;
- and to increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers. (p. 13)
The Standards were established to support learning for all students. In doing so, the NSES recognized that students arrive in the classroom with different backgrounds and different experiences. In addition, students also learn at different rates and with varying levels of prior knowledge. The NSES considers content to be fundamental if it:

1) represents a central event or phenomena in the natural world; 2) represents a central scientific idea and organizing principle; 3) has rich explanatory power; 4) guides fruitful investigations; 5) applies to situations and contexts common to everyday experiences; 6) can be linked to meaningful learning experiences; and 7) is developmentally appropriate for students at the grade level specified. (NRC, 1996b)

For example, in science students should understand by the end of high school that “the physical properties of [a] compound reflect the nature of the interactions among its molecules” (NRC, 1996b, p. 179). It is likely that students may simply memorize this statement without truly understanding the entire concept. However, students would better understand the concept if they were awarded opportunities to experiment with varying properties and develop an understanding of atoms.

Development of an effective and coherent curricular program requires that teachers:

1) focus on the important ideas and skills that are critical to the understanding of important phenomena and relationships and that can be developed over several age levels; 2) help students develop an understanding of these ideas and skills over several years in ways that are logical and that reflect intellectual readiness; (3) explicitly establish the connections among the ideas and skills in ways that allow students to understand both ideas and the connections among them; and (4) assess and diagnose what
students understand to determine the next steps in instruction. (Kreuger & Sutton, 2001, p. 51)

The NSES (NRC, 1996b) also contains program standards that describe the conditions needed for high-quality school science. These standards include:

- consistency across all elements of the science program and across the K-12 continuum;
- quality in the program of studies; coordination with mathematics; quality resources;
- equitable opportunities for achievement; and collaboration within the school community to support a quality program. (NRC, 1999, p. 10)

The NSF designated the use of high-quality, standards-based mathematics and science curricula as important components in order to support systemic initiatives. The NSF supports the development and selection of materials that convey scientific processes in a coherent manner within and across grade levels. The NSF believes that doing so provides teaching and learning opportunities of science and math in a continuous, interconnected, and cumulative manner K-12 with the greatest potential for maximizing the use of time and improving student achievement. The NSF is clear that leadership at the school and district level is required for an effective science program (NSES, 1996). The NSES identifies that leadership may include a variety of people such as teachers, administrators, and science coordinators and that the most critical aspect is providing the support necessary to sustain and improve such programs to provide the opportunities for students to learn and teachers to teach (NSES, 1996). Furthermore:

Developing a community of learners requires strong leadership, but that leadership must change dramatically from the hierarchical and authoritarian leadership often in place in schools and in school districts today. Leadership should emerge from a shared vision of science
education and from an understanding of the professional, social, and cultural norms of a school that is a community of learners. (NSES, 1996, p. 223)

The NSF has made the recommendation for the engineering of curriculum and instructional materials to create coherent curriculum programs. However, mobilizing such efforts is no easy task. Math and science curricula in the majority of U.S. schools lack coherence and focus, which has caused researchers associated with TIMSS to describe the typical curriculum in U.S. schools as a mile wide and an inch deep (Schmidt et al., 1997). Subsequently, the NSES reminds us that learning is cumulative over time and that curriculum programs should be designed to support student learning. The overwhelming number of topics is an indication of the fragmentation and lack of curricular focus that is required in order to support teaching and learning in the classroom.

When compared with an international cohort of students, students in the United States are typically not among the high performers (Martin et al, 2004; Parker & Gerber, 2000; Roth et al., 2006; Stigler & Hiebert, 1999). The TIMSS renewed interest in conversations about competition in the global workforce. TIMSS data results indicated that U.S. students performed at levels far below other industrialized nations (Martin et al., 2000). The results from this international assessment came as a blow to U.S. educators and revived reform initiatives in science and math. U.S. students continue to be outperformed by other nations on exams such as TIMSS and PISA (OECD, 2006). Such outcomes further motivate calls for improved student learning. In 2001, President George W. Bush enacted an amendment to the Elementary and Secondary Education Act of 1965 known as NCLB. NCLB became a new law that substantially increased testing requirements for states and set demanding accountability standards for schools, districts, and
states. NCLB established measurable adequate yearly progress objectives for all students, as well as for subgroups of students defined by socioeconomic background, race/ethnicity, and English language proficiency (Betebenner, 2002).

The National Center for Educational Statistics (NCES) reported that while 92.7% of students could understand basic scientific principles, only 57.9% could apply them, and an astounding 10.9% could analyze procedures or data (2002). “Having a basic knowledge of scientific principles is no longer a luxury but, in today’s complex world, a necessity” (Miller, 2007, p. 1). These statistics pose a significant concern in regard to the future potential of our students and the position of the United States in the global economy. These statistics indicate that our schools are not preparing students in the development of critical thinking and analysis.

The AAAS began Project 2061 in order to develop and promote science literacy with the understanding that a commitment focused solely on providing students with more science content is not an effective means of preparing learners to maximize their individual potential. AAAS found that teaching the foundations of science content more efficiently is of utmost importance (1989). Project 2061 revealed most Americans are not scientifically literate and as a result, U.S. students are outperformed by students in other nations in both science and mathematics (AAAS, 1989). AAAS benchmarks for science literacy have been used in the development of state standards.

Change often occurs slowly in public education since longstanding teaching practices are prevalent and deeply ingrained. Many teachers practice the type of instructional delivery that they had been accustomed to in their own experiences as students. Instructional programs in math and science lean on methodologies grounded in repetition and rote memorization of
disconnected facts in order to attain mastery. This type of teaching is deficient in quality pedagogy and mastery regarding the depth of knowledge critical to expand on the fragmented acquisition of basic knowledge.

Mlot (1997) examined 100 Westinghouse Science Talent Search students to determine their future careers. The results indicated that 60% of students who participated in the science competition did not pursue science as a career. On the other hand, students whose family members or mentors were scientists were more likely to pursue a career in science. Students reported poor teaching as the main reason for not pursuing a career in science. Furthermore, the majority of students (83%) agreed that a lack of quality inquiry teaching relevant to their everyday lives was the main reason for deciding not to enter into any science or engineering field (Mlot, 1997).

In a time when U.S. students continue to lack growth toward becoming scientifically literate, it is imperative to foster learning environments that nurture inquiry. Research on the implementation of an IBS program appears promising in that it promotes the use of research-based instructional practices and engages students in critical thinking. U.S. students must be prepared with strong foundational skills and the ability to apply content knowledge in science. The U.S. government has devoted extensive financial resources to research in curriculum design in the field of science. As a result of this funding, the NSES reliable and research-based set of standards can be utilized by every school. For educational reform to be successful, public policy must be created that requires state government to revise curriculum standards informed by the NSES. Science instruction must foster critical thinking and problem solving through inquiry and investigation. Rather than traditional cookbook lab experiments, science instruction must allow
students an opportunity to truly experiment and foster problem solving ability by tinkering with experimental conditions. In 2013, NGSS was authored by a consortium of 26 states facilitated as part of the “culmination of a 3-year, multi-step process jointly undertaken by the National Research Council (NRC), the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve, Inc., with support from the Carnegie Corporation of New York” (p. iv). The NGSS is an evolution from NSES and the result of years of research focused on three distinct and equally important dimensions of learning science: practices, crosscutting concepts, and core ideas.

U.S. public education maintains the responsibility to the nation to ensure that there is sustained improvement in the development of scientifically literate citizens in order for students to become internationally competitive global citizens, especially in the STEM fields. A focus and commitment is critical to science achievement in middle and high school if we are to prepare students for a rapidly changing and competitive technological society (Martin et al., 2004). The reform movement in science education has made a call to action for students to experience authentic teaching and learning opportunities (AAAS, 1989; NRC, 1996, 2000; NSTA, 2003). “Meaningful school reform must address the central unit of the entire enterprise, the classroom, and must seek to alter the ways teaching and learning have traditionally been thought to interact in that unit” (Brooks, 1999, p. 120).

The Current State of Science Education

The first step in solving any problem is recognizing that there is one and that we can do better. IBS encourages hands-on instruction rather than traditional textbook instruction. It also provides opportunities to remediate common misconceptions about science, observed even
amongst the brightest students. Students should be able to master science concepts through hands-on learning. IBS instruction calls for students to be able to correctly explain scientific phenomenon through open-ended investigation rather than replicated cookbook laboratory experiments and memorization of textbook facts.

Many science teachers have not made the paradigm shift to inquiry-based teaching and learning. Those teachers who have not made the shift need to tap into what students already know, focus on fewer topics, engage students in predicting outcomes, assess for deep understanding, and recognize failures as learning experiences and opportunities for ongoing assessment. The importance of developing scientifically literate citizens lies in the changing world around us that depends heavily on basic understanding of concepts and applications. The delivery of instruction has been controlled by teachers in an effort to quickly and efficiently impart knowledge that will be assessed by standardized tests. This is an unfortunate and unintended consequence of high stakes testing. Advocates of IBS have shared deep concern that students need to explore in order to truly understand material rather than merely memorizing it.

Teachers and school administrators continue to face enormous challenges with student performance on standardized testing. Many of these pressures hinge on student performance on basic skills tests in the areas of math and language arts. As a result, many schools have reduced the amount of time and resources devoted to other content areas, including science, in an effort to focus on test preparation in math, reading, and writing. Fragmentation of science from math and language arts has been a result rather than embracing an interdisciplinary approach to teaching math and reading skills through science content knowledge. High stakes testing has created a fragmented culture for learning. Teachers and administrators believe that our current system is
set up where the only way educators can support student achievement on assessments is by providing test preparation and the memorization of facts rather than engaging students in the exploration of science. Science must continue to be a priority in reform movements across our nation. Evidence from national and international assessments suggests that instructional practices designed as test prep only skim the surface and do not foster deep learning that may be transferred by the learner in authentic settings.

The 2005 NAEP results for science assessment showed no significant change in student achievement in grades 4 and 9, and a decline in performance at grade 12, since 1996 (Grigg, Lauko, & Brockway, 2006). U.S. students continue to lag behind international standards and underperform in science (Martin, Mullis, Gonzalez, & Chrostowski, 2004; Parker & Gerber, 2000; Roth et al., 2006; Stigler & Hiebert, 1999). According to the TIMSS, “standards in the USA lack the coherence, focus and level of demand that are prevalent across the world” (Valverde & Schmidt, 2000, p. 652). This study also indicates that by eighth grade, U.S. students “scored only slightly above the national average in science among the 41 countries involved” (Martin, 2010, p. 53). There is no absolute method of identifying a direct correlation between the inadequate performances by middle school students. However, the data conveys a clear message:

our current science education in the United States is failing to provide our students with the comprehensive science education that they need to thrive in a highly competitive and technical world. (Martin, 2010, p. 53)

Thomas Friedman, New York Times columnist and author of The World is Flat, highlights a need for the United States to shift toward preparing our country to compete globally,
economically, technologically, and scientifically in a rapidly changing world. The future is bleak for U.S. competition in the field of science and engineering. Friedman (2005) cites research from the NSF indicating that approximately half of U.S. scientists and engineers are at least 40 years old and this average is steadily climbing. Furthermore:

The proportion of scientists and engineers in the U.S. labor force over age 50 increased from 20% in 1993 to 33% in 2010. The median age of such individuals was 44 years in 2010, compared to 41 years in 1993. (NSB, 2014, p. 3.6)

NASA employees younger than 30 years of age currently account for only 5% of the workforce (NRC, 2007). Alternatively, NASA employees over 50 years of age outnumber those under 30 by three times (NRC, 2007). These figures indicate an expanding dilemma for an already thin sector of the engineering workforce with retirement looming on the horizon. As a result, NASA has established Explorer Schools across the country in an effort to attract more students to careers in STEM. NASA’s Explorer Schools are committed to inquiry in all branches of learning science and have found inquiry to be as effective in the subjects of technology, engineering, and mathematics as it is in life sciences. Even more disconcerting, U.S. students have not been able to compete internationally on performance measures in the STEM fields (Grigg et al., 2006; Lemke & Gonzales, 2006). More specifically, female students and low-income, minority students lack understanding of science and scientific inquiry skills (Grigg et al., 2006; Lemke & Gonzales, 2006; USDOE, 2006). Furthermore, as referenced in the Condition of Education 2006, males were found to outperform females at all three grade levels tested (USDOE, 2006). Among culturally diverse learners and females, scientific literacy was even less prevalent (AAAS, 1989; USDOE, 2006).
The U.S. public education system has faced numerous pressures because of the lack of workforce representation and poor math and science achievement. As a result, public education has experienced an upsurge of increased standards, high stakes testing, and higher teacher accountability (NRC, 1999). Unfortunately, many teachers feel they are required to focus their attention on teaching to the test. Bruner (1971) cautions educators on the dangers of such a focus:

A method of instruction should have the objective of leading the child to discover for himself. Telling children and then testing them on what they have been told inevitably has the effect of producing bench-bound learners whose motivation for learning is likely to be extrinsic to the task—pleasing the teacher, getting into college, artificially maintaining self-esteem. The virtues of encouraging discovery are of two kinds. In the first place, the child will make what he learns his own, will fit his discovery into the interior world of cultures that he creates for himself. Equally important, discovery and the sense of confidence it provides is the proper reward for learning. (pp. 123-124)

Likewise, teachers possess limited scientific knowledge, limited instructional resources, larger class sizes, and increased pressure due to high stakes testing and achievement in science (NRC, 1999). Instructional approaches toward coverage of material have been influenced by these developments. Many teachers also lack the instructional strategies or content background necessary to give them confidence to effectively teach (NRC, 1999a). Middle school science teachers often possess inadequate pedagogical skills to implement the Standards that include major inquiry components (Basista, Tomlin, Pennington, & Pugh, 2001). Teachers resort to the type of instruction they are familiar with from their experiences as students in pre-college and college programs. Teaching is sustained at a surface level to dispense a voluminous amount of material without understanding and deep content knowledge. Unfortunately, this approach is a trap with no development of scientific skills (NRC, 1999).
Most curricula are constructed with fairly rigid timelines and broad scope and sequence. The amount of content and the prescribed timelines make it impossible to provide learners with appropriate time for intellectual development but foster standardization and broad coverage of material (Brooks, 1999). Establishing rigid timelines is problematic for teaching and learning. Research by Duckworth (2006) indicates that rigid timelines prevent learners from forming meaningful theories about how the world works. In addition, these timelines inhibit students and teachers from developing an appreciation of knowledge and understanding (Eisner, 1985) and the development of an approach to an inquiry mindset (Katz, 1985). The current state of fragmented curricula has made the prospect of encouraging inquiry in the classroom impossible. Even learning science has become highly specialized and departmentalized with little connection between disciplines. The ability to solve complex problems requires an ability to tap into prior knowledge and apply that which an individual knows to a new, authentic situation. The transfer of learning is assumed by many teachers to occur automatically after the acquisition of basic knowledge (Brooks, 1999). However, a survey of high school graduates suggests that this acquisition of base knowledge only occurs in the short term and that transfer to new, authentic situations occurs only sporadically (Ravitch & Finn, 1987). The majority of developed curricula include more information than necessary with too many time constraints to accomplish learning goals (Brooks, 1999). There is a true need to apply the recommendations from the existing body of research assembled over several decades about how people learn in order to coordinate systemic initiatives to construct a better educational system that enables all students to achieve at the highest level.
Howard Gardner (1991b) contends that although schools appear to be successful because of the high marks they achieve, they still fail to achieve the most important mission. Gardner argues that successful students do not demonstrate competence in their level of understanding concepts. This proclamation is consistent with findings from *A Private Universe* where recent graduates of elite universities, such as Harvard and MIT, could not accurately describe the changing seasons despite receiving one of the most privileged educations in the world.

A study was conducted that examined academic preparation and the role of IBS instruction (Welch, Klopfer, Aikenhead, & Robinson, 1981). They determined that although science educators used the term inquiry they were uncertain of its meaning. Teachers viewed inquiry positively despite a true understanding of the concept. Nonetheless, little evidence exists that inquiry is being used in classrooms (Hurd, Bybee, Kahle, & Yager, 1980).

Martin Brooks provides evidence as to how current teaching practices do not embody inquiry but are chiefly dominated by traditional approaches. Classrooms in the United States are dominated by teacher talk (Flanders, 1973; Goodlad, 1984). Most of the interactions in U.S. classrooms occur from teacher to student where students are passive recipients of information and are expected to simply recount knowledge. Teachers disseminate information to students directly from textbooks without incorporating other resources, experiences, or viewpoints (Ben-Peretz, 1990). Cooperative learning has gained notoriety in recent years with increasing interest by many schools in facilitating learning environments that encourage students to work collaboratively. Despite this interest, not much has changed in how students are taught. In many instances, educators continue to design instruction with students working in isolation and on low-level tasks such as worksheets (Brooks, 1999). Learning in the ubiquitous traditional classroom
is dominated by students identifying the right answer rather than creating learning environments that foster student thought (Brooks, 1999). Finally, U.S. schools are grounded in the assumption that learners must acquire a body of knowledge and be able to make evident that they have successfully accomplished this goal (Brooks, 1999).

Teachers today are overly dependent on textbooks to present topics as a laundry list of items in an attempt at coverage. There is often little or no regard for connecting themes and thus miss the opportunities to establish relationships. Hence, this approach becomes nothing more than a collection of disjointed facts with the learners’ inability to see the big picture (Schmidt & Valverde, 1998). In sum:

As a result, when a student is not able to recall immediately a concept or procedure, often in a situation free of any context such as a drill-and-practice exercise, this is interpreted as a lack of mastery. One consequence is that the same procedures and content are re-taught each year, often with minimal improvement in student outcomes. Another consequence is that, when mastery is a major goal yet students fail to achieve it, new concepts and procedures are delayed or not taught at all. Instead, as students are exposed to an annual cycle of repeating what was previously taught, they lose motivation as well as denied access to higher-level concepts, procedures, and problems. Students who are slower to gain skills early are especially hard hit by this practice because the impact of denied access to new concepts begins so early and accumulates over time, causing these students to fall farther and farther behind. (NRC, 1999, p. 6)

Time may be the most important commodity in public education. Coherent instruction must build upon prior knowledge with multiple entry points to address student preconceptions and maximize learning time.

**Constructivism**

Gardner (1993) shared with Brandt in an interview, “The greatest enemy of understanding is coverage. As long as you are determined to cover everything, you actually ensure that most kids are not going to understand” (Brandt, 1993). Constructivism differs
significantly from the long-standing traditional methods of teaching in U.S. schools (Brooks, 1999). Since the inception of public schools, students have been exposed to learning environments as a mimetic activity that involves students repeating, or miming, new basic information (Jackson, 1968). In 1938, John Dewey argued that education at that time hindered the development and curiosity that occurs naturally in children. Dewey concluded that schools assign to students what they might want to do in the future rather than take their individual interests and abilities into consideration when structuring learning opportunities (1938). Education should be viewed “as a process of living and not as preparation for future living” (Dewey, 1959, p. 30).

Jean Piaget is recognized as one of the great pioneers of constructivist theory. He dedicated a great deal of his life’s work to cognitive development and the formation of knowledge. In his research, he conducted observations of his own children and also identified similar patterns in other children. Piaget concluded that there were parallels between his children and other children in relation to intellectual tasks. He asserted that children use different mental structures to think about and make sense of their world (Piaget, 1971). Piaget believed that what enables a child to be ready to learn hinges on biological readiness and life experiences. Learners construct their own knowledge and this process is not static but a continual construction (Piaget, 1971). Forman and Kuschner (1977) expand on this theory by describing how Piaget would explain knowledge not as rote memorization of the rules to the game of baseball but rather an understanding of how to navigate the rules in order to maximize success in the game.

Lev Vygotsky is recognized for his theory of social constructivism in which he believed that learning and development is a collaborative process. His theory concluded that children must
interact with the social environment and internalize the experience for learning to occur (Vygotsky, 1978). His contributions include the zone of proximal development where “it is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). This important concept elaborates on the notion that students can achieve at a higher level with the appropriate support such as mentors or peers. Assistance from social interaction enables students to better comprehend concepts rather than learning on their own. He believed that students should think independently and develop their own understanding of concepts as opposed to utilizing rote memorization and acceptance of others’ ideas. Transformation occurs when students are capable of processing new information and reorganizing it to construct new understandings (Jackson, 1986; Gardner, 1991).

Jerome Bruner, influenced by Piaget’s work, describes constructivism as a learning theory with an “emphasis on discovery ... helps the child to learn the varieties of problem solving, of transforming information for better use, helps him to learn how to go about the very task of learning” (1960, p. 87). He suggested that factors such as language and prior experience are more closely associated with the development of new structures than is the quest for cognitive equilibrium (Bruner, 1964). Bruner suggested three primary principles for learning: 1) children must be ready to learn and instruction should be focused on the child’s experiences and contexts that make him willing to learn; 2) curriculum must be spiraled so instruction may revisit basic ideas and build upon them for the learner to develop their own understanding of concepts; and 3) instruction should be designed in an effort to extend learning beyond the information
Bruner’s theoretical contributions to constructivism advocated for learning as an active process, complete with discovery experiences, and inclusion of active dialogue between teacher and student rather than student as a passive learner.

Gardner’s Theory of Multiple Intelligences, from his book titled *Frames of Mind* (1983), highlights the various modalities of how people learn such as auditory, visual, kinesthetic, and logical. Gardner asserts that a topic taught in multiple ways reaches a broader audience of learners. He writes:

Additionally, the multiple modes of delivery convey what it means to understand something well. When one has a thorough understanding of a topic, one can typically think of it in several ways, thereby making use of one’s multiple intelligences.

Conversely, if one is limited to a single modality, one’s own understanding is likely to be unsettled. (Gardner, 1983)

Gardner advocates for learning environments to be structured around active participation where students are awarded opportunities to recreate things. Learning should be more than a good grade on an exam. Moreover, learners should experience a thorough review of data for analysis and make predictions based on the findings they discover. Students must learn to think scientifically by creating a hypothesis and testing it. By learning through conducting science experiments and observing results, students can focus on process rather than just memorization of content. Content should be the medium to teach scientific process regardless of the subject matter being discussed. Student-centered learning must extend beyond mere memorization and has the promise of sticking for long-term understanding rather than short-term recitation of facts. Gardner believes that this type of learning atmosphere appeals to multiple intelligences by not
treating everyone the same way and reaching every child. Coverage of material only achieves superficial knowledge that is quickly forgotten.

Adopting a constructivist theoretical framework to teaching and learning requires a monumental pedagogical shift that demands extensive support for educators. Brooks (1999) highlights the following most effective practices teachers can implement that cultivate learning environments supported by constructivism:

1. Constructivist teachers encourage and accept student autonomy and initiative
2. Constructivist teachers use raw data and primary sources, along with manipulative, interactive, and physical materials
3. When framing tasks, constructivist teachers use cognitive terminology such as “classify,” “analyze,” “predict,” and “create”
4. Constructivist teachers allow student responses to drive lessons, shift instructional strategies, and alter content
5. Constructivist teachers inquire about students’ understandings of concepts before sharing their own understandings of those concepts
6. Constructivist teachers encourage students to engage in dialogue, both with the teacher and with one another
7. Constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other
8. Constructivist teachers seek elaboration of students’ initial responses
9. Constructivist teachers engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion
10. Constructivist teachers allow wait time after posing questions

11. Constructivist teachers provide time for students to construct relationships and create metaphors

12. Constructivist teachers nurture students’ natural curiosity through frequent use of the learning cycle model. (Brooks, 1999, pp. 103-116)

Constructivist theory considers multiple viewpoints from students as opportunities to connect their preconceptions to new understandings. Constructivism depends on a climate where learners may construct personal meaning from their own point of view within the classroom (Correiro, Griffin, & Hart, 2008). When students learn new content, they connect new knowledge to their prior knowledge or reconstruct their deeply held misconceptions based on this new information (Lambert, Walker, Zimmerman, & Cooper, 2002). The term misconceptions (Lochhead, 1988) has been referenced in cognitive research to examine engaging students to change their minds, or construct new understandings, about how to think about new ideas. It is important for students to build their own understanding of new ideas based on their prior knowledge. Unfortunately, teaching and learning in many U.S. schools maintains a narrow curriculum with only one correct answer to a question. Brooks cites research by Hunt and Sullivan (1974) that states, “If an educational system has only universal goals and a limited variety of educational approaches, it is not surprising that the results for many students will end in failure” (p. 45). Change in the curricular and instructional approaches are necessary now if we are to expect to provide our students with authentic learning opportunities that will cultivate original and independent thought.
Inquiry Instruction

“Inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (NRC, 1996, p. 31). Three statements summarize the NRC synthesis of research:

1. Students bring to the classroom individual preconceptions about how the world works that affect learning; 2. Developing competences in the area of inquiry require: a) a foundation of factual knowledge, b) understanding facts and ideas in the context of a conceptual framework, and c) organizing knowledge for retrieval and application; 3. Helping students learn to take control of their own learning by defining goals and monitoring their progress in achieving them. (NRC, 1996, p. 31)

Dewey asserted that children should experience science and not be passive vessels of knowledge (1910). He believed that inquiry-based learning should focus on understanding scientific processes through the study of content and the cultivation of formulating habits of mind through developmental thinking (Dewey, 1910). Dewey attributed the term habits of minds as a way of thinking that promotes scientific reasoning skills, a critical component of inquiry-based learning (1910).

It is through investigations at the students’ own rates and levels of ability that learning takes place (Chiappeta, 1997). On the other hand, in scientific inquiry, content becomes the focus over process. The teacher utilizes questioning strategies to guide the instruction, directing student learning toward development of understanding of main concepts or principles of science that explain the phenomena. Students are then able to apply newly constructed knowledge and skills
to authentic situations with an understanding of how all concepts are interconnected (Kluger-Bell, 2000).

The NSTA encourages all science teachers to incorporate inquiry learning into their teaching practices at all grade levels. The NSTA views inquiry teaching practices as integral in the development of problem solving skills. The NSTA defines scientific inquiry as,

The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NSES, 1996, p. 23)

Cartier and Stewart define inquiry as the process by which knowledge is generated and justified (2000). Upon further examination, scientific inquiry is specifically focused on discovery learning of the natural world (Welch et al., 1981). Bruner (1971) writes:

It is my hunch that it is only through the exercise of problem solving and the effort of discovery that one learns the working heuristics of discovery; the more one has practice, the more likely one is to generalize what has been learned into a style of problem solving or inquiry that serves for any kind of task encountered—or almost any kind of task. Of only one thing am I convinced: I have never seen anybody improve in the art and technique of inquiry by any means other than engaging in inquiry. (Bruner, 1971, p. 94)

A large body of research provides substantial evidence for the implementation of inquiry teaching practices in schools. Despite these findings, separate studies indicate that most teachers
are still using traditional, didactic methods (Harms & Yager, 1981; Seymour, 2002; Unal & Akpinar, 2006). Incorporating inquiry into the classroom environment is not in alignment with the significance of the literature (Aoki, Foster, & Ramsey, 2005). Despite the evidence correlating IBS instruction with increased achievement, many teachers are still resistant to such changes in pedagogy. Research reveals that an inquiry-based approach improves student interest and science achievement across all ability groups (Walker, 2007).

Curriculum programs that are developed based on standards and benchmarks should make clear connections between lessons and units in order to foster the increasingly rigorous development of ideas possible by students engaged in learning. Connections can best be made among ideas and skills that are well understood and extend beyond memorization of facts, not limited to a low level of cognitive ability with a focus mainly on knowledge and comprehension. Low-level cognition will not lead to depth of understanding. On the other hand, curriculum programs should be designed with fewer topics in mind, where the teacher can devote time and energy on cultivating a greater depth of understanding and fostering richer, meaningful discussions around main ideas.

Research findings indicate that students must acquire foundational knowledge prior to learning content using an inquiry approach (Fisher, Grant, & Frey, 2009). This study highlights student development of foundational knowledge as one of the most significant prerequisites for learning science (Fisher, Grant & Frey, 2009). The two main goals of science instruction should be to teach for understanding and the application of knowledge (Krajcik & Marx, 2000). An approach that deviates from inquiry results in a collection of science facts that are memorized and disconnected from authentic, real world context. Memorization should not be the
predominant mode of teaching, especially in the field of science where the ability to develop problem solving skills is paramount. Scientists are required to effectively frame and find problems, ask appropriately relevant questions, and design methods for collecting information that will lead them to meaningful solutions. These skills can only be taught through inquiry in order to prepare our learners for important careers in research, medicine, and engineering.

Learning science can be abstract and complex therefore students benefit from engaging with and manipulating objects related to the scientific topics they are learning. Doing so enables students to develop a relationship with the science topics that makes learning abstract content more concrete for learners (Guzman & Bartlett, 2012). Traditional, didactic lecture methods tend to be less effective as students exhibit an inability to apply scientific knowledge and forget what they have learned (Friedlander & Tamir, 1990). Traditional, didactic instruction is effective when teaching higher functioning students (Rossi & Mustaro, 2013). It was found that the use of traditional, didactic instruction with an inquiry-based approach allowed lower functioning students to discover ways to learn and retain information (Foster, 2011). Incorporating these skills into science instruction on a regular basis can establish connections for learners between content that is familiar and concrete and curriculum that is unfamiliar and abstract (Bell, Mulvey, & Maeng, 2012). Additionally:

The assumption has been made that students must demonstrate proficiency in low-level skills before engaging interesting and challenging ideas and problem solving. In such a system, a student with gaps in low-level skills or computational proficiency is highly unlikely to succeed. A well-developed, coherent curriculum program not only is designed to take advantage of important previous knowledge but to have multiple entry points to allow students who may have gaps in their previous knowledge to participate and learn rigorous content. At least one NSF-funded curriculum project is built on this premise, with units that evolve to increasing levels of rigor and sophistication with entry points for students with less than complete prior experience. All students have opportunities to be
Designing and implementing curriculum materials that engage students in inquiry allows educators to make learning accessible for all students regardless of their background knowledge. Actively engaging students in investigations, as real scientists do, empowers them to apply their knowledge to new concepts with a common set of concrete experiences. According to the NRC (1999), although ideas and activities may build on previous activities, each new investigation presents new opportunities for students with gaps in their past experience to contribute to the team or class solution to the investigation. Students who may have less comprehensive prior knowledge can still attain an acceptable level of understanding, especially since the concrete experiences of the investigations enables students to learn through application of concepts.

*How People Learn: Bridging Research and Practice* by the NRC (NRC, 1999) provides several key findings that contribute to the seminal works as it relates to the literature. *How People Learn* explains that students arrive ready to learn with preconceptions about how their world works (NRC, 1999). Students’ understanding is developed by their experiences with the natural world. At times, their understanding may be accurate, but often they possess misunderstandings about the world around them. Students may fail to learn new concepts if their initial understanding is not engaged (NRC, 1999). Additionally, students may learn new concepts for taking a test but return to their long-held preconceptions. Students must possess deep foundational knowledge with an understanding of ideas, and an organization of knowledge in a way that supports retrieval and application, in order to develop a competent level of inquiry (Donovan, Bransford, & Pellegrino, 1999). According to Rodger Bybee (1997), students bring their current explanations, attitudes, and abilities to the learning environment. Students bring a
wide range of different experiences, attitudes, and abilities to the classroom that are critical components for understanding new concepts. Inquiry-based instruction allows students the opportunity to investigate, reevaluate, and construct new knowledge with a personalized approach to their preconceptions at their own pace.

Science reforms recommend inquiry instruction and associated features. Reforms recommend that students engage in inquiry and construct artifacts, with students finding solutions to real problems by actively asking and refining questions, designing and conducting investigations, gathering and analyzing data, making interpretations, and drawing conclusions (Krajcik, Blumenfeld, Marx, & Soloway, 2000). Through interactions in the learning environment and inquiry-based experiences, challenging the students’ current preconceptions provides opportunities to reconstruct their knowledge. According to How People Learn, “a metacognitive approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them” (NRC, 1999).

**Inquiry and Achievement**

*The Process of Education* (Bruner, 1960) describes inquiry as the process of discovery where students find solutions to problems through scientific investigation. This is the method of choice for classroom instruction but has faced many obstacles, especially in the world of high stakes testing. We have not yet achieved the goals and vision set forth by *Science for All Americans* (AAAS, 1989). Students continue to underperform in science (Martin et al., 2004; Parker & Gerber, 2000; Roth et al., 2006; Stigler & Hiebert, 1999). A review of NAEP since 1996 indicates a slight increase in fourth grade science performance. However, U.S. students’
science achievement has declined by the time students leave high school (USDOE, 2006). In 2005, only 29% of grade 4 and grade 8 students were at or above proficient in addition to only 18% of grade 12 students (USDOE, 2006). These results indicate declines from results in 1996 (USDOE, 2006).

Meta-analysis research was conducted on 105 experimental studies dealing with the effects of new science curricula vs. traditional science curricula on student performance (Shymansky, Kyle, and Alport, 1983). Researchers defined new science curricula as having the following characteristics: (a) developed after 1955; (b) emphasizing the nature, structure, and processes of science; (c) integrating laboratory activities as an integral part of the class routine; and (d) emphasizing higher cognitive skills and appreciation of science. Traditional curricula were defined as: (a) having been developed or patterned after a program developed prior to 1955; (b) emphasizing facts, laws, theories, and applications; and (c) using lab activities as verification exercises or as secondary applications of previously covered concepts. The researchers found that the new curricula had a positive impact on student performance criteria in the areas of achievement, process skills, analytic skills, related skills such as reading and math, and creativity and logical thinking (Shymansky, Kyle, and Alport, 1983).

A study conducted at Ohio's Statewide Systemic Initiative (SSI) examined the impact of various inquiry-based teaching practices on the urban achievement of African-American seventh and eighth grade students. Professional development was provided to the treatment group of eight teachers. Alternatively, a similarly matched control group of teachers did not participate in professional development and implemented traditional instructional practices. Results from questionnaires and achievement tests indicate that teachers who frequently used inquiry-based
teaching methods positively influenced the students' science achievement and attitudes, especially the boys (Kahle, Meece, & Scantlebury, 2000). A separate longitudinal study involved collecting scores on the Discovery Inquiry Test (DIT) in science over a 3-year period. Results from this study indicate that inquiry-based teaching practices increase student achievement and close achievement gaps for all students (Johnson, Kahle, & Fargo, 2006). A body of research correlates an increase in achievement with IBS practices (Escalada & Zollman, 1997; Freedman, 1997; Johnson, Kahle, & Fargo, 2006; Kahle, Meece, & Scantlebury, 2000; Mattern & Schau, 2002; McReary, Golde, & Koeske 2006; Morrell & Lederman, 1998; Okebukola, 1987; Oliver-Hoyo & Allen 2005; Parker & Gerber, 2000).

A study by O’Donnell on the effectiveness of IBS programs examined data from the NAEP Data Explorer. The findings concluded that the more often fourth grade teachers reported conducting hands-on activities with their students, the more likely these students were to score at or above basic on the NAEP assessment (O’Donnell, 2007). O’Donnell also found that in a study of North Carolina students, eighth grade students demonstrated an increase in performance. This study found that the more often teachers reported doing hands-on activities with their students, the more likely these students were to attain higher scale scores on the NAEP assessment for both reading and math (O’Donnell, 2007). O’Sullivan & Weiss (1999) found that the more often teachers reported doing hands-on activities with their eighth grade students, the more likely they were to score at or above proficient on the NAEP science assessment than students who rarely did hands-on activities. As a result, for students who participate in hands-on activities, a critical component of inquiry-based learning, academic success is more likely in science, and the skills
extend into other subjects, causing higher scores on assessments in other subjects as well (O’Donnell, 2007).

School districts in Green Bay, Wisconsin attained positive results after implementing *Science and Technology Concepts* (STC) kits as their curriculum and instructional methods. The Einstein Project 2007 Study at the University of Wisconsin-Green Bay implemented IBS modules with fourth grade students in 21 area school districts. The study examined the effects of these kits on students who engaged in learning with inquiry materials and methods as opposed to a separate group that did not use these kits but learned the science content with the traditional, textbook-driven method (The Einstein Project, 2005). A comparison of test scores between districts that used STC kits and those that did not was conducted and statewide averages were examined. After using the STC modules for 4 consecutive years, students using STC scored higher than students in districts that did not use STC (The Einstein Project, 2005). Research results also indicated that students using IBS surpassed the statewide average on the Wisconsin Knowledge Concept Exam (WKCE) (Ashmann, 2007). Furthermore, the findings show that female students, students with disabilities, students with limited English proficiency, and Asian students in the test group significantly outperformed the control group.

In the second study, the Einstein Project’s Cornerstone Study, students taught with inquiry-based methods (STC kits) were compared to five control schools that were not using inquiry-based methods. It was found that 81% of students who studied via inquiry methods demonstrated mastery of science beyond rote memorization compared to only 20% of students receiving traditional, textbook-driven instruction. The IBS students also exhibited a statistically significant increase (4%) between pretests and posttests and did better on both written and group
performance assessments compared to the control group. Similar results were found in school
districts in Fresno, California. Students exposed to IBS materials in fifth grade for more than 4
years demonstrated significantly higher scores on the Stanford Achievement Test Ninth Edition
(SAT 9) standardized statewide student performance assessment in reading and science tests in
the state of California (Vladez, 2002). A separate study at the Alabama Math, Science, and
Technology Initiative (AMSTI) compared a set of schools that used STC and other IBS
programs. This study also included an examination of intense professional development provided
to teachers and accounted for comparable demographical groupings as a control. Research
findings from this study indicated that students exposed to IBS programs scored better on
assessments than students who received traditional science instruction (University of Alabama,
2004).

In 2005, Young and Lee found that nearly 400 fifth graders in Rhode Island who received
inquiry, kit-based instruction in schools with teacher professional development scored
significantly higher than a demographically matched group in a non-kit school without teacher
professional development (2005). Furthermore, this study indicated that students in the treatment
group scored significantly higher than students receiving traditional forms of instruction. It is
important to note that this study revealed positive results for IBS classrooms even though
traditional classrooms received more minutes of science instruction.

Washington LASER is a public/private partnership launched in 1999 by the NSRC and
connected to the NRC. LASER supports school districts through research and best practices in an
effort to increase student learning and achievement. Findings from the study indicated that IBS
programs had a positive impact on student achievement (Schatz, Weaver, & Finch, 2005).
Students exhibited a significant positive relationship between the amount of professional development teachers participated in that supported inquiry instructional practices and the percentage of fifth grade students who met the science standard on the 2004 WASL. Additionally, schools that implemented to a high degree the classroom practices promoted by Washington State LASER did better than the low-implementing schools at meeting the needs of students who qualified for free or reduced-price lunch, based on the pretests and posttests (Schatz, Weaver, & Finch, 2005).

Students receiving IBS instruction in Imperial Valley Public Schools, California outperformed their classmates who had traditional, textbook-based science instruction despite the majority of the student population received free/reduced-price lunches and nearly half of the population was comprised of English language learners (Klentschy, 1999, 2004). Results from the SAT convey that students enrolled in inquiry-based programs for an extended duration of time perform better on nationally-normed science, writing, and mathematics tests.

Shamansky’s (1990) analysis of 81 studies compared the effectiveness of hands-on elementary science instructional programs compared to traditional, didactic instruction. Findings concluded that the students exposed to hands-on instruction scored 1.4 standard deviations higher than the control group. In a separate study, Wise (1996) compared 140 studies of IBS education and traditional teaching in middle and high schools. This study indicated that students who learned through inquiry-based instruction realized an average 13% increase in achievement scores over students who learned through traditional instruction. Finally, a longitudinal study of nearly 25,000 students by Stohr-Hunt (1996) found that students who frequently participated in
hands-on science instruction demonstrated significantly higher levels of science achievement than those who did not.

A study examining the effects of an IBS curriculum unit on diverse populations compared five randomly selected schools in Maryland to five control schools when implementing a chemistry program. Results from this study concluded that the treatment group outperformed the control group on the administered assessments (Lynch, Kuipers, Pyke, & Szesze, 2005). In a separate study, students in fourth and seventh grades in three Philadelphia middle schools were engaged in inquiry-based instruction and their assessment results were compared to students who received instruction through traditional methods. Student achievement scores on standardized assessments were higher for students in the experimental group. In addition, the student achievement gains correlated with the number of years that students received instruction through inquiry methods (Ruby, 2006). In a study conducted in southwestern Pennsylvania, 50 school districts followed the NSRC model for science education reform under the leadership of Pittsburgh-based ASSET Inc., a nonprofit educational leadership group. An analysis of TIMSS results indicated that students who engaged in IBS in these districts performed better than their peer group in the United States and their performance results were comparable to those of students from the highest scoring nations internationally (Raghavan, Cohen-Regev, & Strobel, 2001; Davison & Raghavan, 2000).

Finally, the Center for the Study of Testing, Evaluation, and Education Policy (CSTEEP) at Boston College conducted an independent evaluation of IBS curricula (Pedulla, 2002). Students received instruction through the use of STC/MS, the same materials utilized in this study. Pedulla concluded that, through the findings of the study, students demonstrated
statistically significant performance compared to more traditional instructional approaches in the control group. Findings from student assessments indicated that students in the treatment group outperformed national and international groups. There exists a relationship between hands-on learning and student academic outcomes. Research by Guzman and Bartlett also suggests that a hands-on approach to lab experiments is a means to improve student achievement, especially in science education (2012). This study seeks to examine the effects of STC/MS on student achievement and the mediating effects of self-concept on academic outcomes.

**Inquiry and Academic Self-Concept**

There exists a longstanding belief that student success hinges on the level of student engagement in a classroom and a student’s attitude toward learning. Ornstein’s (2006) study encompassed a review of classrooms from across the United States. This analysis concluded that learners must develop an appreciation for science and establish an understanding of scientific principles present in everyday life. In order for students to become scientifically knowledgeable adults, schools must create learning environments that cultivate deep foundational knowledge and critical thinking skills. Adults must be capable of leaning on their understanding of the scientific world when reading or listening to current issues, debating relevant topics, or making informed decisions in society about the impact of scientific issues on the environment, medical issues, or politics. The most effective approach to increasing appreciation for sciences is through the implementation of the inquiry method (Ornstein, 2006). This approach also enables students to remain engaged in scientific study longer throughout adolescence. If students are able to advance into later stages of their education with a passion and enthusiasm for science, they may determine that they are interested enough in a particular field of science to pursue it as a college
major and possible careers in STEM. This philosophical approach runs counter to the current state of traditional scientific instruction where learners are required to memorize facts. Educators have observed students become more disengaged through traditional methodology.

There exists a positive attitude toward the importance of inquiry-based instruction. However, implementation of inquiry practices has been scarce despite support for and belief in its value. Never has there been a more important time in education to incorporate inquiry practices to ameliorate declining motivation in adolescents. Studies have shown that motivation decreases over time in children, particularly in content areas such as math and science (Anderman & Young, 1994; Hidi & Harakiewicz, 2000). Many students’ attitudes toward science begin to decline during middle school (Simpson, Koballa, Oliver, & Crawley, 1994). Declining motivation is especially evident for students who have experienced academic struggles (Anderman & Young, 1994), and students with learning challenges can easily become disengaged and unmotivated. Student engagement may be affected by individual students’ motivation or lack thereof (DeBacker & Nelson, 2000). Bandura (1986) contended that learners’ perceptions of their own ability must be matched to criteria outcomes. Student engagement is comprised of multiple variables including an individual’s perception of personal competence. In order to create environments that bolster student engagement, teachers must establish relevance for the topic of study, cultivate collaboration in the classroom, and coordinate the students’ preconceptions with curricular goals.

Motivation is defined in How People Learn as essential for student learning (Bransford, Brown, & Cocking, 2000). Learning requires effort and energy, and motivation depends on students’ background and can be changed (Bransford, Brown, & Cocking, 2000). Dewey (1938)
suggests students will become more engaged if the learning environment is nurturing and learners have the ability to construct their own knowledge. Bruner (1960) refers to motivation as an interest in the content area as the best stimulus for learning.

Self-concept is described as a person’s perception of himself (Shavelson et. al., 1976). Fromm (1956) clearly described self-concept as life being aware of itself. Rosenberg (1979) explained self-concept as the “totality of the individuals’ thoughts and feelings having reference to himself as an object” (p. 9). Byrne (1984) defined self-concept as attitudes, feelings and knowledge about abilities, skills, appearance, and social responsibility. Kurtz-Costes and Schneider (1994) broadly define academic self-concept as children’s views of themselves as learners. Skaalvik and Valas (1999) describe academic self-concept as the general feeling of doing well or poorly in a particular subject area.

Purkey (1988) identifies self-concept as consisting of at least three major qualities of interest: 1) it is learned; 2) it is organized; and 3) it is dynamic. He states that self-concept is learned and it is shaped and reshaped through repeated perceived experiences. Purkey (1988) also describes self-concept as organized, requiring consistency and stability, and tending to resist change. Self-concept development is a dynamic and continuous process where there is constant assimilation of new ideas and expulsion of old ideas throughout life (Purkey, 1988). Students who exhibit confidence in science but do not value science may not devote themselves to their potential in the subject. Changes associated with an adolescent’s social and biological development during the middle school years influence students' self-beliefs. In early adolescence, students' self-concepts of ability often begin to decrease (Wigfield, Eccles, MacIver, Reuman, & Midgley, 1991). This decline is especially evident beginning in sixth and
seventh grades (Anderman & Maehr, 1994). Wigfield et al. (1991) conclude that many students regain their loss in self-confidence during the later adolescent years, but other students continue to decline and do not regain previous levels of self-beliefs.

A person’s attitude, like self-concept, has an evaluative component and can influence achievement (Weinburgh & Englehard, 1994). Self-concept has been examined and determined to exhibit motivational properties that directly impact academic achievement (Byrne, 1984; Marsh, Byrne, & Yeung, 1999). Farrell and Johnson (1998) indicate a positive relationship between academic self-esteem and achievement where one’s self-concept in academic outcomes acts as a predictor of academic performance (Smith, Sapp, Farrell, & Johnson, 1998).

Self-concept is a hierarchical system of self-beliefs, each level divided into more specific components of self-concept (Marsh, 1990). Closer examination of motivation leads one to a review of self-concept defined as beliefs about one’s competence in a specific domain (DeBacker & Nelson, 2000). Upon further analysis, the idea of academic self-concept can be grouped into two distinct categories: cognitive (math, science, etc.) and non-cognitive (i.e., attentiveness to work, academic responsibility). Academic self-concept refers to the judgments of self-worth associated with one's self-perception across content areas. Academic self-concept is essential for student success because one’s decision to commit oneself to individual learning and higher education influences future economic outcomes for self and for the national workforce (Trusty, 2000). Wei-Chang (2003) concludes that self-concept has an impact on career aspirations in math and science careers, and higher levels of self-concept can lead to better job satisfaction and lower unemployment (Pinquart, Juang, & Silbereisen, 2002). Raimy (1948) introduces measures of self-concept in counseling interviews. He argues that one’s self-concept
could be altered in how one sees himself. Self-concept influences academic outcomes across domains (Skaalvik, 1997). Students have been shown to not take pride in their performance even though they perceive themselves to be confident about how well they achieve in science (Pajares, 1996).

A broad range of studies have indicated that teaching through IBS has positive effects on students’ science achievement, cognitive development, laboratory skills, science process skills, and understanding of science, compared to students who have been taught via traditional, didactic approaches (Cartier & Stewart, 2000; Chin & Tsai, 2004; Gibson & Chase, 2002; Talton & Simpson, 1987; Tuan, Russell, & French, 2002). Research has also concluded that students who learn through inquiry maintain more positive attitudes toward science (Gibson & Chase, 2002; Russell & French, 2002; Talton & Simpson, 1987; Tuan, Chin, & Tsai, 2004). Studies by Pintrich and Schunk (2002) suggest that if students are motivated, then they will approach learning tasks with feelings of efficacy and interest. The researchers explain that cognitive engagement hinges on the quality of motivation in order for learners to use metacognition in their learning (Pintrich and Schunk, 2002). Education reform in science calls for the use of teaching practices that inspire students to construct their own understanding in an effort to develop deeper learning. These reform initiatives are intended to enhance motivation and cognitive engagement through elements such as variety, authentic tasks, and opportunities to collaborate (Blumenfeld, Kempler, & Krajcik, 2006; Blumenfeld et al., 1991). Tuan, Chin, and Tsai (2004) examined the effectiveness of inquiry-based instruction on the motivation of eighth grade science. They used Pintrich and Schunk’s (1996) definition of motivation of “the process whereby goal-directed activity is instigated and sustained.” Findings from this study reveal that
inquiry-based teaching practices in science increase motivation of eighth grade students regardless of student learning style (Tuan, Chin, & Tsai, 2004). In addition, middle school students report high levels of cognitive engagement in classrooms where teachers maintain a high degree of challenge and press for synthesis (Blumenfeld & Meece, 1988; Blumenfeld, Puro, & Mergendoller, 1992). A review of interviews with students concludes student enjoyment and “liking” learning through inquiry with classroom observations suggest students engaged in active participation (Barron et al., 1998; Holbrook & Kolodner, 2000; Mistier-Jackson & Songer, 2000). Students engaged in inquiry reported higher interest, efficacy, and strategy use compared to students exposed to traditional instructional methods (Guthrie, Wigfield, & VonSecker, 2000; Hickey, Moore, & Pellegrino, 2001). Notwithstanding, some literature conveys results that are inconsistent regarding the relationship between cognitive engagement and student achievement. These conflicting results may be attributable to the curriculum, subject matter, or varying ages of students because learning tasks in traditional classrooms often include low-level strategies such as recall and comprehension (Doyle, 1983).

In 2001, Weinburgh conducted further investigation by analyzing the impact on fifth graders’ attitudes through the implementation of kit-based science programs in an urban school setting. Although fifth graders in the study demonstrated increased achievement and higher attitudes, no significant gender differences existed. Interestingly, Weinburgh found that longer participation in the program (up to 3 years) resulted in reports of students’ decreased value of science.

An analysis of the 1995 TIMSS assessment included results from 37 countries that participated in math and science assessments targeting eighth grade students from around the
Students participated in achievement tests and completed an accompanying background questionnaire. U.S. students reported a high level of self-concept in science (45%) despite scoring lower in academic achievement on the content assessments (Martin et al., 2000). A strong negative relationship was evidenced by a correlation, aggregated at the national level of -.74, between science achievement scores and how much U.S. students like science. Compelling findings from this study indicate that students from top achieving nations reported lower levels of liking science. Interestingly, students from nations at the bottom of international achievement “like science” more than children from any other nation in the world.

A separate analysis was conducted by Webster and Fisher (2000) of 1994 TIMSS data examining seventh and eighth graders from Australia. The researchers used the positive attitude variable in science to explore the mediating effect of attitude on achievement. The study found that science attitude explains 15.1% of the science achievement variance. Webster and Fisher (2000) conclude that there exists a strong and significant positive effect between attitude and achievement.

Inquiry and Gender

An analysis of international assessments discloses no statistically significant improvement in mathematics and science achievement for eighth grade male and female students between 1995 and 1999 in the United States (Martin, 2000). In addition, there exist gender differences between male and female students that impact college participation and readiness in the majors of science, technology, engineering, and mathematics that ultimately lead to careers in STEM. Investigation of TIMSS data reveals that there existed no measureable difference for performance of all students regarding science achievement between 2007 and 2011 (Martin,
Even more alarming are the gender differences that prevail in science achievement. Males outperformed females at 4th, 8th, and 12th grades in science, with statistical significance at the fourth and eighth grades (Martin, 2000). The gender achievement gap has become pervasive, widening by the time students reach high school, especially as males dominate the fields of Earth Science, Physics, and Chemistry.

Traditionally, male students have been on the weak side of the education gender gap, as it relates to literacy. A typical male student in the United States is over a year behind a typical female and is less likely to enroll in college. Twelfth grade females outperformed males by fourteen points in reading and seventeen points in writing (NAEP, 1996). A 2010 analysis of full-time college enrollments reveals that only 43% of students were male compared to 57% of females (NCES, 2010), and this statistic has been steadily climbing over the past 20 years. The STEM workforce is crucial to America’s ability to compete in a global society. Females are vastly underrepresented in these STEM jobs, yet practitioners and policy makers can institute initiatives that can bolster female academic self-concept, engagement, achievement, and participation and the capacity for females to contribute in this critical field.

Literature indicates that stereotyped beliefs influence students (Jones, Howe, & Rua, 2000). Attitudes toward science influence females’ participation and performance in science. Science has traditionally been viewed as a male dominated area of study. Male students tend to maintain more positive attitudes toward science with the only exception being female students maintaining more positive attitudes in biology (Weinburgh & Englehard, 1994). However, female students outperform male students in earning higher science grades despite female students possessing less positive attitudes than boys (Weinburgh, 1995). Weinburgh’s (1995)
analysis of gender differences produced several important findings that frame how we examine the correlation between attitudes toward science and academic outcomes. Male students of average ability maintained a more positive attitude toward science than did female students of average ability. On the other hand, when reviewing the relationship of high achieving students, female students maintained a more positive attitude toward science than males. Weinburgh (1995) concludes a positive correlation between attitudes toward science and science achievement, especially among low achieving girls. The implementation of effective and coherent science curriculum and inquiry teaching practices may provide a gateway to future careers and increased science literacy to support male and female students to maximize their individual potential.

**Inquiry and Students with Learning Disabilities**

Although some research exists on teaching academics to students with significant learning disabilities, the research on teaching science is especially limited (Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2006; Browder, Wakeman, et al., 2006; Courtade et al., 2006). The *Individuals with Disabilities Education Act* (IDEA, 1997) requires access to the general curriculum for all students, including students with the most significant disabilities. Inquiry-based instructional practices in science classrooms have been extensively researched and these studies have indicated inquiry to be effective in teaching general education students (Bredderman, 1984; Renner & Marek, 1990; Renner & Phillips, 1980; Schneider & Renner, 1980; Shymansky, Kyle, & Alport, 1983). Studies have also described effective teaching practices in special education that contributed to overall quality of life for these learners (Odom et al., 2005).
An analysis of national statistics paints a startling picture. The representation of general education students in advanced science courses of study at the secondary level is 19% compared to an astounding 9% for students with learning disabilities (NAEP, 1996). These statistics indicate that general education students are more than twice as likely to enroll in advanced science courses than students with disabilities. In addition, students with learning disabilities pursue careers in science at approximately half the rate as non-disabled peers (NAEP, 1996). This evidence suggests that curriculum and instruction at the younger level is not engaging students with learning disabilities and fails to provide them with the instructional support they need in order to succeed.

Research on students with learning disabilities concluded that students preferred inquiry-based instruction to traditional instruction (Mastropieri & Scruggs, 1999). Teachers in the study provided inquiry-based instruction that required limited use of reading and writing but incorporated significant guidance and coaching in task redundancy, behavior modification techniques, disability specific accommodations, and adaptations (Mastropieri & Scruggs, 1999). In a separate study implementing assessment methods, students with learning disabilities demonstrated higher achievement in hands-on performance assessments than on multiple-choice tests, questionnaires, or constructed diagrams (Dalton, Tivnan, Riley, Rawson, & Dias, 1995). Students with learning disabilities in other research exhibited increased levels of motivation and demonstrated significantly higher achievement with guided IBS than by traditional means (Gurganus, Janas, & Schmitt, 1995; Hurd, 1997; Mastropieri et al., 1999).

In another study, elementary students with learning disabilities exposed to inquiry instruction in inclusive classrooms achieved comparable gains to general education students.
Additionally, students with learning disabilities and general education students both produced significant growth in learning (Palincsar, Magnusson, Collins, & Cutter, 2001). Inquiry-based classroom science instruction reveals promising results in supporting the needs of diverse learners.

Piaget’s theory emphasizes an individual learner’s cognitive processes (Piaget, 1969). Vygotsky’s theory suggests that the learning process is influenced by input from the social environment (1962). In a separate study, approximately half of all students with disabilities were mainstreamed in academic subjects at least 80% of the time (USDOE, 2000). These students with disabilities received some form of accommodation or adaptation during testing (USDOE, 2000). Students are unable to be successful in a constructivist classroom without these academic supports because of a lack of prior knowledge (Scruggs & Mastropieri, 1993).

There is little research to determine to what extent IBS will improve student achievement and academic self-concept or to determine if there exists a correlation between these areas. Bandura’s (1986) self-efficacy theory describes an individual’s self-concept of ability to achieve as affecting students’ participation in academic activities and ultimately student achievement. Students will participate in IBS environments only when they believe that they are able to contribute and learn (Bandura, 1986). Even more important, teachers must understand the needs of their learners, especially when dealing with special populations such as students with learning disabilities. According to Green and Gredler (2002), students with learning disabilities will maintain difficulty in three identified areas:

1. Students with learning disabilities have difficulty finding connections without first learning strategies needed to categorize, prioritize, compare, and combine details.
2. Students with learning disabilities can become overwhelmed by requirements to explore and research topics independently, especially when the task requires reading and background knowledge (two areas where students with learning disabilities exhibit deficiency).

3. Students with learning disabilities are often isolated from the group because they have difficulty participating in and understanding conversations about science topics as a result of low literacy skills.

Effective, research-based curricular programs and instructional methodology may be designed and implemented in order to support instruction for students with learning disabilities, create opportunities to advance students’ academic skills, meet the expectations of new standards, and attain higher academic achievement for all students.

Research has concluded that inquiry-based instruction can increase student interest in general education populations (Fosnot, 1996; Scruggs et al., 1993). However, Carlsisle and Chang (1996) conducted a 3-year self-concept study and arrived at contrasting results. This study consisted of fourth and sixth grade students in inclusive science classrooms, including 20 students with learning disabilities. The researchers examined questionnaires assessing student self-evaluations of their individual abilities regarding achievement in science and then compared these self-evaluations to students’ actual achievements. Results suggest that fourth and sixth grade students with learning disabilities demonstrate little growth in self-concept over 3 years. Students in sixth and eighth grades possessed positive self-concept in the final 2 years of the study despite teachers’ maintaining low evaluations of students with learning disabilities and
general education students after 3 years. However, student achievement for students with learning disabilities still existed well below that of their general education peers.

Results from NAEP (2011) indicate that mean scores for eighth grade students increased to 152 in 2011 from 150 in 2009. Although this indicates a statistically significant increase in science achievement, it is still far below the proficiency cut score of 170 out of a total possible score of 300. The outlook remains bleak for students with learning disabilities. This data indicates an extremely alarming picture for these students who are performing well below basic. A review of NAEP results depicts that students who participated in hands-on science activities at least once a week in class scored 14 points higher than those who never or hardly ever engaged in hands-on experiments (2011).

The NSF has developed content, teaching, program, and system enhancements to the Standards that promote inquiry-based instruction as a validated approach that supports the efficacy of inquiry for learners with diverse abilities (Scruggs & Mastropieri, 1994; Scruggs, Mastropieri, Bakken, & Brigham, 1993; Stefanich, 1994). Studies indicate that students learn, utilize, and improve individual cognitive and meta-cognitive skills in science classes more than other academic settings (AAAS, 1989). Students with learning disabilities are generally lacking in meta-cognition skills (Butler, 1998; Hallanan, Kauffman, & Lloyd, 1999). They also often have difficulty with learning in a traditional environment because of deficient listening and reading skills. Many students with learning disabilities do not process information by using cognitive strategies but the use of these strategies has been associated with successful learning (Borkowski, Carr, & Pressley, 1987; Garner, 1990). Cognitive strategies are defined as the internal processes by which learners select and modify their ways of attending, learning,
remembering, and thinking (Gagne, Brigg, & Wagner, 1988). These strategies enable a learner to organize and understand information in different and more meaningful ways while filtering out unnecessary information. Halpern (1996) indicates that these specific cognitive strategies can be taught to most students. Research indicates that teaching methods in IBS programs teach cognitive strategies effectively to learners with low academic abilities or poor achievement in reading and mathematics (Scruggs & Mastropieri, 1994; Stefanich, 1994).

Inquiry teaching and learning supports a classroom environment that fosters student collaboration and promotes meaningful discussion between peers. Students who learn through inquiry are exposed to activities that promote mental structure development and concept formation that is unable to be obtained in a traditional setting. Students with learning disabilities are capable of making logical connections through engagement in science activities that require problem solving and physical manipulation (Scruggs et al., 1993). Furthermore, mnemonic devices support retention of process steps and vocabulary (Scruggs et al., 1993). On the other hand, research has determined that students with learning disabilities appear to experience considerable challenges when solving problems or performing activities using inquiry methods unless the teacher provides significant support (Scruggs et al., 1993). Teachers must scaffold learning for students and provide them with an appropriate amount of time in order to develop cognitive structures and make sense of prior knowledge. These approaches afford students with multiple points of entry and equip teachers with opportunities to correct misconceptions so learners may construct their own understanding.

A study was conducted to assess the effectiveness of two forms of inquiry on students with learning disabilities at the elementary level (Dalton, Morocco, Tivnan, & Mead, 1997). The
standard inquiry method was comprised of discovery activities with little attention to student interactions and the development of misconceptions. Alternatively, the supported inquiry method consisted of discovery activities plus the development of student conceptions through teacher questioning and guided instruction. The supported inquiry group outperformed the standard inquiry group by almost two times in achievement scores. Findings from this study indicate that teachers play a critical role in student learning because of the guidance teachers provide. However, these students did not perform as well as their general education peers.

Researchers conducted a crossover study that consisted of the examination of inquiry-based methods versus traditional approaches (Scruggs & Mastropieri, 1993). It was determined that seventh and eighth grade students with learning disabilities retained significantly more knowledge through inquiry methods as evidenced by higher assessments scores measuring recall after a 1-week delay. In addition, nearly 96% of these students preferred inquiry methods compared to traditional instruction. Much research exists that suggests that inquiry methods should be used to teach science because they generate growth in student knowledge, increased achievement, and improvement in process and analytic skills (Schneider & Renner, 1980; Shymansky et al., 1983). Research has shown that inquiry methods reveal positive achievement in science for students with mild learning disabilities (Bay et al., 1992; Scruggs et al., 1993). However, more research in this area is needed in order to determine to what extent IBS instruction mediates student outcomes and academic self-concept for students with learning disabilities at the middle school level.
Science and Leadership

The role of the principal is critically important in supporting the implementation of IBS programs. The NGSS lays out clear areas of focus for school leaders to consider in supporting teachers. The NGSS conveys that principals can

focus on what the students are doing first and then think about what the teacher has designed to make that happen; know the standards enough to identify and provide feedback on aspects of the three dimensions during classroom visits; and engage teachers on how the three dimensions are incorporated into lessons. (NRC, 2015)

Additionally, the NGSS (NRC, 2015) states that principals can “build a long-term plan that focuses on the building’s collective vision for science education” (p. 20), “elevate teacher leaders and support them as they work to help their colleagues” (pp. 38-40), “find ways to provide high-quality, intensive professional learning to all teachers” (pp. 41-46), “seek out professional learning for yourself” (p. 49), “connect what is happening with science in your building to other buildings in your district, state, or any NGSS-adopted state” (pp. 70-73), “be critical consumers of any new curricula” (pp. 56-57), and “provide leadership to develop or revise a system of assessment for measuring student learning in science” (pp. 61-66).

Summary

There is a significant amount of research in the field of cognitive development that supports student exposure to a rich repertoire of experiences and actions in order to develop abstract thought (Arlin, 1975). Implementation of IBS curricula is clustered around broad conceptual themes or big ideas. The majority of students have limited experience with hands-on, inquiry-based learning in the classroom. As a result, students tend to have a poor understanding
of how to engage in scientific inquiry (Adb-Hamid, Campbell, Der, & Wolf, 2012). These modules cultivate a learning environment where the teacher participates as facilitator, seeking to understand students’ points of view in order to understand students’ present conceptions for use in subsequent lessons. Curricula should be presented to students from the perspective of whole-to-part rather than part-to-whole, providing multiple entry points for students. Students need to be awarded the opportunities to interact with the scientific world around them while receiving guidance and support from the teacher. These types of activities help learners transition their concepts from concrete experiences to abstract understandings (Caskey & Anfara, 2007). It is critically important in today’s society for all citizens to have a basic understanding of science and the way it affects daily lives and decision-making (AAAS, 1989; NRC, 1996, 2000; NSTA, 2003). Teaching inquiry is in itself often a large shift in pedagogical practices for teachers, requiring extensive support and professional development (Marx et al., 2004). Therefore, educators must give priority to effective implementation (Martin, 2010).
CHAPTER III: RESEARCH DESIGN

Introduction and Overview of the Method

The purpose of this quantitative study was to evaluate to what extent IBS instruction has an effect on academic self-concept and student achievement. This study was conducted in a PK-12 public school district in Bergen County, New Jersey, and was predominantly funded through a local education foundation grant and the Bristol-Myers Squibb Grants for Teaching Excellence. The district also provided funding to accommodate any additional expenses not covered by these grants. The research questions are listed in the first chapter and the corresponding null hypotheses are as follows:

Null Hypothesis 1: Middle school students who participate in IBS classrooms will not achieve a statistically significant difference in their non-cognitive outcomes and academic performance compared to students in traditional classrooms.

Null Hypothesis 2: Gender does not have a statistically significant moderating effect on non-cognitive outcomes and academic achievement for middle school students in IBS classrooms compared to traditional classrooms.

Null Hypothesis 3: There is no statistically significant difference for middle school special education students with respect to non-cognitive outcomes and academic achievement in IBS classrooms compared to traditional classrooms.

Design

This research study is a random control group design in which the achievement and non-cognitive outcomes of students in grades 6-8 in the IBS instruction group (treatment) were compared to students receiving traditional, didactic instruction (control). This study included
randomly assigning teachers and students to treatment or control groups prior to the intervention in both middle schools. The teacher class sections randomly selected for this study included both general education and special education students heterogeneously mixed by gender. Classrooms were required to have special education students in order to be eligible for this study. The treatment and control groups were assigned six teacher class sections each as per Table 1.

Table 1: Treatment vs. Control Distribution

<table>
<thead>
<tr>
<th>Middle School I</th>
<th>Middle School II</th>
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<tr>
<td>Grade 6 Treatment</td>
<td>Grade 6 Treatment</td>
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<td>Grade 6 Control</td>
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<td>Grade 7 Treatment</td>
<td>Grade 7 Treatment</td>
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<td>Grade 7 Control</td>
<td>Grade 7 Control</td>
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<td>Grade 8 Treatment</td>
<td>Grade 8 Treatment</td>
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<tr>
<td>Grade 8 Control</td>
<td>Grade 8 Control</td>
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</table>

School District Setting

This study was conducted in a suburban public school district in Bergen County in northern New Jersey. Students participating in this study attended one of two large middle schools within the same public school district. The school district where this study was conducted had identified a widening achievement gap on state standardized testing in grade 8, entitled the NJASK 8 Science, between district student mean and the peer group mean in the same DFG between 2004 and 2007. The widening performance gap concerned teachers and administration. These concerns drew parallels to the national and international achievement crisis in science academic performance. Furthermore, anecdotal feedback from students to their teachers became disconcerting as students expressed a lack of interest and motivation in relation to their science coursework. Students expressed a sense of boredom as a result of direct lecture
instruction and memorization of facts with limited participation in hands-on laboratory investigations. The district recognized a lack of student interest could impact future enrollment in higher-level science coursework in high school and at the post-secondary level.

This school district planned and implemented three distinct phases. Phase One included an audit of the existing curriculum and programs. Phase Two provided science teachers with professional development on a research-based scientific inquiry teaching approach supported by the Bristol Myers-Squibb Grants for Teaching Excellence. Phase Three included the implementation of the STC/MS IBS pilot program intervention to measure the effectiveness of the program on academic self-concept and student achievement.

**Phase One-Audit**

In 2006-2007, a review and audit was conducted of the existing middle school science curriculum. The middle school science department, comprised of 12 teachers and 1 middle school assistant principal/researcher, participated in articulation sessions, realignment of curriculum with New Jersey Core Curriculum Content Standards, sequencing, and the development of a pacing guide in an effort to further unify and add consistency to content taught and methods of instruction implemented in the classroom. The purpose of this audit was to address district curriculum needs by infusing research-based best practices in order to best align district curriculum with National Science Education Standards. The realignment project occurred during department meetings and full day in-district professional development days over the course of 2 academic years. A curriculum needs assessment by the department and district administration identified recommendations that should be implemented to address district goals.
Science department meeting time was utilized for teacher discussions and the completion of this curriculum project. Phase One was completed by September, 2008.

**Phase Two-Professional Development**

Simultaneously, the Bristol Myers-Squibb Grants for Teaching Excellence was awarded to the district and provided funding for professional development and resources to support the implementation of the IBS pilot program in grades 6-8 (Phase Two). In 2009, the grant-based pilot program supported a total of 5 professional development days for staff before implementing the pilot program intervention between 2008 and 2010. These sessions included 2 large whole group, general overview professional development days, and 3 small group, kit-specific professional development days. The first whole large group, professional development workshop for middle school science teachers was provided at Montclair State University in Upper Montclair, New Jersey through the support of the NSRC. The goal of this professional development day was to provide foundational knowledge and develop teacher pedagogy through an IBS approach. Staff developers from PRISM at Montclair State University conducted an overview of inquiry teaching and learning with supporting research-based curricula materials. PRISM staff developers conducted a guided introduction to the inquiry process for staff. Teachers learned about research-based curricula and multiple methods of inquiry instruction.

In the second whole large group, professional development workshop for middle school science teachers, PRISM representatives implemented a “jigsaw” activity utilizing a STC-MS kit titled Catastrophic Events to encourage teacher engagement in IBS. The purposes of the “jigsaw” activity were for teachers to experience the inquiry-based approach from a student’s point of view, understand the benefits associated with the program, and ask questions about program
implementation. Teachers conducted individual investigations in this workshop and presented their findings, learning objectives, procedures, and conclusions to the entire group. Due to the nature of the “jigsaw” activity, teachers had the opportunity to observe how all of the investigations as individual parts contributed to the “big picture” of the module.

**Phase Three-Intervention**

In January, 2010, 3 days were allocated for small, grade-level group professional development specific to each module and the implementation of each respective STC-MS kit. Carolina Biological Supply Company is the provider of STC-MS IBS kits. Carolina Curriculum Programs for Science and Math provided teacher training for the six teachers in the treatment group who would implement the inquiry-based pilot program in the following district curriculum content areas: Physical Science (grade 6), Life Science (grade 7), and Earth Science (grade 8). Teachers in the control group did not participate in this professional development. Two teachers, one from each middle school at each grade level, were randomly selected to participate in this program prior to the intervention. Each teacher in the treatment groups received 1 full day of kit-specific inquiry training. These participating teachers were provided an opportunity to engage in inquiry kit exploration and to experience hands-on experimentation and manipulation of program materials. All of the professional improvement activities occurred with support from PRISM and Carolina Curriculum Programs for Science and Math, were funded by the Bristol-Myers Grants for Teaching Excellence, and were conducted in conjunction with district administration. The intervention was implemented between January, 2010 and May, 2010 (Phase Three). The intervention was relatively short in duration, ranging from 6 to 10 weeks dependent upon the unit of study. The following STC-MS kits were used as the program intervention: Energy, Machines,
and Motion (grade 6), Organisms-From Macro to Micro (grade 7), Earth in Space (grade 8). The teachers in the treatment groups implemented the intervention over a 6-8 week period.

**Treatment Group**

STC/MS was created to provide research-based inquiry lessons for teachers. STC/MS is an eight-module curriculum for grades 6 through 9. Inquiry-based experiences are the cornerstones for meeting the science standards for science literacy. The National Science Resources Center, in partnership with The National Academies and the Smithsonian Institution, provides support for the development of research-based instructional materials. These organizations maintain a curriculum development center that develops and disseminates research-based curriculum for improving science learning and teaching.

Forces and Motion is one example of a unit of study in the STC/MS series. Students have the opportunity to investigate the nature of energy and the different forms it can take, the nature of different forces, and how those forces affect the motion of the objects. The teacher engages students in an exploration of elastic, magnetic, frictional, and gravitational forces. Students learn through experimentation and are able to identify the concept that force affects the motion of objects. As real scientists do, students record their observations throughout the experiments and apply scientific terminology. Students engage in the process of collecting, analyzing, and interpreting data. Ultimately, students make inferences and draw conclusions from the evidence they have collected, analyzed, and discussed in collaboration with their peers. Inquiry-based learning is learner-centered and focuses on students as active participants in learning content, process, and habits of mind. Inquiry is an effective instructional method for meeting the needs of diverse learners, resulting in deeper understanding and application of concepts.
The NSF has funded research in partnership with the National Academies and the Smithsonian Institution to support the development STC/MS. The modules incorporated as the intervention for the treatment group in this research study (Phase Three) are as follows: Energy, Machines, and Motion (grade 6), Organisms-From Macro to Micro (grade 7), and Earth in Space (grade 8). These curriculum modules, also referred to as IBS kits, were selected because of their alignment with the existing district curriculum, New Jersey Core Curriculum Content Standards, and NSES. Three separate and grade level specific modules were implemented in this research study. The sixth grade module, titled Energy, Machines, and Motion, engages learners in the study of physical science on how energy, friction, and force affect motion. The seventh grade module, titled Organisms-From Macro to Micro, engages students in the study of the functions and roles organisms play in the environment, identifying how organisms are organized in living systems, the interdependence of organisms, and the function of the cell. The eighth grade module, titled Earth in Space, engages students in the study of the relationships in the Sun-Earth-Moon system, characteristics of planets, planetary processes, and a discovery of the Earth’s history.

Two teachers at each grade level in sixth, seventh, and eighth grade participated in the treatment group (inquiry-based instruction) for a total of six teachers and a treatment group population of \( n = 119 \). Each science teacher taught five total classes daily. However, only one of each teacher’s classes was used for this study as the treatment group. The coeducational classes that were included in this study reflect the only class for that teacher with in-class support services for inclusive classrooms. Each of the inclusive classrooms included in this randomized study was comprised of a heterogeneous coeducational class of general education and special
education students. Each inclusive class included a general education teacher and special education in-class support teacher to support students with disabilities. A total of six treatment groups (one at each grade level in Middle School I and Middle School II) were randomly selected for this study. Approximate class size for each class ranged between 18-25 students with an average class size of 21 students per class. Instructional class periods were 55 minutes in duration during the time of this study.

**Control Group**

Traditional, didactic instruction seeks to build upon the current level of knowledge that students possess. The predominant method for the delivery of instruction in the traditional, didactic classroom is lecture. Traditional instruction reflects a teacher-centered pedagogical approach where learning is derived from the teacher-led instruction and students are passive recipients of taught knowledge. Teachers impart the knowledge they possess to their students with the goal of the transfer of knowledge. Students memorize content for the purpose of passing assessments. Traditional instruction rewards student reproduction of facts and therefore promotes superficial learning.

An example of traditional, didactic instruction is where a teacher presents factual information on a topic such as forces and motion. The teacher imparts knowledge with little to no interaction from students. The teacher models for students the nature of energy, the different forms it can take, the nature of different forces, and how those forces affect the motion of the objects, while students record notes. Students are taught how to solve problems by using equations and algorithms. There is less questioning in traditional classrooms on how to solve
problems or finding alternative methods for arriving at a solution than in an inquiry-based classroom. This type of instruction does not include hands-on learning.

Two teachers at each grade level in sixth, seventh, and eighth grade participated in the control group (traditional, didactic instruction) for a total of six teachers and a control group population of \( n = 110 \). Each science teacher taught five total classes daily. One of each teacher’s classes was used for this study as the control group. The coeducational classes that were included in this study reflect the only class for that teacher with in-class support services for inclusive classrooms. Each of the inclusive classrooms included in this randomized study was comprised of a heterogeneous coeducational class of general education and special education students. Each inclusive class included a general education teacher and special education in-class support teacher to support students with disabilities. A total of six control groups (one at each grade level in Middle School I and Middle School II) were randomly selected for this study. Approximate class size for each class ranged between 18-25 students with an average class size of 21 students per class. Instructional class periods were 55 minutes in duration during the time of this study.

**Population**

Descriptive data collected for the purpose of this study consisted of background information. The researcher collected information about the DFG of the school district, demographics of the entire student body, and assessment results of the student body. The combined student population of both middle schools to choose from in this study was 1,353 students, including 663 students at Middle School I and a student enrollment of 690 at Middle School II and comprised of 75% Caucasian, 15% Asian, 6% Hispanic, 3% two or more races, and 1% Black. In a review of the 2005 NAEP national assessment scores for 8th graders, it was
revealed that the achievement results remained unchanged, while scores for 12\textsuperscript{th} graders declined (NAEP, 2005). Alternatively, results were more promising for elementary students that showed elementary students performing better in science on the NAEP assessment in 2005 compared to previous results from 1996 and 2000 (NAEP, 2005).

**Sample**

This research study was conducted in two middle schools within one public school district. The intervention was administered to each grade level in this study in Middle School I and Middle School II (see Table 2). Grade 6 treatment groups were comprised of 19 and 18 students for a total of 37 students. Grade 7 treatment groups were comprised of 16 and 22 students for a total of 38 students. Finally, Grade 8 treatment groups were comprised of 19 and 25 students for a total of 44 students. Alternatively, Grade 6 control groups were comprised of 21 and 20 students for a total of 41 students. Grade 7 control groups were comprised of 17 and 17 students for a total of 34 students. Grade 8 control groups were comprised of 15 and 20 students for a total of 35 students. This research study was a randomized study including a pretest and posttest with a sample population of \(n=229\). This research design included a treatment group \((n=119)\) and the control group \((n=110)\) out of a total middle school population of 1,353, representing a participation rate of approximately 17% of the total middle school population.
A review of Table 3 provides a summary of the samples used to answer the research questions in this study. Research question 1 included a sample of 229 students. Of these, 110 students were randomly assigned to the Non-IBS control group and 119 students were included in the IBS treatment group. A total of 228 participants were included in the analytic sample for research question 2. Of these participants, 55 were male non-IBS students, 56 were male IBS students, 55 were female non-IBS students, and 63 were female IBS students. Lastly, research question 3 included a total of 229 participants randomly assigned to each respective group. For this comparison, 43 special education students in the control group were compared to 41 special education students in the treatment group. In addition, 67 general education non-IBS students in the control group were compared to 78 general education students in the IBS treatment group.

<table>
<thead>
<tr>
<th>Middle School I</th>
<th>Middle School II</th>
<th>Total Participants (n)</th>
</tr>
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<tbody>
<tr>
<td>Grade 6 Treatment (n=19)</td>
<td>Grade 6 Treatment (n=18)</td>
<td>n=37</td>
</tr>
<tr>
<td>Grade 6 Control (n=21)</td>
<td>Grade 6 Control (n=20)</td>
<td>n=41</td>
</tr>
<tr>
<td>Grade 7 Treatment (n=16)</td>
<td>Grade 7 Treatment (n=22)</td>
<td>n=38</td>
</tr>
<tr>
<td>Grade 7 Control (n=17)</td>
<td>Grade 7 Control (n=17)</td>
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<tr>
<td>Grade 8 Treatment (n=19)</td>
<td>Grade 8 Treatment (n=25)</td>
<td>n=44</td>
</tr>
<tr>
<td>Grade 8 Control (n=15)</td>
<td>Grade 8 Control (n=20)</td>
<td>n=35</td>
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</tbody>
</table>
Table 3: Analytic Sample for Research Questions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Total Number of Participants</th>
<th>Comparable Groups and Participation Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Question 1</td>
<td>229</td>
<td>110 Non-IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>119 IBS Students</td>
</tr>
<tr>
<td>Research Question 2</td>
<td>229</td>
<td>55 Male Non-IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>56 Male IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55 Female Non-IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63 Female IBS Students</td>
</tr>
<tr>
<td>Research Question 3</td>
<td>229</td>
<td>43 Special Education Non-IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41 Special Education IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67 General Education Non-IBS Students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78 General Education IBS Students</td>
</tr>
</tbody>
</table>

**Instrumentation**

The instruments administered to students in this study included the ASC scale, the district developed unit assessments, and the NJASK 8 Science. The dependent variables in this study were student mean gain scores on the ASC scale, mean gain scores on district developed unit assessments, and the NJASK 8 Science mean scale scores. The independent variable was the intervention of IBS instruction. Each instrument is described in greater detail below.

**Academic Self-Concept Scale**

The first instrument measured non-cognitive outcomes through the administration of the ASC scale. This instrument was designed on a Likert scale and administered before and after the intervention. The ASC included seven questions assessing student level of interest in school and academic studies using a Likert scale. Items on the ASC include the following statements: a) I am happy to come to school; b) My classes are a lot of fun; c) I get bored in my classes; d) I feel I can learn anything; e) I like doing work in school; f) I feel I learn a lot in my classes; and g) Homework can be fun, sometimes. The ASC scale is a measure of student engagement that has been administered and tested for validity by Dr. Elaine Walker from Seton Hall University. The
researcher field-tested the ASC scale to ensure the clarity and validity of the instrument. Cronbach’s Alpha was calculated at .807 and resulted in the good range for reliability.

**Table 4: Cronbach’s alpha**

<table>
<thead>
<tr>
<th>Reliability Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cronbach's Alpha</td>
</tr>
<tr>
<td>N of Items</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cronbach's Alpha</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.807</td>
<td>7</td>
</tr>
</tbody>
</table>

**Unit Assessment**

The second instrument measured academic outcomes in science content knowledge through the administration of unit assessments specific to each science unit of study in the intervention. The researcher developed unit assessments from reliable, previously released standardized test questions to measure student gain scores in the randomized study. The unit assessment instruments for this research study included content specific, district-developed tests with multiple objective item (multiple choice) questions that reflected acquisition of learning objectives for each inquiry unit. The following unit assessments used in this study have been included in Appendix B of this research study: Energy, Machines, and Motion (grade 6), Organisms-From Macro to Micro (grade 7), and Earth in Space (grade 8). The unit assessments were designed by compiling previously released NJASK Science 8 and NAEP exam questions that directly related to the learning standards that were aligned to the intervention. All assessment question items were tested for validity by the respective authors of the NJASK 8 Science and NAEP. The NJASK 8 Science measured students’ knowledge of scientific factual knowledge and the ability to apply concepts, based on the state science standards, through multiple choice and constructed response items. The NJASK 8 assessed student ability in three
main areas: Life Science, Earth Science, and Physical Science. The NJASK Technical Report for 2010 may be found at the following website:


NAEP released exam questions were included from the National Center for Education Statistics that states:

The NAEP Validity Studies (NVS) reports are written by members of the NVS Panel. These studies are conducted as needed to identify and develop technically sound techniques for use in NAEP assessments. The Panel, whose membership includes nationally recognized psychometricians and experts in NAEP subject areas, advises NCES on the research agenda for maintaining and developing the high technical quality of NAEP assessments. Through discussions between the Panel and NCES, a rich assortment of topics has emerged. Since 1997, papers have been published on the research conducted by NVS Panel members; all are listed below. Papers from 2004 up to the present are in the NVS Panel library on another website. Click any title below to be taken to the abstract, where you can link to the complete paper. Papers earlier than 2004 are on the NCES website. (NAEP, 2013)

More information regarding specific details and reports on reliability and validity may be found at the following websites:

https://nces.ed.gov/search/?q=validity

https://nces.ed.gov/search/?q=validity

NJASK 8 Science

The third and final instrument used in this research study was from the standardized test results from the NJASK 8 Science to measure academic outcomes from 2010, 2011, and 2012 tests. The NJASK 8 Science was administered at the end of grade 8 and the exam includes multiple choice and constructed response items. The NJASK was a criterion-referenced test aligned with New Jersey Core Curriculum Content Standards (NJCCCS). The NJASK was administered each spring to all New Jersey public school students in grades 3-8. The NJASK 8
test included multiple-choice questions and questions requiring written responses in mathematics, language arts, and science. It measured basic as well as higher-level skills. Students took the test for approximately 90-120 minutes each day. There were 4 days of testing: 2 days for literacy, 1 day for math, and 1 day for science. School districts reported the scores to their schools and school districts reported the scores to students and parents. The NJASK scores showed how well students learned the reading, math, and science skills aligned to state standards. The NJASK scores measuring student performance in this study had a range from 100-300 points. The lowest possible scale score was 100 on each of the three exams in math, reading, and science with the highest scale score of 300. Partial proficiency level, the lowest range of scale score, was in the 100-199 range. Proficiency level was in the 200-249 range. Advanced proficiency was in the 250-300 range. The NJASK 8 Science measured a student’s knowledge of scientific factual knowledge and the ability to apply concepts based on the state science standards. The NJASK 8 assessed student ability in three main areas: Life Science, Earth Science, and Physical Science.

The NJASK was a statewide academic measure accepted as a valid assessment instrument. The NJDOE was required by law to ensure that the assessment instruments that were administered to measure student achievement provided reliable results. The NJDOE established that student test scores and measurement components were consistent.

**Data Collection**

Several instruments were used to collect data about non-cognitive outcomes and academic achievement, including the ASC scale, unit assessments, and NJASK 8 Science. Student gender and special education status were obtained from school records.
Academic Self-Concept Scale

The ASC scale was used to measure to what extent students enjoyed science and participation in academic work (see Appendix A). The ASC instrument was administered as a pretest and posttest during Spring, 2010 to students in both groups (treatment and control) in the randomized study to examine the level of student engagement and student perceptions about school. Each student was assigned a coded number on his or her pretest and posttest ASC instrument that correlated to a class roster provided to each teacher. Each class roster indicated student name, gender, and special education status. Teachers were provided the ASC instrument immediately prior to the assessment administration and were required to submit completed instruments to the researcher immediately following student completion. Results were recorded and then analyzed to measure the gain scores after the intervention as it related to academic self-concept. All student test data were coded in accordance with the coding procedures for the ASC instrument and collated into one Excel file. All data files had student names omitted to ensure anonymity.

Unit Assessment

Science teachers administered the unit assessment to middle school students as a pretest prior to the intervention during Spring, 2010. Students were administered the posttest after the implementation of the intervention. Each teacher administered unit assessments coded with numbers correlated to a class roster that indicated student name, gender, and special education status. Results were then analyzed to measure the gain scores after the intervention related to academic outcomes. All student test data were coded in accordance with the coding procedures
for the unit assessments and collated into one Excel file. All data files had student names omitted to ensure anonymity.

**NJASK 8 Science**

Data collection for the NJASK 8 Science occurred in Spring, 2010 for the eighth grade student cohort in this study, in Spring, 2011 for the seventh grade students, and in Spring, 2012 for the sixth grade students, as each cohort progressed through grade 8. All student test data were coded in accordance with the coding procedures for the NJASK 8 Science and collated into one Excel file. All data files had student names omitted to ensure anonymity.

The researcher obtained academic outcome data from NJASK 8 Science test scores, disaggregated by gender and special education classification. For this study, only NJASK test scores for grade 8 were analyzed because that was the only grade in middle school where student science performance was measured. The NJASK 8 was only administered to grade 8 students. Results were collected and analyzed using NJASK 8 Science scale scores in this research study, coding for gender and special education status. Analysis of scale score results was conducted comparing treatment versus control groups.

**Data Analysis**

In this study, the researcher examined the impact of an IBS program on student non-cognitive outcomes and academic achievement. Pretest findings on the ASC scale and unit assessments were compared to posttest results. In addition, student performance measures were analyzed in science using the NJASK Science 8 scores of eighth grade students. These results were further examined as they related to gender and special education status. These comparisons were analyzed to investigate whether there were statistically significant differences at the .05
level in non-cognitive outcomes and achievement performance between students in the IBS middle school program and students not in the IBS program.

Quantitative data were obtained from 12 teacher participants, six treatment and six control groups, via the ASC scale, unit assessment, and NJASK 8 Science results. The quantitative data collection method for this study consisted of gathering student test results from the district test coordinator for NJASK 8 Science between 2010-2012. The researcher analyzed the science test scores of 229 eighth grade students attending two middle schools in the same public school district from 2010-2012. The researcher analyzed test data from the NJASK 8 Science for evidence of academic performance outcomes of science content knowledge after the inquiry science intervention in Spring, 2010. There was a sustaining impact in the long-term effects of this intervention. The intervention itself was relatively short in nature administered over several weeks. However, the NJASK 8 Science assessment was administered to students at a later date. Furthermore, the intervention focused on a specific unit of study. The NJASK assessed student knowledge and skills of broader topics, not isolated to just the units taught in the intervention. This randomized study selected students and teachers for each assigned cohort. Internal validity was satisfied by randomization. This study sought to achieve the most valid and reliable results possible in the hope of expanding the existing body of research in the field. The data collected was statistically analyzed using the SPSS 22.0 software package.

The independent variables for this study were middle school students in the IBS (IBS) program and middle school students not in the IBS (IBS) program (traditional, didactic instruction). The dependent variables for this study were non-cognitive outcomes (academic self-concept mean gain scores) and academic outcomes (unit assessment mean gain scores and
NJASK 8 Science mean scores). All other conditions that the experiment took place under were controlled so any observed changes in the values of the dependent variables can be assumed to be produced as a result of the intervention. Quantitative measures such as one-way analysis of variance (ANOVA) tests were run to determine if a statistically significant difference existed between the groups. Results from the statistical analyses are provided in both descriptive tables and analysis of variance (ANOVA) tables in Chapter IV.

Student responses to the ASC scale questions (pretest & posttest) were recorded into an Excel spreadsheet by the researcher. Unit assessment scores (pretest & posttest) were also recorded into an Excel spreadsheet. Student data test results from 3 years of NJASK 8 Science tests by eighth grade students were recorded into an Excel spreadsheet and analyzed to determine if there was any change in the students’ science scores during the years following the IBS program intervention. Similarly, subgroup analyses were conducted for gender and special education using an analysis of variance. ANOVA was used to analyze the effects of IBS on both subgroups as it related to academic self-concept, unit assessments, and NJASK Science 8 achievement mean scores. Baseline equivalency testing was conducted prior to the commencement of the study. Researchers must utilize baseline equivalency testing to determine if the outcomes of the study were caused by the treatment or if these results were the effects of other factors. The researcher established that both the treatment and control groups were equivalent in this study. Table 5 contains a summary of data sources and analysis for each research question.
Table 5: Summary Table of Steps for Data Collection and Analysis

<table>
<thead>
<tr>
<th>Research Question Number</th>
<th>Research Question</th>
<th>Data Source</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the impact of an IBS curriculum on the non-cognitive outcomes (academic self-concept) and academic outcomes (unit assessments and NJASK 8 Science) for students who participated in the IBS program compared to students who did not participate in IBS (traditional, didactic instruction)?</td>
<td>a. ASC</td>
<td>i. ANOVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Unit Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. NJASK 8 Science</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>To what extent do there exist any differences as it relates to gender?</td>
<td>a. ASC</td>
<td>i. ANOVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Unit Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. NJASK 8 Science</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Does an IBS curriculum significantly impact the non-cognitive and academic outcomes of special education students?</td>
<td>a. ASC</td>
<td>i. ANOVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Unit Assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. NJASK 8 Science</td>
<td></td>
</tr>
</tbody>
</table>

Summary

This research study drew conclusions from the comparison of student performance measures to show if a statistically significant difference was present in the measures of:

- students in the IBS science program as compared to students not in the IBS science program (traditional, didactic instruction)
- female students in the IBS science program as compared to female students not in the IBS science program (traditional, didactic instruction)
• male students in the IBS science program as compared to male students not in the IBS science program (traditional, didactic instruction)
• special education students in the IBS science program as compared to special education students not in the IBS science program (traditional, didactic instruction)
• general education students in the IBS science program as compared to general education students not in the IBS science program (traditional, didactic instruction)

Chapter III provides a description in the introduction, method, design, intervention/treatment and control, population, sample, instrumentations, data collection, and data analysis. This chapter demonstrates a distinct association between the hypotheses, research questions, and methodology. Chapter III addresses the research methodology that frames the quantitative investigation and guides the research procedures. This study seeks to expand the research on the inquiry-based instruction program at the middle school level. The researcher examined the effectiveness of this program and whether or not it is worth implementing to assist in closing the achievement gap. Specifically, this study examined the program’s ability to improve non-cognitive outcomes and academic outcomes among gender and special education students. This is the evaluative component of this research where educational leaders must take into consideration the results of the study and determine whether such a financial expenditure in the program is worth the investment. The key findings of this study are identified in Chapter IV. Chapter IV presents the data and analyses of student data, specifically the ASC scale mean gain scores, unit assessment mean gain scores, and NJASK 8 Science mean scores.
CHAPTER IV: FINDINGS

Purpose of the Study

The purpose of this randomized study is to determine to what extent the teaching in inquiry science classrooms has an effect on the level of student engagement and student academic achievement compared to traditional instruction. This research includes data from the administration of a pretest and posttest using the ASC scale and unit assessments for both the control group (traditional classrooms) and treatment group (IBS classrooms). This study also analyzes assessment results from the NJASK 8 Science. This study specifically examines the impact on non-cognitive and academic outcomes as relates to gender and special education students. Analysis of non-cognitive outcomes was completed via the administration of the ASC scale and academic outcomes were measured by unit assessments and NJASK 8 Science scores.

Effective educational leadership is critical to improve student learning and, as a result, increase learning outcomes and achievement. Knowledge and understanding of the effect of positive levels of student attitudes, interests, and perceived self-efficacy in science may help school leaders assess and implement effective programs. Strategic leadership actions can support school administrators in the attainment of these goals and meeting the increased expectations for positive student outcomes. Study participants included middle school science students ($n=229$) in grades 6, 7, and 8 in two middle schools in the PK-12 public school district in Bergen County, New Jersey. Both district middle schools, identified in this study as Middle School I and Middle School II, participated in an evaluation of the STC/MS IBS program funded through a grant received by the researcher through a Bristol-Myers Squibb Grants for Teaching Excellence award. Within these two middle schools, 119 students were included in the IBS classroom group
compared to 110 students in the traditional classroom group. All students in grades 6 through 8 were randomly selected to participate in this study. This evaluation study was guided by the three main research questions. Findings are reported throughout this chapter. A decision is concluded as to whether to accept or reject the null hypotheses at the end of each analysis. The research questions were as follows:

1. What is the impact of IBS classrooms on non-cognitive outcomes (academic self-concept) and academic outcomes (unit assessments and NJASK 8 Science) compared to students who learn in traditional classrooms?
2. To what extent does gender moderate these relationships?
3. Do IBS classrooms have an effect on learning outcomes for special education students?

In this chapter, the researcher identifies the methodology that was used to examine and evaluate the effectiveness of the IBS program. This chapter includes sections on the purpose of the study, baseline equivalency testing, research questions, null hypotheses, and data analysis results.

**Baseline Equivalency Testing**

Baseline equivalency testing was used to establish comparability between the IBS classrooms (treatment) and traditional classrooms (control) before the start of the study. The researcher administered the ASC scale and district developed unit assessments (grade level, content specific) to gather baseline data for all students. It was assumed that both groups were equivalent and therefore no differences existed between both groups before the start of the intervention. With regards to gender, and special education status, a Chi square analysis was
conducted in order to determine whether the groups were equivalent. For gender, two cells (33.3%) had an expected count less than five. This value was greater than 20% which meant the assumption had been violated. Since this was the case, the likelihood ratio was examined in Table 6 at p < .05 and the null hypothesis (H₀) was accepted, confirming there was no difference in population between male and female groups: \( \chi^2 (2, N = 229) = 1.19, p = .55 \).

**Table 6: Chi Square Comparison Baseline Equivalency for Gender**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>female</td>
</tr>
<tr>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Control</td>
<td>%</td>
</tr>
<tr>
<td>Test</td>
<td>%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>1.190a</td>
<td>2</td>
<td>.551</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>1.575</td>
<td>2</td>
<td>.455</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>.846</td>
<td>1</td>
<td>.358</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>229</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* 2 cells (33.3%) have expected count less than 5. The minimum expected count is .48.

A Chi square analysis was conducted as reported in Table 7 to make sure to assess whether the groups were comparable for special education and general education status. Results indicated no significant difference in proportions between the groups: \( \chi^2 (1, N = 229) = .53, p = .47 \).
### Table 7: Chi Square Comparison Baseline Equivalency for Special Education and General Education

<table>
<thead>
<tr>
<th></th>
<th>Special Education</th>
<th>General Education</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>43</td>
<td>67</td>
<td>110</td>
</tr>
<tr>
<td>%</td>
<td>39.1%</td>
<td>60.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>41</td>
<td>78</td>
<td>119</td>
</tr>
<tr>
<td>%</td>
<td>34.5%</td>
<td>65.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>84</td>
<td>145</td>
<td>229</td>
</tr>
<tr>
<td>%</td>
<td>36.7%</td>
<td>63.3%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
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</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>.529&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td>.467</td>
<td>.467</td>
<td>.467</td>
</tr>
<tr>
<td>Continuity Correction&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.348</td>
<td>1</td>
<td>.555</td>
<td>.555</td>
<td>.555</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>.529</td>
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<td>.467</td>
<td>.467</td>
<td>.467</td>
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<tr>
<td>Fisher's Exact Test</td>
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<td>.495</td>
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<tr>
<td>Linear-by-Linear Association</td>
<td>.527</td>
<td>1</td>
<td>.468</td>
<td>.468</td>
<td>.468</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>229</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 0 cells (0.0%) have expected count less than 5. The minimum expected count is 40.35. Computed only for a 2x2 table.

One-way ANOVA and Chi square tests of associations were run to establish equivalency between groups for gender, students with disabilities, and the dependent variables (ASC scale mean gain scores, mean gain scores on science unit assessments, and the NJASK 8 Science mean scale scores). The ANOVA (Table 9) showed no statistically significant difference between the two groups in $F(1, 227) = .000$, $p = .994$ in their responses to the item that measured how students felt about attending schools. Based on the descriptive analysis provided in Table 8, students in the IBS classrooms had a mean of 2.12 ($SD = .51$), while the mean for students in traditional classrooms was 2.12 ($SD = .59$). Similarly, there was no statistically significant difference between the two groups in $F(1, 227) = .289$, $p = .591$ on the item that asked students how engaging their classes were. Table 8 shows that students in the IBS classrooms had a mean of 3.00 ($SD = .64$) which was a lower mean for pre-assessment question 2 than for students who were in the traditional
classrooms, with a mean of 3.05 ($SD = .64$). There existed no statistically significant difference between the two groups in $F (1, 227) = 1.707, p = .193$ in their responses to the item that measured how bored students felt in class. Table 8 shows that those students in the IBS classrooms had a mean of 2.25 ($SD = .52$). The traditional classroom group had a mean of 2.16 ($SD = .50$) and was not significant. A review of student responses to the item that measured how much students felt they could learn resulted in no statistically significant difference between the two groups in $F (1, 227) = .184, p = .668$. Table 8 shows that students in the IBS classrooms had a mean score of 2.93 ($SD = .70$) compared to students in the traditional classroom group who had a mean score of 2.97 ($SD = .71$). These results were not significant. In addition, Table 9 showed no statistically significant difference between the two groups in $F (1, 227) = 3.491, p = .063$ in their responses to the item that measured to what extent they liked doing work in school. The descriptive analysis shows that students in the IBS classrooms had a mean of 2.71 ($SD = .77$) while the results from the traditional classrooms had a mean of 2.90 ($SD = .73$), which were not significant. The student responses to the last question item on the ASC scale that measured to what extent students felt homework could sometimes be fun showed no statistically significant difference between the two groups in $F (1, 227) = 2.044, p = .154$. Table 8 shows that students in the IBS classrooms had a mean of 2.45 ($SD = .79$) while the traditional classroom group had a mean of 2.60 ($SD = .85$), which was not significant.

Alternatively, the ANOVA showed a statistically significant difference between the two groups in $F (1, 227) = 6.283, p = .013$ in their responses to the second to last question item on the ASC scale (question #6) that measured to what extent students felt they could learn a lot in their classes. Based on the descriptive analysis provided in Table 8, students in the IBS classrooms had a mean of 3.38 ($SD = .60$) while the mean for students in the traditional classrooms was 3.16 ($SD =$
.70). This result was the only question that was statistically significant. Overall, the two groups were found to be equivalent on most of the study variables at the start of the intervention. Thus, we can be confident that the randomization process resulted in groups that were essentially equivalent.

Table 8: Grades 6-8 Middle School Students in IBS Classrooms vs. Traditional Classrooms

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Lower Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Classrooms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE Q1</td>
<td>110</td>
<td>2.1182</td>
<td>.58626</td>
<td>.05590</td>
<td>2.0074</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>2.1176</td>
<td>.50718</td>
<td>.04649</td>
<td>2.0256</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>2.1179</td>
<td>.54538</td>
<td>.03604</td>
<td>2.0469</td>
<td></td>
</tr>
<tr>
<td><strong>PRE Q2</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Traditional Classrooms</td>
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<td>3.0455</td>
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<td>.06111</td>
<td>2.9243</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>3.0000</td>
<td>.63779</td>
<td>.05847</td>
<td>2.8842</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>3.0218</td>
<td>.63829</td>
<td>.04218</td>
<td>2.9387</td>
<td></td>
</tr>
<tr>
<td><strong>PRE Q3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>110</td>
<td>2.164</td>
<td>.4982</td>
<td>.0475</td>
<td>2.069</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>2.252</td>
<td>.5243</td>
<td>.0481</td>
<td>2.157</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>2.210</td>
<td>.5127</td>
<td>.0339</td>
<td>2.143</td>
<td></td>
</tr>
<tr>
<td><strong>PRE Q4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>110</td>
<td>2.9727</td>
<td>.70981</td>
<td>.06768</td>
<td>2.8386</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>2.9328</td>
<td>.69783</td>
<td>.06397</td>
<td>2.8061</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>2.9520</td>
<td>.70235</td>
<td>.04641</td>
<td>2.8605</td>
<td></td>
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<tr>
<td><strong>PRE Q5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>110</td>
<td>2.9000</td>
<td>.72883</td>
<td>.06949</td>
<td>2.7623</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>2.7143</td>
<td>.77178</td>
<td>.07075</td>
<td>2.5742</td>
<td></td>
</tr>
<tr>
<td>Table 9: One-Way ANOVA to Determine Difference between IBS Classrooms and Traditional Classrooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Groups</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PRE Q1</td>
<td>.000</td>
<td>1</td>
<td>.000</td>
<td>.000</td>
<td>.994</td>
</tr>
<tr>
<td></td>
<td>67.817</td>
<td>227</td>
<td>.299</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>67.817</td>
<td>228</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PRE Q2</td>
<td>.118</td>
<td>1</td>
<td>.118</td>
<td>.289</td>
<td>.591</td>
</tr>
<tr>
<td></td>
<td>92.773</td>
<td>227</td>
<td>.409</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>92.891</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE Q3</td>
<td>.447</td>
<td>1</td>
<td>.447</td>
<td>1.707</td>
<td>.193</td>
</tr>
<tr>
<td></td>
<td>59.492</td>
<td>227</td>
<td>.262</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>59.939</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE Q4</td>
<td>.091</td>
<td>1</td>
<td>.091</td>
<td>.184</td>
<td>.668</td>
</tr>
<tr>
<td></td>
<td>112.380</td>
<td>227</td>
<td>.495</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>112.472</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE Q5</td>
<td>1.971</td>
<td>1</td>
<td>1.971</td>
<td>3.491</td>
<td>.063</td>
</tr>
<tr>
<td></td>
<td>128.186</td>
<td>227</td>
<td>.565</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>130.157</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PRE Q6  | Between Groups | 2.630 | 1  | 2.630 | 6.283 | .013
| Within Groups | 95.038 | 227 | .419 |
| Total          | 97.668 | 228 |     |

PRE Q7  | Between Groups | 1.367 | 1  | 1.367 | 2.044 | .154
| Within Groups | 151.795 | 227 | .669 |
| Total          | 153.162 | 228 |     |

Data Analysis Results for Hypothesis 1

This randomized study included 229 students in grades 6-8 in the IBS classrooms between two district middle schools. This study included 110 students in the traditional classrooms and 119 students in the IBS classrooms. When comparing all students that were in the IBS classrooms with those students who were in the traditional classrooms condition, an ANOVA was used to determine if there were any statistically significant differences between the two groups in terms of non-cognitive outcomes (ASC scale) and academic outcomes (Unit Assessment and NJASK 8 Science).

Impact Findings:

The following research questions and their associated hypotheses were addressed in the analysis of impact.

Findings: Research Question 1

What is the effect of IBS on the non-cognitive outcomes (academic self concept) and academic outcomes (unit assessments and NJASK 8 Science) for students who participated in IBS classrooms compared to students who participated in traditional classrooms?
Null Hypothesis 1

Middle school students who participate in IBS classrooms will not achieve a statistically significant difference in their non-cognitive outcomes and academic performance compared to students in traditional classrooms.

Findings: Hypothesis 1

Non-Cognitive Outcomes

The results from the ANOVA reported in Table 11 show no statistically significant difference, $F(1, 227) = 1.34$, $p = .248$, between the IBS classrooms and traditional classrooms for non-cognitive gain outcomes. Based on the descriptive analysis provided in Table 10, students in the IBS classrooms had a mean gain score of $-0.08$ ($SD = 2.68$) while the traditional classrooms’ mean gain score was $-0.51$ ($SD = 2.98$). Although both IBS and traditional classrooms revealed an improvement in academic self-concept, the results were not significant. Gain scores were calculated by subtracting the posttest mean from the pretest mean. A negative gain score signified a decrease in mean score on the posttest compared to the pretest, indicating an improvement in academic self-concept. Alternatively, a positive gain score correlated to an increase in mean score on the posttest compared to the pretest, representing a decline in academic self-concept.

Academic Outcomes-Unit Assessment

The results from the ANOVA reported in Table 11 show that students participating in the IBS classrooms performed better on the science unit assessment than students who participated in the traditional classrooms. These results were significant, $F(1, 227) = 6.406$, $p = .012$. The descriptive analysis in Table 10 indicates that the IBS classrooms’ mean gain score was $14.68$.
(SD = 17.97) while the traditional classrooms’ mean gain score was 8.69 (SD = 17.82). The traditional classrooms’ pretest mean score was 57.98 while the posttest mean was 66.67, accounting for a mean gain score increase of 8.69. The IBS classrooms’ pretest mean was 56.28 with a posttest mean of 70.96, revealing an increase in mean gain score of 14.68.

**Table 10: Students in IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (Unit Assessment) and Non-Cognitive Gains (Academic Self-Concept Scale)**

<table>
<thead>
<tr>
<th>Descriptives</th>
<th>N</th>
<th>Mean Gain</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic Performance Gain-Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>110</td>
<td>8.6900</td>
<td>17.81865</td>
<td>1.69894</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>14.6809</td>
<td>17.96745</td>
<td>1.64707</td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>11.8032</td>
<td>18.10707</td>
<td>1.19655</td>
</tr>
<tr>
<td>Noncog. Gain-Academic Self-Concept Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>110</td>
<td>3.0912</td>
<td>1.97619</td>
<td>.28377</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>119</td>
<td>2.8380</td>
<td>2.68442</td>
<td>.24608</td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>2.8380</td>
<td>2.83040</td>
<td>.18704</td>
</tr>
</tbody>
</table>

**Table 11: Data Analysis of One-Way ANOVA for Null Hypothesis 1: Academic Performance Gains (Unit Assessment) and Non-Cognitive Gains (Academic Self-Concept Scale)**

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Academic Performance Gain-Unit Assessment</td>
<td>Between Groups</td>
<td>2051.597</td>
<td>1</td>
<td>2051.597</td>
<td>6.406</td>
</tr>
<tr>
<td>Within Groups</td>
<td>72701.840</td>
<td>227</td>
<td>320.272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>74753.437</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncog. Gain-Academic Self-Concept Scale</td>
<td>Between Groups</td>
<td>10.740</td>
<td>1</td>
<td>10.740</td>
<td>1.343</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1815.810</td>
<td>227</td>
<td>7.999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1826.550</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Academic Outcomes - NJASK 8 Science

The results from the ANOVA reported in Table 13 show that the effect of IBS classrooms and traditional classrooms on the NJASK 8 Science scale score was not significant, $F(1, 227) = .370 \ p = .544$. Achievement results in Table 12 indicate traditional classrooms outperformed IBS classrooms with a mean of 243.46 ($SD = 32.50$) to 240.98 ($SD = 28.92$), respectively, but again, these results were not significant.

**Table 12: Students in IBS Classrooms vs. Traditional Classrooms for Academic Performance Gain (NJASK 8 Science)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Traditional Classrooms</th>
<th>IBS Classrooms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>110</td>
<td>119</td>
<td>229</td>
</tr>
<tr>
<td>Mean</td>
<td>243.46</td>
<td>240.98</td>
<td>242.17</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>32.49</td>
<td>28.92</td>
<td>30.64</td>
</tr>
<tr>
<td>Std. Error</td>
<td>3.098</td>
<td>2.651</td>
<td>2.025</td>
</tr>
</tbody>
</table>

**Table 13: Data Analysis of One-Way ANOVA for Null Hypothesis 1: NJASK 8 Science**

| Summary for Hypothesis 1
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>This research question was designed to examine if students in the IBS classrooms outperformed students in traditional classrooms. An ANOVA was used to determine if there were any differences between the treatment and control groups in terms of the ASC scale gains, unit assessment gains, and NJASK 8 Science scale scores. The researcher’s findings indicated</td>
</tr>
</tbody>
</table>
that traditional classrooms outperformed IBS classrooms with respect to non-cognitive outcomes, although not significantly. However, students in the IBS classrooms outperformed students in traditional classrooms for academic outcome gains as measured by the unit assessment. The ANOVA results revealed that students in the IBS classrooms maintained a higher mean average than students in traditional classrooms when comparing academic outcome gains. However, the mean averages were only statistically significant for unit assessment gain scores. Traditional classrooms did better than IBS classrooms for NJASK 8 Science scale scores, but these results were not significant. The null hypothesis was accepted for non-cognitive outcomes and academic outcomes for NJASK 8 Science. However, the null hypothesis was rejected for academic outcomes on the unit assessment. Table 14 below summarizes these results.

Table 14: Research Question 1 Summary of Results

<table>
<thead>
<tr>
<th>Non-Cognitive Outcome</th>
<th>Academic Self-Concept Scale Gains</th>
<th>Statistically Significant</th>
<th>IBS Classrooms (Mean Score)</th>
<th>Traditional Classrooms (Mean Score)</th>
<th>Null Hypothesis Accepted/Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Outcome</td>
<td>Unit Assessment Gains</td>
<td>Yes</td>
<td>14.68</td>
<td>8.69</td>
<td>Rejected</td>
</tr>
<tr>
<td>Academic Outcome</td>
<td>NJASK 8 Science</td>
<td>No</td>
<td>240.98</td>
<td>243.46</td>
<td>Accepted</td>
</tr>
</tbody>
</table>

Data Analysis Results for Hypothesis 2

This program evaluation included a total of 110 male students in grades 6-8 in the randomized study between two district middle schools. This study included 55 male students in traditional classrooms and 56 male students in IBS classrooms. This research was also comprised
of a total of 118 female students in grades 6-8. The randomized study included 55 female students in traditional classrooms and 63 female students in IBS classrooms. The hypothesis was created to determine to what extent IBS classrooms had an effect on various student performance measures. The statistical results and analysis of the data are shown in the tables accompanying each analysis. When comparing all students who were in IBS classrooms with students who were in traditional classrooms, an ANOVA was used to determine if there were any statistically significant differences between these two groups in terms of non-cognitive outcomes (ASC scale) and academic outcomes (Unit Assessment and NJASK 8 Science) as relates to gender. The statistical results and analysis of the data are shown in the next section.

Findings: Research Question 2

Research question 2 sought to determine the moderating effects of gender. Subgroups analyses were conducted for males and females separately. The research question is restated below along with the relevant hypotheses.

Research Question 2

To what extent does gender moderate these relationships?

Null Hypothesis 2

Gender does not have a statistically significant moderating effect on non-cognitive outcomes and academic achievement for middle school students in IBS classrooms compared to traditional classrooms.
Findings: Hypothesis 2

Male Students

Non-Cognitive Outcomes

The results from the ANOVA reported in Table 16 show no statistically significant difference for male students between IBS classrooms and traditional classrooms for non-cognitive gain outcomes, $F (1, 108) = .433, p = .512$. Based on the descriptive analysis provided in Table 15, male students’ in IBS classrooms’ mean gain score was -.15 (SD = 3.04) which meant they revealed lower improvement gains on the ASC scale than male students in traditional classrooms, who had a mean gain score of -.55 (SD = 3.33).

Academic Outcomes-Unit Assessment

The results from the ANOVA reported in Table 16 show that the effect of IBS classrooms and traditional classrooms on gain academic performance for males was significant, $F (1, 109) = 8.653, p = .004$. The descriptive analysis in Table 15 indicates that IBS classrooms with a mean gain score of 16.98 ($SD = 19.06$) outperformed traditional classrooms with a mean gain score of 6.70 ($SD = 17.58$). The traditional classrooms’ pretest mean score for males was 58.88 while the posttest mean was 65.58, accounting for a mean gain score increase of 6.70. The IBS classrooms’ pretest mean was 55.70 with a posttest mean of 72.68, revealing an increase in mean gain score of 16.98.
Table 15: Males in IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (Unit Assessment) and Non-Cognitive Gains (Academic Self-Concept Scale)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean Gain</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Performance Gain-Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
<td>6.6982</td>
<td>17.57834</td>
<td>2.37026</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>56</td>
<td>16.9818</td>
<td>19.05708</td>
<td>2.56966</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td>11.8400</td>
<td>18.96530</td>
<td>1.80827</td>
</tr>
<tr>
<td>Noncog. Gain-Academic Self-Concept Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
<td>-0.5455</td>
<td>3.32676</td>
<td>0.4485</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>56</td>
<td>-0.1455</td>
<td>3.03936</td>
<td>0.40983</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td>-0.3455</td>
<td>3.17801</td>
<td>0.30301</td>
</tr>
</tbody>
</table>

Table 16: Data Analysis of One-Way ANOVA for Null Hypothesis 2: Academic Performance Gains (Unit Assessment) and Non-Cognitive Gains (Academic Self-Concept Scale) for Males

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Performance Gain-Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>2908.186</td>
<td>1</td>
<td>2908.186</td>
<td>8.653</td>
<td>.004</td>
</tr>
<tr>
<td>Within Groups</td>
<td>36297.199</td>
<td>109</td>
<td>336.085</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39205.385</td>
<td>110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncog. Gain-Academic Self-Concept Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>4.400</td>
<td>1</td>
<td>4.400</td>
<td>.433</td>
<td>.512</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1096.473</td>
<td>109</td>
<td>10.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1100.873</td>
<td>110</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Academic Outcomes-NJASK 8 Science

The results from the ANOVA reported in Table 18 reveal that effects did not differ for males. Male students in traditional classrooms slightly outperformed males in IBS classrooms, although the results were not significant, $F (1, 109) = .040 \ p = .842$. Achievement results in Table 17 indicate that male students in traditional classrooms maintained a mean score of 241.80 ($SD = 34.51$) and performed slightly better than the males in IBS classrooms with a mean of 240.54 ($SD = 28.95$), but again, it was not significant.
Table 17: Males in IBS Classrooms vs. Traditional Classrooms for Academic Performance Scale Score (NJASK 8 Science)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
<td>241.80</td>
<td>34.512</td>
<td>4.654</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>56</td>
<td>240.54</td>
<td>28.946</td>
<td>3.868</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td>241.16</td>
<td>31.687</td>
<td>3.008</td>
</tr>
</tbody>
</table>

Table 18: Data Analysis of One-Way ANOVA for Null Hypothesis 2: Males NJASK 8 Science IBS Classrooms vs. Traditional Classrooms

ANOVA

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>44.353</td>
<td>1</td>
<td>44.353</td>
<td>0.040</td>
<td>0.842</td>
</tr>
<tr>
<td>Within Groups</td>
<td>110400.729</td>
<td>110</td>
<td>1012.851</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>110445.081</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Female Students Non-Cognitive Outcomes

The results from the ANOVA reported in Table 20 show no statistically significant difference for female students in IBS classrooms and traditional classrooms for non-cognitive outcome gains, $F(1, 116) = .804, p = .372$. Based on the descriptive analysis provided in Table 19, female students in IBS classrooms had a mean gain score of -.06 ($SD = 2.35$) on the ASC scale. Females in traditional classrooms performed better than females in IBS classrooms for academic self-concept with a mean gain score of -.47 ($SD = 2.61$), although not significant.

Academic Outcomes-Unit Assessment

The results from the ANOVA reported in Table 20 show that the effect of IBS classrooms on females for academic performance gains on unit assessments was not significant,
\( F(1, 116) = .428, p = .514 \). However, the descriptive analysis in Table 19 indicates that females in IBS classrooms with a mean gain score of 12.79 (SD = 17.00) outperformed females in traditional classrooms with a mean gain score of 10.68 (SD = 17.99), although not statistically significantly. The traditional classrooms pretest mean score for females was 57.08 while the posttest mean was 67.76, demonstrating a mean gain score increase of 10.68. The IBS classrooms’ pretest mean was 56.65 with a posttest mean of 69.45, revealing a mean gain score increase of 12.79.

**Table 19: Females in IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (Unit Assessment) and Non-Cognitive Outcome Gains (Academic Self-Concept Scale)**

<table>
<thead>
<tr>
<th>Females</th>
<th>N</th>
<th>Mean Gain</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Performance Gain-Unit Assessment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
<td>10.6817</td>
<td>17.99470</td>
<td>2.42641</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>63</td>
<td>12.7918</td>
<td>16.99608</td>
<td>2.14130</td>
</tr>
<tr>
<td>Total</td>
<td>118</td>
<td>11.8083</td>
<td>17.42534</td>
<td>1.60413</td>
</tr>
<tr>
<td><strong>Noncog. Gain-Academic Self-Concept Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
<td>-0.4727</td>
<td>2.60949</td>
<td>0.35186</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>63</td>
<td>-0.0635</td>
<td>2.34777</td>
<td>0.29579</td>
</tr>
<tr>
<td>Total</td>
<td>118</td>
<td>-0.2542</td>
<td>2.47098</td>
<td>0.22747</td>
</tr>
</tbody>
</table>

**Table 20: Data Analysis of One-Way ANOVA for Null Hypothesis 2: Academic Performance Gains (Unit Assessment) and Non-Cognitive Outcome Gains (Academic Self-Concept Scale) for Females**

<table>
<thead>
<tr>
<th>Females</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Performance Gain-Unit Assessment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>130.745</td>
<td>1</td>
<td>130.745</td>
<td>.428</td>
<td>.514</td>
</tr>
<tr>
<td>Within Groups</td>
<td>35395.436</td>
<td>116</td>
<td>305.133</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35526.181</td>
<td>117</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Noncog. Gain-Academic Self-Concept Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>4.918</td>
<td>1</td>
<td>4.918</td>
<td>.804</td>
<td>.372</td>
</tr>
<tr>
<td>Within Groups</td>
<td>709.455</td>
<td>116</td>
<td>6.116</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>714.373</td>
<td>117</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Academic Outcomes-NJASK 8 Science

The results from the ANOVA reported in Table 22 reveal that effects did not differ for females, $F(1, 116) = .460, p = .499$. The achievement results in Table 21 indicate that the female students in traditional classrooms slightly outperformed the female students in IBS classrooms, with a mean score of 245.13 ($SD = 30.57$) and 241.38 ($SD = 29.12$), respectively. However, these results were not significant.

Table 21: Females in IBS Classrooms vs. Traditional Classrooms for Academic Performance Scale Score (NJASK 8 Science)

<table>
<thead>
<tr>
<th>Descriptives</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Scale Score-Females</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>55</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>118</td>
</tr>
</tbody>
</table>

Table 22: Data Analysis of One-Way ANOVA for Null Hypothesis 2: Females NJASK 8 Science IBS Classrooms vs. Traditional Classrooms

<table>
<thead>
<tr>
<th>ANOVA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Scale Score-Females</td>
<td></td>
</tr>
<tr>
<td>Sum of Squares</td>
<td>df</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Between Groups</td>
<td>412.127</td>
</tr>
<tr>
<td>Within Groups</td>
<td>103050.966</td>
</tr>
<tr>
<td>Total</td>
<td>103463.093</td>
</tr>
</tbody>
</table>

Summary for Hypothesis 2

An ANOVA was used to determine if there were any differences between the IBS classrooms and traditional classrooms in terms of the ASC scale gains, unit assessment gains,
and NJASK 8 Science gains for male and female students. This research question was designed to determine if IBS classrooms had differential impact for males and females. The researcher’s findings indicated that traditional classrooms, both male and female, outperformed students in IBS classrooms with respect to non-cognitive outcomes. Overall, both male and female students in IBS classrooms outperformed students in traditional classrooms on unit assessments, but it was only significant for males. The results in Table 21 also reveal that male and female students in traditional classrooms maintained slightly higher mean scale scores than male and female students in IBS classrooms for NJASK Science 8; however, these results were not statistically significant. The null hypothesis is accepted for non-cognitive outcomes for both males and females. The null hypothesis is also accepted for academic outcomes on the unit assessment gains for females but it is rejected for males. The null hypothesis is accepted for academic outcomes on NJASK 8 Science for both males and females. Table 23 summarizes these results.

Table 23: Research Question 2 Summary of Results for Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Statistically Significant</th>
<th>IBS Classrooms (Mean Score)</th>
<th>Traditional Classrooms (Mean Score)</th>
<th>Null Hypothesis Accepted/Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>No</td>
<td>-.15</td>
<td>-.55</td>
<td>Accepted</td>
</tr>
<tr>
<td>Female</td>
<td>No</td>
<td>-.06</td>
<td>-.47</td>
<td>Accepted</td>
</tr>
<tr>
<td>Male</td>
<td>Yes</td>
<td>16.98</td>
<td>6.70</td>
<td>Rejected</td>
</tr>
<tr>
<td>Female</td>
<td>No</td>
<td>12.79</td>
<td>10.68</td>
<td>Accepted</td>
</tr>
<tr>
<td>Male</td>
<td>No</td>
<td>240.54</td>
<td>241.80</td>
<td>Accepted</td>
</tr>
<tr>
<td>Female</td>
<td>No</td>
<td>241.38</td>
<td>245.13</td>
<td>Accepted</td>
</tr>
</tbody>
</table>
Data Analysis Results for Hypothesis 3

This program evaluation included 84 special education students in grades 6-8 in the IBS program between two district middle schools. This study included 43 special education students in traditional classrooms and 41 special education students in IBS classrooms. The study included an analysis of the effectiveness of the IBS program on 145 general education students, including 67 general education students in traditional classrooms and 78 general education students in IBS classrooms. This hypothesis was created to determine the effect of the IBS program on the previously stated student performance measures. The statistical results and analysis of the data are shown in the tables accompanying each analysis.

When comparing all special education students in IBS classrooms to special education students in traditional classrooms, an ANOVA was used to determine if there were any statistically significant differences between these two groups in terms of non-cognitive outcomes and academic outcomes. A similar comparison was also conducted to examine the effect on general education students. Assessment results were used to determine to what extent IBS classrooms had an effect on non-cognitive outcomes and academic outcomes.

Findings: Research Question 3

To what extent do IBS classrooms significantly affect non-cognitive and academic outcomes for special education students?

Null Hypothesis 3

There is no statistically significant difference for middle school special education students with respect to non-cognitive outcomes and academic achievement in IBS classrooms compared to traditional classrooms.
Findings: Hypothesis 3: Special Education Students Non-Cognitive Outcomes

The results from the ANOVA reported in Table 25 show no statistically significant difference in the non-cognitive gain scores $F(1, 82) = 1.008$, $p = .318$, for special education students in IBS classrooms and those in traditional classrooms. Based on the descriptive analysis provided in Table 24, students in IBS classrooms’ mean gain score was -.15 ($SD = 3.50$) representing lower improvement gains on the ASC scale than for students who were in traditional classrooms, with a mean of -.86 ($SD = 3.00$).

Academic Outcomes—Unit Assessment

The results from the ANOVA reported in Table 25 show that the effect of IBS classrooms on academic performance gains was significant, $F(1, 82) = 5.901$, $p = .017$. The descriptive analysis in Table 24 indicates IBS classrooms outperformed traditional classrooms with mean gain scores of 19.33 ($SD = 19.89$) and 9.11 ($SD = 18.67$), respectively. Traditional classrooms’ pretest mean score for special education students was 47.94 while the posttest mean was 57.05, demonstrating a mean gain score increase of 9.11. IBS classrooms’ pretest mean was 49.10 with a posttest mean of 68.43, revealing a mean gain score increase of 19.33.

Table 24: Special Education IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (Unit Assessment) and Non-Cognitive Outcome Gains (Academic Self-Concept Scale)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean Gain</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain—Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>43</td>
<td>9.1081</td>
<td>18.67294</td>
<td>2.84760</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>41</td>
<td>19.3288</td>
<td>19.88699</td>
<td>3.10583</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>14.0968</td>
<td>19.83567</td>
<td>2.16425</td>
</tr>
<tr>
<td>Noncog. Gain—Academic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>43</td>
<td>-.8605</td>
<td>3.00461</td>
<td>.45820</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>41</td>
<td>-.1463</td>
<td>3.50400</td>
<td>.54723</td>
</tr>
</tbody>
</table>
Table 25: Data Analysis of One-Way ANOVA for Null Hypothesis 3: Academic Performance Gains and Non-Cognitive for Special Education Students

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Performance Gain-Unit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td>Between Groups</td>
<td>2192.460</td>
<td>1</td>
<td>2192.460</td>
<td>5.901</td>
</tr>
<tr>
<td><strong>Noncog. Gain-Academic Self-Concept Scale</strong></td>
<td>Total</td>
<td>32656.657</td>
<td>83</td>
<td>371.515</td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>10.703</td>
<td>1</td>
<td>10.703</td>
<td>1.008</td>
<td>.318</td>
</tr>
<tr>
<td>Within Groups</td>
<td>870.285</td>
<td>82</td>
<td>10.613</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>880.988</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Academic Outcomes Special Education-NJASK 8 Science

The results from the ANOVA reported in Table 27 show that the academic outcome results of special education in IBS classrooms compared to traditional classrooms on the NJASK 8 Science scale score was not significant, $F (1, 82) = 0.12, p = .730$. However, the achievement results in Table 26 indicate that special education students in traditional classrooms had a mean score of 225.51 ($SD = 25.56$) and outperformed special education IBS classrooms with a mean of 223.40 ($SD = 30.00$), although not significantly.

Table 26: One-Way ANOVA to Determine Difference between Special Education IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (NJASK 8 Science)

<table>
<thead>
<tr>
<th>Science Scale Score</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Education</td>
<td>41</td>
<td>225.51</td>
<td>25.561</td>
<td>3.992</td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 27: Data Analysis of One-Way ANOVA for Null Hypothesis 3: NJASK 8 Science Special Education IBS Classrooms vs. Traditional Classrooms

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>94.049</td>
<td>1</td>
<td>94.049</td>
<td>0.12</td>
<td>0.730</td>
</tr>
<tr>
<td>Within Groups</td>
<td>63946.523</td>
<td>82</td>
<td>779.836</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>64040.571</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Education Students Non-Cognitive Outcomes

The results from the ANOVA reported in Table 29 show no statistically significant difference, \( F (1, 143) = .331, \ p = .566 \), between IBS classrooms and traditional classrooms for general education students for non-cognitive gain outcomes. Based on the descriptive analysis provided in Table 28, students in IBS classrooms’ mean gain score was -0.04 \((SD = 2.16)\) representing lower improvement gains on the ASC scale than for students in traditional classrooms, with a mean gain score of -0.28 \((SD = 2.96)\).

Academic Outcomes-Unit Assessment

The results from the ANOVA reported in Table 29 show that the effects of IBS classrooms and traditional classrooms on gain academic performance were not significant, \( F (1, 143) = 1.836, \ p = .178 \). However, the descriptive analysis in Table 28 indicates that IBS classrooms had a mean gain score of 12.24 \((SD = 16.48)\), performing better than traditional classrooms with a mean gain score of 8.42 \((SD = 17.39)\), but again, it was not significant.
Traditional classrooms’ pretest mean score for general education students was 64.42 while the posttest mean was 72.85. IBS classrooms’ pretest mean was 60.05 with a posttest mean of 72.29.

**Table 28: General Education IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (Unit Assessment) and Non-Cognitive Outcome Gains (Academic Self-Concept Scale)**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean Gain</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain-Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>67</td>
<td>8.4216</td>
<td>17.38648</td>
<td>2.12410</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>78</td>
<td>12.2378</td>
<td>16.48411</td>
<td>1.86646</td>
</tr>
<tr>
<td>Total</td>
<td>145</td>
<td>10.4744</td>
<td>16.95560</td>
<td>1.40809</td>
</tr>
<tr>
<td><strong>Noncog. Gain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic Self-Concept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td>67</td>
<td>-.2836</td>
<td>2.95833</td>
<td>.36142</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td>78</td>
<td>-.0385</td>
<td>2.15890</td>
<td>.24445</td>
</tr>
<tr>
<td>Total</td>
<td>145</td>
<td>-.1517</td>
<td>2.55313</td>
<td>.21203</td>
</tr>
</tbody>
</table>

**Table 29: Data Analysis of One-Way ANOVA for Null Hypothesis 3: Academic Performance Gains and Non-Cognitive for General Education Students**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain-Unit Assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>524.876</td>
<td>1</td>
<td>524.876</td>
<td>1.836</td>
<td>.178</td>
</tr>
<tr>
<td>Within Groups</td>
<td>40874.003</td>
<td>143</td>
<td>285.832</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>41398.879</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Noncog. Gain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic Self-Concept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>2.166</td>
<td>1</td>
<td>2.166</td>
<td>.331</td>
<td>.566</td>
</tr>
<tr>
<td>Within Groups</td>
<td>936.497</td>
<td>143</td>
<td>6.549</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>938.662</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Academic Outcomes General Education-NJASK 8 Science**

The results from the ANOVA reported in Table 31 show that the academic outcome results of general education in IBS classrooms compared to traditional classrooms on the NJASK 8 Science scale score were not significant, $F(1, 143) = 2.53$, $p = .114$. The achievement results
in Table 30 indicate that general education students in traditional classrooms had a mean score of 256.34 ($SD = 27.20$) and outperformed general education IBS classrooms with a mean of 249.12 ($SD = 27.35$), although not significantly.

Table 30: One-Way ANOVA to Determine Difference between General Education IBS Classrooms vs. Traditional Classrooms for Academic Performance Gains (NJASK 8 Science)

<table>
<thead>
<tr>
<th>Science Scale Score</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Education</td>
<td>67</td>
<td>256.34</td>
<td>27.20</td>
<td>3.32</td>
</tr>
<tr>
<td>Traditional Classrooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Education</td>
<td>78</td>
<td>249.12</td>
<td>27.347</td>
<td>3.096</td>
</tr>
<tr>
<td>IBS Classrooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>145</td>
<td>252.46</td>
<td>27.425</td>
<td>2.278</td>
</tr>
</tbody>
</table>

Table 31: Data Analysis of One-Way ANOVA for Null Hypothesis 3: NJASK 8 Science General Education IBS Classrooms vs. Traditional Classrooms

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1882.893</td>
<td>1</td>
<td>1882.893</td>
<td>2.53</td>
<td>0.114</td>
</tr>
<tr>
<td>Within Groups</td>
<td>106427.066</td>
<td>143</td>
<td>744.245</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>108309.959</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary for Hypothesis 3

This research question was designed to examine if middle school special education students in IBS classrooms outperformed special education students in traditional classrooms as relates to student learning classification. A similar comparison was conducted for general education students. An ANOVA was used to determine if there were any differences between
IBS classrooms and traditional classrooms in terms of the ASC scale gains, unit assessment gains, and NJASK 8 Science gains for special education and general education students.

The researcher’s findings indicate that both special education and general education students in traditional classrooms outperformed IBS classrooms with respect to non-cognitive outcomes and NJASK 8 Science, although not significantly. However, both special education and general education students in IBS classrooms outperformed students in traditional classrooms for academic performance gains as measured by unit assessments. Results were only significant for special education students for the unit assessments. The ANOVA results also revealed that both special education and general education students in traditional classrooms maintained higher mean scale scores on the NJASK 8 Science than students in IBS classrooms, although not significantly.

The null hypothesis is accepted for non-cognitive outcomes for both special education and general education students. The null hypothesis is accepted for academic outcomes on the unit assessment gains for general education students but it is rejected for special education students. Finally, the null hypothesis is accepted for academic outcomes on NJASK 8 Science for special education and general education students. Table 32 summarizes these results.

Table 32: Research Question 3 Summary of Results for Special Education & General Education Students

<table>
<thead>
<tr>
<th>Non-Cognitive Outcome</th>
<th>Learning Classification</th>
<th>Statistically Significant</th>
<th>IBS Classrooms (Mean Score)</th>
<th>Traditional Classrooms (Mean Score)</th>
<th>Null Hypothesis Accepted/Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Self-Concept Scale Gains</td>
<td>Special Education</td>
<td>No</td>
<td>-.15</td>
<td>-.86</td>
<td>Accepted</td>
</tr>
<tr>
<td></td>
<td>General Education</td>
<td>No</td>
<td>-.04</td>
<td>-.28</td>
<td>Accepted</td>
</tr>
</tbody>
</table>
### Summary

The quantitative analysis in this study provided evidence that IBS classrooms had a positive effect on academic outcomes as relates to unit assessments as follows:

- students in IBS classrooms performed better than students in traditional classrooms on unit assessments
- male students in IBS classrooms outperformed male students in traditional classrooms on unit assessments
- special education students in IBS classrooms performed better than special education students in traditional classrooms on unit assessments

The data in this study also demonstrated that there existed no statistically significant difference between IBS classrooms and traditional classrooms for academic self-concept and the NJASK 8 Science. It is also important to note that females in IBS classrooms attained higher mean gain scores on unit assessments than females in traditional classrooms, but these results were not significant. Lastly, general education students in IBS classrooms outperformed students in traditional classrooms on unit assessments, but again, it was not significant.

There was a sustaining impact in measuring the long-term effects of this intervention. The intervention itself was relatively short in nature administered over several weeks. However,
the NJASK Science assessment was only administered to grade 8 students. As a result, this assessment was administered to students at a later date depending on the student’s grade level at the time of the intervention. Students in grade 8 at the time of intervention were assessed on the NJASK Science that spring. However, students in grade 7 at time of intervention were administered the NJASK Science over 1 year later. Similarly, grade 6 students were administered the NJASK Science over 2 years later. Furthermore, the intervention focused on a specific unit of study. The NJASK assessed student knowledge and skills of broader topics, not isolated to just the units taught in the intervention.
CHAPTER V: SUMMARY FINDINGS, RECOMMENDATIONS, AND CONCLUSION

Summary Findings

This study focused on addressing some of the apparent gaps in the existing research literature. This research defined IBS instruction and identified the difference between inquiry and traditional science instruction. This research established whether differences existed in non-cognitive and academic outcomes between students in IBS classrooms and those in traditional science classrooms in a middle school setting in a suburban school district in New Jersey. The study examined the moderating effects gender and special education has on these outcomes.

The purpose of this study was to determine to what extent IBS instruction has an effect on non-cognitive outcomes and academic achievement in a middle school setting. The intervention was implemented between January and May, 2010. The intervention was relatively short in duration, ranging from 6 to 10 weeks depending upon the unit of study. This random design study was guided by three main research questions: 1) What is the impact of IBS classrooms on non-cognitive outcomes (academic self-concept) and academic achievement (unit assessments and NJASK 8 Science) compared to students who learn in traditional classrooms? 2) To what extent does gender moderate these relationships? and 3) Do IBS classrooms have an effect on learning outcomes for special education students?

The effects of IBS instruction on non-cognitive outcomes and academic performance were examined through a random control design. Middle school students in grades 6 through 8 were randomly assigned to one of two groups (experimental group or control group) at each grade level. Both groups at each grade level were administered a pretest to assess academic self-concept and science content knowledge. After the administration of the pretest, each
experimental group received IBS instruction, while the control group received traditional science instruction. Upon conclusion of instruction, both groups were administered a posttest to assess academic self-concept and science content knowledge. Students in the experimental group learned science through inquiry by the administration of STC-MS investigation kits. For the purpose of this study, quantitative research methods were utilized. Student achievement data were analyzed from the NJASK 8 Science administered in May, 2010, May, 2011, and May, 2012. The NJASK 8 Science was the only middle school state assessment that measured science knowledge and skills. This pilot program was administered in the 2009-2010 academic year.

Project 2061 revealed most Americans are not scientifically literate and, as a result, U.S. students are outperformed by students in other nations in both science and mathematics (AAAS, 1989). Traditional, didactic lecture methods tend to be less effective as students exhibit an inability to apply scientific knowledge and forget what they have learned (Friedlander & Tamir, 1990). Pedulla concluded that, through the findings of a study, students demonstrated statistically significant performance compared to more traditional instructional approaches in the control group (2002). The findings of this study are mixed; however, the results trend in favor of the IBS classroom as an effective instructional program when reviewing unit assessment mean gain scores for students in IBS classrooms compared to traditional classrooms. Upon closer analysis, male, female, special education, and general education students all performed better in IBS classrooms than traditional classrooms. In particular, the results were statistically significant for males in IBS classrooms on unit assessments compared to male students in traditional classrooms. Results for special education students in IBS classrooms were also significant as they outperformed special education students in traditional classrooms on unit assessments.
Although not statistically significant, females in IBS classrooms attained higher mean gain scores on unit assessments than females in traditional classrooms. Additionally, general education students in IBS classrooms outperformed students in traditional classrooms on unit assessments, but again, it was not significant. Findings in this study also revealed there existed no statistically significant difference between IBS classrooms and traditional classrooms for academic self-concept. Results of this study also demonstrated that the NJASK 8 Science results were not significant.

The results of research question 1 measured the overall impact of IBS classrooms on non-cognitive outcomes and academic achievement compared to traditional classrooms. Analysis of findings for academic self-concept, unit assessment, and NJASK Science 8 only revealed statistical significance for unit assessment mean gain scores. Overall, students in IBS classrooms performed better than traditional classrooms on the unit assessments. These findings were consistent with the literature. Klentschy (2004) found that students who participated in hands-on science instruction demonstrated significantly higher levels of science achievement than those in traditional classrooms. A University of Alabama (2004) study concluded that students exposed to IBS programs scored better on assessments than students receiving traditional science instruction.

The findings of this study do, however, contradict the research for inquiry effect on standardized assessments, as no statistically significant difference was observed for research question 1 on the NJASK Science 8. Wise (1996) notes that inquiry-based instruction resulted in an average of a 13% increase in achievement scores over traditional instruction, while O’Donnell (2007) also found that students demonstrated an increase in performance on standardized tests.
O’Sullivan & Weiss (1999) found that the more often teachers reported doing hands-on activities with their students, the more likely the students were to score at or above proficient on the NAEP science assessment than students who rarely did hands-on activities.

Furthermore, the results for this research question demonstrated no difference for academic self-concept. These findings contradict the existing research as cited by Guthrie et al. (2000), where students engaged in inquiry reported higher interest compared to students exposed to traditional instructional methods. Research also concluded that students who learn through inquiry maintain more positive attitudes toward science (Gibson & Chase, 2002). The 1995 TIMSS findings indicated U.S. students reported a high level of self-concept in science (45%) despite scoring lower in academic achievement on the content assessments (Martin et al., 2000).

Research question 2 examined to what extent gender moderated these relationships. A review of these findings revealed that both male and female students in IBS classrooms outperformed their respective gender on unit assessments in traditional classrooms. However, these results were only significant for male students on unit assessments. These findings are consistent with the research supported by a study that demonstrated male students outperformed females at 4th, 8th, and 12th grades in science, with statistical significance at fourth and eighth grades (Martin, 2000). In the Condition of Education 2006, males were found to outperform females at all three grade levels tested (USDOE, 2006). Among females, scientific literacy was even less prevalent (AAAS, 1989; USDOE, 2006). A separate longitudinal study by Johnson et al. (2006) indicated that inquiry-based teaching practices increase student achievement and close achievement gaps for all students. Alternatively, the results of this study indicated that there were no statistically significant differences in achievement for males and females on the NJASK.
Science 8. These findings were inconsistent with the research noted above. Additionally, a study by Ashmann (2007) demonstrated female students using IBS in the test group significantly outperformed the control group on the WKCE (Ashmann, 2007). The finding in that study was not consistent with this researcher’s findings.

Alternatively, academic self-concept was not significant for males and females. This finding is consistent with Weinburgh (2001), who found in that study that although students demonstrated increased achievement and higher attitudes, no significant gender differences existed. However, the results of this study are contradicted by Weinburgh & Englehard (1994). In that study, male students tended to maintain more positive attitudes toward science, with the only exception being female students maintaining more positive attitudes in biology (Weinburgh & Englehard, 1994). That research finding is consistent with the results of this study where males had more positive attitudes than females. Additionally, female students possess less positive attitudes than boys (Weinburgh, 1995). This study found that IBS classrooms did not have a statistically significant effect on gender for academic-self-concept, for males or females.

Finally, this study examined findings for research question 3 to determine the extent that IBS classrooms have an effect on learning outcomes for special education students. It was found that special education students in IBS classrooms outperformed special education students in traditional classrooms. These results were only significant for unit assessments. Although general education students in IBS classrooms outperformed those in traditional classrooms on unit assessments, these results were not statistically significant. The findings of this study are consistent with the literature described in Chapter 2. Students with learning disabilities and general education students both produced significant growth in learning based on the study by
Palincsar et al. (2001). Foster (2011) revealed infusing an inquiry-based approach allowed lower functioning students to discover ways to learn and retain information. Incorporating inquiry into science instruction can establish connections for learners between content that is familiar and concrete to curriculum that is unfamiliar and abstract (Bell, Mulvey, & Maeng, 2012). Students with learning disabilities produced significant growth in learning (Palinscar, Magnusson, Collins, & Cutter, 2001). The findings of this study for unit assessments are also consistent with a study by Ashmann (2007). In that study, special education students using IBS in the test group significantly outperformed the control group on the WKCE (Ashmann, 2007). Alternatively, this study did not find a statistically significant difference in academic achievement for special education and general education students as measured by the NJASK Science 8. The results of this study contradict the literature as relates to standardized achievement data measured by the NJASK Science 8.

The findings of this study for research question 3, measuring the impact of IBS classrooms on academic self-concept, found no significant differences for special education students or general education students. The findings of this research are consistent with some of the literature for academic self-concept. A study by Carlsisle and Chang (1996) suggested that fourth and sixth grade students with learning disabilities demonstrated little growth in self-concept over 3 years. However, the results of this researcher’s findings contradict other existing literature. Findings by Tuan et al. (2004) reveal that inquiry-based teaching practices in science increase motivation of students regardless of student learning style. Student engagement may be affected by individual students’ motivation or lack thereof (DeBacker & Nelson, 2000). Motivation is defined in How People Learn as essential for student learning (Bransford, Brown,
& Cocking, 2000). Studies have also described effective teaching practices in special education that contribute to overall quality of life for these learners (Odom et al., 2005). In some research, students with learning disabilities and general education students both produced significant growth in learning (Palincsar, Magnusson, Collins, & Cutter, 2001).

**Recommendations for Future Practice, Policy, and Research**

Students may fail to learn new concepts if their initial understanding is not engaged (NRC, 1999). Martin Brooks (1993) provides evidence as to how current teaching practices do not embody inquiry but are chiefly dominated by traditional approaches. Classrooms in the United States are dominated by teacher talk (Seymour, 2002; Unal & Akpinar, 2006). Teaching best practices that comprise a constructivist classroom where inquiry is the basis of instruction should be a consideration for teachers and educational leaders in all content areas. These strategies and instructional methods should be implemented in an effort to improve student achievement. Educational leaders and policy makers should consider utilizing the existing research to make decisions about the development of standards and curriculum design, and in the implementation of instructional programs to improve student academic self-concept and achievement.

The results of this research provide inconclusive evidence about the impact of IBS teaching on academic self-concept. It is possible that an explanation for these findings that were not significant resulted from the intervention being short in duration. Furthermore, student learning through inquiry is considerably different from traditional instruction. Students in the treatment group were actively engaged in challenging learning where they were required to grapple with concepts and activities in order to master learning. This is a paradigm shift in
teaching and learning from traditional instruction methods. It is possible that how students were feeling after the intervention influenced the posttest outcomes of the ASC scale.

It is recommended that further research be conducted to examine the effect of IBS classrooms on academic self-concept as relates to gender and special education students. Consideration should also be given to additional research that will broaden the knowledge base on the impact of inquiry on achievement as measured by standardized assessments. Expanding this research to include a larger sample size of students with school districts who implement the STC/MS IBS program will provide a more robust analysis of comparison groups in each of the quantitative measures of student ability. Future studies should include additional controlled randomized designs to measure both the short and long-term effects of IBS classrooms on academic self-concept and academic achievement. It is recommended that longitudinal studies are included in future research design to show the effects of student learning outcomes as students progress from elementary through high school. These results may be beneficial to understand the long-term effects of IBS classrooms. Designing assessment instruments that include a variety of questions such as constructed response questions and performance assessments may provide insight into student performance through the use of multiple measures. Such findings may provide a better understanding about the impact of inquiry teaching on learning outcomes.

The inclusive classroom, which includes both general education and special education students, may be taught differently in many instances than a non-special education classroom. This may be the case because differentiation in inclusive settings is even more important than in the non-special education classroom to meet the variety of learning needs of those students.
Alternatively, a researcher may observe teaching methods in non-special education classrooms that include less differentiation. As a result, future research is recommended to determine whether an IBS intervention effect would produce different results in classrooms with non-special education students. Lastly, future consideration should be given to design a study that will enable the researcher to examine the correlation between academic self-concept and student achievement. Such findings may shed light on the relationship between academic self-concept and academic outcomes.

The cost of the STC/MS IBS program with professional development varies based on the size of the district. However, estimates for a particular district reveal an approximate cost of $130,000 for 1,300 students. This estimate averages to $100 per student for a full-scale adoption that includes three curriculum units at each grade level. Refurbishment materials required to sustain this program in subsequent years is estimated at $30,000, or $23 per student. Educational leaders must take these costs into consideration as they evaluate whether the expenditure in such a program is worth the investment, compared to the costs associated with a traditional science instructional model.

**Conclusion**

The results of this study are mixed but promising for academic achievement on the unit assessments. These results contribute to the existing body of literature in the field of science education and leadership. School and district leaders may consider implementing IBS programs at the middle school level to assist in increasing academic outcomes and narrowing the achievement gap. The findings of this study were positive in specific areas, especially for males and students with disabilities. There exists much research that supports inquiry-based programs
as one option to implement at the secondary level to foster academic success in the area of science. The results of this researcher’s findings reveal that IBS classrooms are effective for student achievement as pertains to academic outcomes for overall students, males, and students with disabilities. The results of this study may be of particular importance for districts interested in improving achievement for males and special education students.

Leadership is critical in sustaining an effective science education program. School and district leaders can make significant contributions that will improve learning opportunities for students by incorporating assessment practices aligned to the Standards. Leadership can support faculty by providing ongoing professional development for teachers, and fostering a distributed leadership approach by encouraging decision-making at the teacher level. Principals and other educational leadership may also engage in pedagogical dialogue and recommend policies to support changes that align with the Standards. The adoption and/or design of curriculum aligned with the Standards to encourages a conceptual approach to science teaching with hands-on science materials is important in sustaining an IBS approach.
REFERENCES


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Appendix A

Academic Self Concept Scale

1) I am happy to come to school.
   All the time  □
   Sometimes    □
   Never        □

2) My classes are a lot of fun.
   Agree a lot   □
   Agree         □
   Disagree      □
   Disagree a lot □

3) I get bored in my classes.
   All the time  □
   Sometimes     □
   Never         □

4. I feel I can learn anything.
   Agree a lot   □
   Agree         □
   Disagree      □
   Disagree a lot □

5. I like doing work in school.
   Agree a lot   □
   Agree         □
   Disagree      □
   Disagree a lot □

6. I feel I learn a lot in my classes.
   Agree a lot   □
   Agree         □
   Disagree      □
   Disagree a lot □

7. Homework can be fun, sometimes.
   Agree a lot   □
   Agree         □
   Disagree      □
   Disagree a lot □
Appendix B  
Unit Assessments  

PHYSICAL SCIENCE ASSESSMENT

1. A raft is floating on a lake. When Ali dives out of the raft in the direction indicated by arrow A, the raft moves in the direction indicated by arrow B. Which principle does this illustrate?
   A. Force equals mass times acceleration.
   B. Energy is neither created nor destroyed, it changes form.
   C. For every action there is an equal and opposite reaction.
   D. An object in motion will move at a constant speed in a straight line unless acted upon by an outside force.

2. The graph shown above provides information about the motion of a bicycle. When is the bicycle's acceleration the greatest?
   A. at 0 seconds only
   B. from 0-3 seconds
   C. from 3-8 seconds
   D. from 8-9 seconds
3. What variable can be changed to increase the acceleration of this stack of bricks?
   A. decrease the force
   B. increase the mass
   C. decrease the mass
   D. increase the friction

4. A model rocket is launched straight upward from the surface of the Earth at a speed of 50 m/sec. At its highest point above ground, its velocity in m/sec will be
   A. 0
   B. 10
   C. 20
   D. 50
5. Which of the following statements best describes the relationship between speed and time shown in the graph above?
   A. Speed remains constant over time.
   B. Speed increases over time.
   C. Speed decreases over time.
   D. There is no relationship between speed and time.

6. Each figure below shows a force measured in Newtons pushing on a block. If there are no other forces pushing on the block, in which case is the acceleration of the block greatest?

   A. \[4 \text{ Newtons} \rightarrow 4 \text{ kilograms}\]
   B. \[1 \text{ Newton} \rightarrow 4 \text{ kilograms}\]
   C. \[4 \text{ Newtons} \rightarrow 1 \text{ kilogram}\]
   D. \[1 \text{ Newton} \rightarrow 1 \text{ kilogram}\]
Suppose you are riding in a car along the highway at 55 miles per hour when a truck pulls up along the side of your car. This truck seems to stand still for a moment, and then it seems to be moving backward.

7. How can the truck look as if it is standing still when it is really moving forward?
   A. The truck is on your side and you cannot see the wheels.
   B. The truck and the car are traveling at the same rate per hour.
   C. The truck is traveling faster than the car.
   D. The car is traveling faster than the truck.

8. How can the truck look as if it is moving backward when it is really moving forward?
   A. The truck is on your side and you cannot see the wheels.
   B. The truck and the car are traveling at the same rate per hour.
   C. The truck is traveling faster than the car.
   D. The car is traveling faster than the truck.

9. The picture above shows the positions of two runners at one-second intervals as they move from left to right. For each runner, indicate what is happening to the speed of each runner.
   A. Runner 1 speed is increasing and runner 2 speed is decreasing.
   B. Runner 1 speed is increasing and runner 2 speed is constant.
   C. Runner 1 speed is constant and runner 2 speed is increasing.
   D. Runner 1 speed is decreasing and runner 2 speed is increasing.
10. Two identical cars travel at 45 miles per hour toward the center of the intersection (point A, as shown above) with equal force. The cars collide at the intersection. If after they collide the cars stick to each other and move together, they will come to rest closest to

A. point A  
B. point B  
C. point C  
D. point D
LIFE SCIENCE ASSESSMENT

1. Seeds develop from which part of a plant?
   A. Flower
   B. Leaf
   C. Root
   D. Stem

2. What is the primary function of the large leaves found on seedlings growing in a forest?
   A. To provide shade for the root systems.
   B. To get rid of excess water that is entering through the roots.
   C. To allow for leaf damage by insects.
   D. To gather as much light as possible for photosynthesis.

3. A son can inherit traits
   A. only from his father.
   B. only from his mother.
   C. from both his father and his mother.
   D. from either his father or his mother, but not from both.

4. Traits are transferred from generation to generation through the
   A. sperm only.
   B. egg only.
   C. sperm and the egg.
   D. testes.
5. The diagram above shows a food web in a large park. Each circle represents a different species in the food web. Which of the organisms in the food web could be referred to as primary consumers?
   A. 7 only
   B. 5 & 6 only
   C. 2, 3 & 4 only
   D. 2, 5 & 7 only

6. Why does the leaf of a plant look green?
   A. Because it absorbs green light.
   B. Because it reflects green light.
   C. Because it absorbs only yellow and blue light.
   D. Because it reflects a mixture of yellow and blue light.
A student took a sample of water from a pond and examined it under a microscope. She identified several species of protozoans, including two species of *Paramecium* that are known to eat the same food. The student decided to examine the water sample every day for a week. She added food for the *Paramecia* each day and counted the number of each species. Her findings are summarized in the table below.

<table>
<thead>
<tr>
<th>Day</th>
<th>Species S</th>
<th>Species T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>150</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>160</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>160</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>20</td>
</tr>
</tbody>
</table>

7. Which of the following can be correctly concluded from the data?
   A. Species S is the food for species T.
   B. Species T is more common than species S.
   C. Species S is a more successful competitor than species T.
   D. Species T is a more successful competitor than species S.
8. What is the role of the pond organisms that Sarah saw in her field of view shown above?
   A. Producer
   B. Primary consumer
   C. Secondary consumer
   D. Decomposer

9. Which of the following living things in the pond system uses the energy from sunlight to make its own food?
   A. Insect
   B. Frog
   C. Water lily
   D. Small fish
10. Using the pictures shown above, arrange the stages of the ecosystem succession in their proper sequence.
   A. Glacier, Barren Land, Mosses, Scrub Growth, Trees
   B. Barren Land, Glacier, Mosses, Scrub Growth, Trees
   C. Mosses, Glacier, Barren Land, Scrub Growth, Trees
   D. Barren Land, Glacier, Scrub Growth, Mosses, Trees

11. When succession takes place in a marsh, which of the following is likely to happen?
   A. Water level rises and a lake is formed.
   B. Bigger plants appear as water levels rise in the marsh.
   C. Water gradually disappears and the area becomes dry land.
   D. There are fewer trees to take in carbon dioxide and produce oxygen.

12. What can you conclude about animals, based on the food web shown above?
   A. They require only sunlight to survive.
   B. They can make their own food.
   C. They do not eat plants.
   D. They must eat other organisms to obtain energy.
13. The food web shown above represents the flow of energy to all participants in an ecosystem. Which participant, if eliminated, would destroy the entire food web?
   A. rabbit  
   B. grass  
   C. hawk  
   D. grasshopper

14. Paramecia reproduce both sexually and asexually. One way to see if a given paramecium is the product of sexual or asexual reproduction is to
   A. See whether its genes are identical to those of its parent. 
   B. Check for traits that are beneficial to its survival. 
   C. Check for traits that are not beneficial to its survival. 
   D. Test it for acquired characteristics.
1. Which of the following is true about the planets in the solar system?
   A. All planets complete one revolution about every 365 days.
   B. All planets have one moon.
   C. All planets have an elliptical orbit.
   D. All planets have the same surface temperature.

2. Why does the tail of a comet always point away from the Sun?
   A. The gravity of the planets pulls the comet’s tail away.
   B. Explosions and the tearing away of ice particles happen on the side of the comet away from the Sun.
   C. The solar wind pushes the ionized gases away.
   D. Comets spin so rapidly that particles are thrown off by centrifugal force away from the Sun.

3. An unusual type of fossil clam is found in rock layers high in the Swiss Alps. The same type of fossil clam is also found in the Rocky Mountains of North America. From this, scientists conclude that
   A. glaciers carried the fossils up the mountains.
   B. the Rocky Mountains and the Swiss Alps are both volcanic in origin.
   C. clams once lived in mountains, but have since evolved into sea-dwelling creatures.
   D. the layers of rocks in which the fossils were found are from the same geologic age.

4. Some scientists think that the Earth’s climate is getting warmer. If these scientists are correct and the Earth keeps getting warmer for the next 50 years, what will happen to the oceans?
   A. The oceans will get larger because of the melting of the ice caps and there will be an increase in storm frequency and plant size.
   B. The oceans will evaporate because the heat would make them dry up.
   C. The air would become hotter and drier because there would be less water.
   D. Plants would die because of the lack of water.

5. The surface of the Moon is covered with craters. Most of these craters were formed by
   A. eruptions of active volcanoes
   B. the impacts of many meteoroids
   C. shifting rock on the Moon’s surface (“moonquakes”)
   D. tidal forces caused by the Earth and Sun
6. Rocks on Earth and on the Moon are made of similar materials. What does this observation likely suggest?
   A. Both the Moon and Earth split off from the Sun.
   B. Life must have existed on the Moon at one time.
   C. The Moon was probably formed from material from Earth.
   D. The whole solar system is made up of the same kinds of rocks.

7. What two gases make up most of the Earth’s atmosphere?
   A. Hydrogen and oxygen
   B. Hydrogen and nitrogen
   C. Oxygen and carbon dioxide
   D. Oxygen and nitrogen

8. In the space below, select the rough sketch (not necessarily to scale) illustrating the simplified model of the Solar System by showing the Sun and the four inner planets with their orbits.
9. The table below gives information about the planets: their mean distance from the Sun, period of revolution about the Sun and rotation about their axes.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mean Distance from the Sun (million kilometers)</th>
<th>Period of Revolution (Earth time)</th>
<th>Period of Rotation (Earth time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>58</td>
<td>88 days</td>
<td>59 days</td>
</tr>
<tr>
<td>Venus</td>
<td>108</td>
<td>225 days</td>
<td>243 days</td>
</tr>
<tr>
<td>Earth</td>
<td>150</td>
<td>365 days</td>
<td>23.9 hours</td>
</tr>
<tr>
<td>Mars</td>
<td>228</td>
<td>687 days</td>
<td>24.6 hours</td>
</tr>
</tbody>
</table>

Which graph below has points plotted correctly for each of the four planets showing the planet's period of revolution and its mean distance from the Sun. The graph must also have a drawn line or curve that best illustrates the relationship between the period of revolution and the mean distance from the Sun that is suggested by the points.
10. The table below gives information about the planets: their mean distance from the Sun, period of revolution about the Sun and rotation about their axes.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mean Distance from the Sun (million kilometers)</th>
<th>Period of Revolution (Earth time)</th>
<th>Period of Rotation (Earth time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>58</td>
<td>88 days</td>
<td>59 days</td>
</tr>
<tr>
<td>Venus</td>
<td>108</td>
<td>225 days</td>
<td>243 days</td>
</tr>
<tr>
<td>Earth</td>
<td>150</td>
<td>365 days</td>
<td>23.9 hours</td>
</tr>
<tr>
<td>Mars</td>
<td>228</td>
<td>687 days</td>
<td>24.6 hours</td>
</tr>
</tbody>
</table>

Suppose that a new planet (Planet P) is discovered and it has a period of revolution of 500 Earth days. What could you predict about the mean distance of Planet P from the Sun based on the data table above and graph in the previous question?

A. 190 million km  
B. 150 million km  
C. 228 million km  
D. 500 million km

11. Use the table in question #10 to answer the following question: Which planet has the longest year in Earth time?

A. Mercury  
B. Venus  
C. Earth  
D. Mars