DISSERTATION

INFLUENCES ON SCIENCE EDUCATION: THE USE OF SUPPLEMENTAL INSTRUCTION ON ACADEMIC SUCCESS IN INTRODUCTORY SCIENCE COURSES AT A TWO-YEAR COMMUNITY COLLEGE

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ABSTRACT

INFLUENCES ON SCIENCE EDUCATION:

AN EXAMINATION OF THE USE OF SUPPLEMENTAL INSTRUCTION ON ACADEMIC SUCCESS IN INTRODUCTORY SCIENCE COURSES AT A TWO-YEAR COMMUNITY COLLEGE

This dissertation uses a mixed method design model to investigate the influences of Supplemental Instruction (SI) on student final grade outcomes in introductory science courses at the community college level. The literature states that student comprehension in the field of science is critical; however, educators are discovering that certain student demographics are falling behind in science comprehension. The research focuses on the issue of disparity among different demographics and analyzes whether the introduction of the academic intervention technique, Supplemental Instruction (SI), increases the academic success of students in introductory community college biology and chemistry courses. A series of Two Way ANOVA analyses revealed that the use of SI had a positive effect (i.e., increased final grade outcomes) on community college student demographics; however, in some sections, a negative final grade outcome was found. In this study, data indicate that SI supported biology classes had a greater effect (or positive direction) on Black Non-Hispanic overall final grades. However, White Non-Hispanic students enrolled in SI supported introductory biology courses showed a slight decrease (or negative direction) in marginal means ($d = -0.180$). Hispanic students enrolled in SI supported courses showed a very slight increase (or positive direction) in final grade outcomes ($d = 0.11$). Another analysis outlined in this study showed the impact of SI on student grades in introductory science courses and first-generation student status. The analysis indicates a positive direction between the use of SI in an introductory science course on overall student final grades and student first-generation status. The data indicate that with the use of SI in an introductory science course, student final grades in the first generation student population showed an effect size of d= 0.1897. These data indicate that SI supported science courses had a positive effect on First Generation student overall final grades. The research examined the impact of SI on the principle SI Student Leaders (SISL) and found that student participation in the program had positive influences on SISL discipline comprehension, engagement, overall course satisfaction.

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CHAPTER ONE: INTRODUCTION

Today's college students encounter an ever-changing scientific and technologically-based society that makes it essential for students to understand science, question science, challenge science, and above all, blend science and the process of scientific inquiry into their everyday lives. As the United States' economic foundation continues to shift toward technology, U.S. students' lack of achievement and participation in science and mathematics generates growing concern among educators (Oakes, 1990).

It is generally accepted that science education is important; however, how to educate and tailor the complicated curriculum to capture the interest of students has been an issue for years. Science literacy is necessary for the democratic process to be successful (Shakhashiri, 2006). In addition, a diverse, globally oriented workforce of scientists and engineers is essential to ensure continued U.S. economic leadership (American Association for the Advancement of Science [AAAS], 2010). As a result, it is imperative that today's science educators challenge students to develop a sound science foundation. Educators must help students develop the skills necessary to process scientific information and to think critically about important scientific issues that influence the current technologically driven society (National Science Foundation, 2004).

In order for students to gain a true appreciation and understanding for the discipline of science, educators must carefully chaperone students through the systematic progression of the scientific method. This type of educational guidance may then lead to a more thoughtful and, at times, elegant art of scientific research. Whether students are studying the basic principles of biology, chemistry, math, or physics, a purposeful understanding of the scientific world is necessary.

Teaching Science

Science is the foundation of an innovative society and is the center of significant political decisions (AAAS, 2011). Students must understand how scientists use the scientific method to understand the living world (AAAS, 2011). Although attention is paid to the nature of science at both the primary and secondary levels, more attention needs to be placed on post-secondary educational levels (Ballard, 2007). Emphasizing the importance of science at all educational levels will help students understand the rich world of science study and discovery, which in turn, may increase student scientific literacy. This type of societal exposure to science can create citizen science, an idea that takes the basic tenets of science to the masses (Bonney, 2009).

The understanding of science requires more than simply memorizing facts or reproducing “cookbook” laboratory experiments. It involves creating a deeper understanding to the process of science discovery. The delivery of science information should include a step-by-step creation of relatable science projects, by which, students learn the tried and true pattern of the scientific method (Bonney, 2009). Science educators should help students build a new relationship that includes a scaffold-like learning model; a model that allows students to build new, relatable understanding by engaging in some form of generative scientific inquiry into authentic questions (National Research Council, 2002).

A scientifically-literate individual has the knowledge base to hold a scientific worldview, engage in scientific inquiry, and appreciate scientific enterprise (Gaffney, 2005). The AAAS (1990) noted that a scientific worldview involves: perceiving a largely understandable world; seeing scientific knowledge as durable, however subject to change; knowing when scientific inquiry is appropriate; and knowing that science does not provide very many answers. Science education (literacy) enlightens and enables people to make informed choices, to be skeptical, and to avoid unproven conjecture (Shakhashiri, 2006).

Teaching Biology

The study of biology covers a range of issues; most are benign, however, a few may be considered controversial. Biological sciences have developed quickly during the last decades. This progress is associated with an increasing importance of biological knowledge for personal and social decision-making (Vilhar, 2010). Students should view biology as a growing and dynamic field that applies the scientific method to global problems (Matyas, 2008). For example, some people question the theory of evolution, as well as the scientific explanation of when life truly begins. Students' understanding of the evolutionary nature of biological knowledge is a process that may reinforce biology students' understanding of the nature of science (Ameny, 1999).

At times, formal biology instruction has not supported students making connections, and as a result, biology education has often been subject to criticism by factions questioning the world of science in general, and the study of biology in particular (Ameny, 1999). Most introductory biology students have a difficult time relating the events of their everyday life to the subject. When biology educators build scientific foundations for students, it allows students to comprehend controversial topics explored in biological research, medical discoveries, and personal health issues. According to Phelan (2008), biological literacy is the ability to use the process of scientific inquiry to think creatively about real-world issues that are biological in nature, communicate biological thoughts and topics to others, and integrate these ideas into a decision making process. A scientifically literate student must be able to communicate ideas through writing or speaking; this is important if demonstrating the most essential skills of science literacy (Norris and Phillips, 2003; Krajcik and Sutherland, 2010; Balgopal and Wallace, 2013). In order to address this critical scientific skill set, Balgopal and Wallace created an instructional writing process, Writing-to-learn, (WTL). This innovative learning strategy focuses on the process of organizing thoughts and integrating scientific ideas (Balgopal & Wallace, 2013). This is an important skill set for budding STEM students to hone as more students are asked blend the personal experiences with scientifically relevant issues or Socio-scientific issues (SSIs) in order to gain a richer understanding of science (Balgopal and Wallace, 2013).

Teaching Chemistry

The chemical sciences are vital to our society because, as some argue, chemistry connects and explains the "how's and why's" of the other sciences (Kitzmann & Otto, 2008). Of the basic sciences, chemistry is the discipline that most directly translates to products that people use and that can have a direct impact on their lives (Carroll, 2008).

In spite of being a "central science," chemistry education, like biology education, has been subject to calls for reform. Chemical education reform is underway for various reasons, including dissatisfaction with the current chemistry curricula, lack of student connection with the curricula, and isolation from current society and technology issues (Jong, 2006). Several issues have forced changes in how chemistry concepts are presented to students. These changes include fundamental shifts in research, understanding how students learn, and how chemistry is applied to societal issues (Mahaffy, 2004).

In the 1990s, AAAS articulated "common themes" or core scientific concepts outlined in two documents, *Science for All Americans* (1990) and *Benchmarks for Science Literacy* (AAAS, 1993). In these landmark documents, educators defined overarching scientific themes as concepts that appear in many, if not all, scientific disciplines (Kitzmann & Otto, 2008). Such themes can build connections between chemistry and other sciences, as well as between chemistry and its applications in our everyday life (Kitzmann & Otto, 2008). Many chemistry educators believe one approach might be using unifying themes as an organizing principle in teaching science content (Kitzmann & Otto, 2008).

With a change in teaching methods, hopefully the world of chemistry will open up a world of insightful questions as to how chemistry impacts everyday processes. Chemistry literacy fosters personal fulfillment and excitement, satisfies students' needs to create and to contribute to human well-being and opens the doors to other endeavors (Kitzmann & Otto, 2008).

Purpose

How science educators are able to help students understand and excel academically in science is critical to student success. The purpose of this study is to focus on how one educational learning practice in particular, peer learning, or as it is also known, Supplemental Instruction (SI), contributes to students' academic success in an introductory science course at a community college. SI is a structured inquiry-based program that pairs upper level science students with students enrolled in introductory science courses (Rath, Peterfreund, & Xenos, 2007). From this study, recommendations are made to improve the overall student success in science courses at the community college level.

Statement of the Problem

The primary focus of biology education on many community college campuses range from preparing students to: transfer and major at four-year institutions, prepare for careers in allied health positions, or prepare for positions as technicians in areas such as biotechnology or environmental technology (Fletcher, 2010). With this type of diverse academic skill set in the community college classroom, the tendency for less academically strong students to “get lost in the mix” is a major issue for educators. Research has also identified an issue with community college student completion rates. Many community college students do not complete their college-level programs or are unable to transfer to four-year programs due to insufficient financial support or poor institutional or state policies and practices (Boggs, 2010).

With this need to improve transfer and completion rates, community colleges must review not only policies, but investigate curriculum delivery methods and modify techniques to include a wider student audience. Therefore, research examining the impact of Supplemental Instruction (SI) on community college introductory science courses and the impact of this academic intervention method is important.

This study examined whether the use of Supplemental Instruction (SI), an academic instructional intervention program, yielded higher numbers of academically successful students (grades of A, B, or C) in introductory science courses at a two-year community college. It focused on three demographic variables as they relate to the implementation of SI: gender (male/female), ethnicity (White Non-Hispanic, Black Non-Hispanic, and Hispanic), and first-generation student status. The gender and ethnicity variables are related to identity issues, which may affect the way students feel about their learning in general, and learning science specifically. The first-generation variable explores the relation to entry-level college students and academic success in introductory science classes.

Research Questions and Focus

The research examined the use of the dichotomous independent factor, Supplemental Instruction (SI), an academic intervention program, on the dependent variable, students’ final grades. The research explored the use of SI and its impact on students’ overall final grade within various student attributive independent groups male/female (gender), White Non-Hispanic, Black Non-Hispanic, and Hispanic (ethnicity), and first-generation status. The research also examined the use of SI in biology and chemistry science disciplines and its impact on student final grades. In order to explore this relationship between SI and its effect on students' overall grades, the research used difference inferential statistics to understand the relationship (interaction) of SI on the various independent groups.

In order to examine the impact of SI on student achievement, this research first examined the student population demographics by answering several descriptive questions that gave a statistical snapshot of the Community College of Denver's science student population. The next set of research questions asked a series of difference questions, which gave insight into how SI impacted each attributive independent group. This research also evaluated how SI impacts the SI Student Leaders. This qualitative measure examined the common pedagogical themes associated with Supplemental Instruction. The final research question examined how the qualitative and quantitative data streams formulate recommendations for the use of SI in community college introductory science courses.

Research Questions

The following questions guided this research:

Are there differences between student academic performance (final grade) in SI and non-SI supported sections?

Are there differences between student academic performance (final grade) in Fall and Spring academic semesters? Is there an interaction of SI and non-SI sections and Fall and Spring academic semesters on student academic performance (final grade)?

Are there differences between student academic performance (final grade) in Introductory Biology and Chemistry courses? Is there an interaction of SI/non-SI supported sections and Introductory Biology and Chemistry courses on student academic performance (final grade)?

Are there differences between student academic performance (final grade) student ethnic demographics (White Non-Hispanic, Black Non-Hispanic and Hispanic)? Is there an interaction between the SI/non-SI supported sections and student ethnic demographics on student academic performance (final grades)?

Are there differences between student academic performance (final grade) and student ethnic demographic (White Non-Hispanic, Black Non-Hispanic and Hispanic)? Is there an interaction between the Introductory Biology (BIO111) SI/non-SI supported sections and student ethnic demographics on student academic performance (final grade)?

Are there differences between student academic performance (final grade) and student ethnic demographic (White Non-Hispanic, Black Non-Hispanic and Hispanic)? Is there an interaction between the Introductory Chemistry (CHE111) SI/Non-SI supported sections and student ethnic demographics on student academic performance (final grade)?

Are there differences between student academic performance (final grade) between male and female (gender) students? Is there an interaction between the Introductory Biology (BIO 111) SI/Non-SI supported sections and student gender demographics?

Are there differences between student academic performance (final grade) between male and female (gender) students? Is there an interaction between the Introductory Chemistry (CHE 111) SI/Non-SI supported sections and student gender demographics on student academic performance (final grade)?

Are there differences between student academic performance (final grade) between CCD first-generation and non-first-generation students? Is there an interaction between the Introductory Biology (BIO 111) SI/Non-SI supported sections and student first-generation and non-first-generation demographic on academic performance (final grade)?

Are there differences between student academic performance (final grade) between CCD first-generation and non-first-generation students? Is there an interaction between the Introductory Chemistry (CHE 111) SI/Non-SI supported sections and student First-generation and non-first-generation demographic?

How well does the combination of SI/Non-SI support, gender, and first-generation status predict student academic performance in CCD Science Courses?

What are the Supplemental Instruction Student Leaders (SISLs) overall impressions of Supplemental Instruction, and has it changed the way they view education in general and Science education specifically?

Delimitations

Study delimitations are parameters imposed upon the research by the researcher. Delimitations for this research include the choice of variables and measures. This research examined gender, ethnicity, and first-generation college status of the students in SI as part of their introductory science course. The study is also delimited to students in selected sections of the introductory science courses.

Other study delimitations are related to selection of the sample. The sample is delimited to one community college in the Denver area. The subject is delimited to entry biology and chemistry courses. The concept of academic freedom is part of the delimited factor. CCD science professors use various assessment instruments throughout the semester, for this study, only students' final grades were analyzed.

Limitations and Assumptions of the Study

The research limitations come in the form of student access to the SI program and other outside tutoring opportunities they may have utilized throughout the semester. The data collected for the study highlight certain important variables, and one important outcome, overall student grade (final grade). The overall grade does not show student excitement regarding the study of science. The idea of academic freedom cannot be overlooked in this study. The SI program spans several semesters, various instructors, and several professors. The Colorado Community College system outlines academic standards for all of the courses, which means certain topics must be covered in order to satisfy community college state requirements. At the Community College of Denver, great care is taken to ensure academic standardization between sections, while allowing professors to develop unique curriculum delivery methods to allow for enhanced learning. The study did not control for these differences.

Research Setting

The study focused on students attending the two-year community college, Community College of Denver. CCD is a well-established institution located in the heart of Denver, Colorado, and provides educational instruction to all academic levels. CCD shares a campus with two other institutions of higher education, Metropolitan State University of Denver (Metro State) and University of Colorado, Denver (UCD). The fact that CCD shares a campus with two other institutions of higher education is a benefit for CCD students. Not only do they share academic facilities, such as the Auraria library and computer stations, but CCD students are also able to utilize a truly valuable resource, students from other institutions.

Definitions of Terms

Supplemental Instruction: A particular type of academic intervention designed to enhance overall student academic achievement. SI is a structured inquiry-based program that includes Student Leaders, a Supplemental Instruction director, and participating faculty (Arendale, 2002).

Supplemental Instructor Student Leaders (SISLs): These students have already successfully completed the course (upper level students). SISLs attend the participating SI section and interact closely with the professor for the class. The SISLs then prepare the necessary workshop documents for the SI workshop and facilitate SI workshop discussions (Arendale, 2002).

Supplemental Instruction Director: This senior academic leader mentors the SISLs. The director holds weekly meetings to answer any questions from the SISLs, helps in crafting workshop documents, and overall, controls the program (Arendale, 2002).

Community College Faculty: Important members of the SI program, the faculty grants access to their classroom, which allows the SISLs to follow the pace of the course and topics covered (Arendale, 2002).

Ethnicity: White Non-Hispanic, Black Non-Hispanic and Hispanic

First-generation Student: Student who is the first in their family to attend college (Terenzini, 1996).

Overall Science Achievement: Receiving an A, B, C, D or F in an introductory biology or chemistry course at a two-year community college.

Withdraw: A student does not complete the course, and leaves after enrolling. This type of information can give insight into student retention rates for introductory science courses.

Course Sequence: Students progressing from the first semester introductory science course to the second semester introductory course.

Cooperative Learning: A type of peer learning instructional method. Usually used in a classroom setting (Blosser, 1993).

Significance of the Study

A review of the literature illustrates the lack of academic preparation and/or interest in science by particular student demographics, particularly women and minorities. However, the literature fails to address the effectiveness of SI and academic success in an introductory science class at the community college level. Therefore, this study looked at one method to enhance academic progress in science for all students. Whether students are studying the basic principles of biology, chemistry, math, or physics, the need for a purposeful understanding of the scientific world in which students live is necessary. It is important that today's science educators instruct their student population to consider socially important biological issues such as reproductive technologies, food production and climate change, which are issues that impact current news cycles (Balgopal & Wallace, 2013). It is important for students to be able to make and justify decisions using scientific information; this should be a hallmark of demonstrating scientific literacy (Balgopal & Wallace, 2013).

If Supplemental Instruction gives students a clearer understanding of science that will in turn open up the world of science to students, then this academic intervention will allow students to examine the world of science in a critical light. For example, students will have a deeper appreciation for cellular processes, which, in turn, will allow students to understand that all people undergo basic cellular processes. Cellular processes have no racial boundaries, socioeconomic ties, or regional constraints, such as the synthesis of proteins with the use of intracellular ribosomes, the production of the cell chemical interferon, which protects neighboring cells from viral infections, and how macromolecules are absorbed and hydrolyzed to produce ATP for cellular energy. These three basic cellular mechanisms outlined above can give students an appreciation of the human condition on a cellular level. Understanding these basic mechanisms, therefore, is critical to students having a solid biological foundation from which to make decisions, regardless of what post-collegiate context decisions are made. It is important for students to be able to make and justify decisions using scientific information; this should be a hallmark of demonstrating scientific literacy (Balgopal & Wallace, 2013).

CHAPTER 2: LITERATURE REVIEW

In today's scientific-focused society, the idea of scientific literacy is becoming more prevalent. American science education has been plagued by a fundamental confusion; a mismatch between the educational goals science educators claim to value, and the strategies science educators use to achieve them (Feinstein, 2011). This confusion is rooted in the seemingly simple idea that science education should prepare students for the future (Feinstein, 2011). Feinstein added that in some cases, science "preparation" should lead to good citizenship and a satisfying life overall. For other educators, it is about creating a scientifically and technically skilled workforce. Each vision is clear and compelling, but each requires a different educational strategy (Feinstein, 2011).

Adequate understanding of the nature of science is a major goal of science education. Understanding the evolutionary nature of biological knowledge is a means of reinforcing biology students' understanding of the nature of science (Ameny, 1999). The onset of the twenty-first century has been a notable watershed for mankind. Science is typically the domain that attracts the most attention, as it showcases human creativity, intelligence, and tenacity, as well as demarcates paradigm shifts and changes in civilization (Gunn, Grigg, & Pomahac, 2008).

Equipping the citizens of the next century with the critical thinking skills and dispositions to ensure that scientific change does not direct society, but that society directs scientific change is paramount (Gunn et al., 2008). In the past, the ability to design an education system around "everyday science" was limited by how little was actually known (Trefil, 2008). Trefil (2008) proposed that the most important use a student would make of whatever science they acquire is in their future role as citizens. Pick up a newspaper or listen to a news broadcast on any day and issues that relate to science will be found, for example, global warming, stem cells, food additives, genetic engineering and new advances in medicine, to name just a few (Trefil, 2008). Trefil added that these topics should be part of the public discourse and they should be part of the fabric of our democracy. Trefil concluded that this should be one of the most important goals of education: to prepare students to be active participants in the scientific process. The idea that the primary goal of general science education is to prepare students to assume the role of active citizen is called the “Argument from Civics” (Trefil, 2008).

Science educators must be mindful of this fact and structure the classroom experience to foster a love and understanding of the subject (Singer, 2006). In order for science educators to truly understand student comprehension in a subject, they must look beyond the realm of science and examine the various educational backgrounds of their students.

The world of science is rich with insight, for example, in the realm of molecular cellular biology, students gain a deeper understanding of what connects us all. Which then raises additional questions. How should science and mathematics educators educate students? How should educators link subjects together in order for students to gain a richer understanding and appreciation of the biological and physical world? How should educators use technology to communicate with their students, as well as to give their students the latest information in the ever-changing world of science?

This review explores several research studies that examined a variety of Science, Technology, Engineering, and Mathematics (STEM) disciplines, and which were linked to student success in science education. This literature examined the link between basic student demographics such as gender, ethnicity, high school preparation, and classroom experiences to academic success in introductory STEM courses. It is important for science educators to examine these variables in order to create a world where science discovery is accessible to all. In order to create an inclusive learning environment, science educators must consider and incorporate various teaching methods that will excite and challenge students of various educational backgrounds. If science educators begin to link substantive theory about some facet of professional practice to real world situations, then students can apply what they see in everyday life to the world of science (Merriam, 2002). This research can then be used as supportive data for proper science funding, grant funding, teacher professional development, and curriculum restructuring.

The Need for Science Education

Current State of College Science Classes

Recent academic techniques in science education have brought into question traditional method of instruction. Science education can no longer be thought about in terms of simple rote recall and memorization of facts. Rather, it is about how to come to understand and verify whether the presenting information is true, valid, and reliable (Gunn et al., 2008). Borrowing teaching tools from psychological literature, science curriculum now emphasizes the importance of learners' meta-cognitive awareness by attending to declarative (what), procedural (how) and conditional (when) questions (Gunn et al., 2008). Now, because of a critical mass of research in the young multi-disciplinary field called Science, Technology and Society, a strong intellectual foundation for that education system finally exists (Feinstein, 2011). Envisioning what a rigorous everyday science classroom looks like, the challenges and the true promise of that vision becomes clearer (Feinstein, 2011).

One study examined the major outcome or goal of basic environmental education, which is the change in student attitude towards environmental topics as a result of instruction on environmental issues (Woodward, 2004). Within the current university systems, the tendency has developed to meet this goal by embedding environmental issues in biology courses. However, Woodward found that the assumption was false and education provided in a particular subject area does not necessarily result in substantive changes in students' environmental knowledge, attitude, or behavior (2004).

Another study which outlines the current state of science education was conducted by Ameny (1999) showed that out of 121 college introductory biology and advanced zoology students, 80-100% of these students had an adequate understanding of scientific methods and that a similar percentage of students had learned the theory of evolution by natural selection in their biology courses. The study added that at least 60-80% of the students did not understand the importance of evolution in biological knowledge. The study also found that about 20-58% of college students hold pre-scientific conceptions, which in part are responsible for students' lack of understanding the nature of biological knowledge (Ameny, 1999).

Science Education-Historical Perspective

Glass (1970) outlined the overwhelming growth of science in the twentieth century and that the unceasing, dramatic changes in our technology produce inevitable alterations in the content of science as taught in schools and universities. Glass outlined a major problem with the study of science as a social process is to find a secure way to distinguish the creative genius, at first appearance, from the crackpot (1970).

Glass' examination of the historical background and link between science and society provides a solid platform from which to explore how to change the process of science education in order to integrate the scientific process to solve societal ills.

Science Education Reform

Trefil (2008) outlined two worlds of science education, an education for future engineers and scientists, where Trefil states that this world is in "pretty good shape." The other world, or what he calls "the other 98 percent" of students who will not go on to careers in science and technology, was the focus of the study. Trefil (2008) then reviewed the history of science education, starting in 1910 when John Dewey argued that the proper goal of science education is to develop a "scientific habit of mind." Dewey's main motivation was to create some type of social utility, of which, Davis (1935) expanded. Davis said that an individual who has a scientific attitude will: (1) show a willingness to change his opinion on the basis of new evidence; (2) will search for the whole truth without prejudice; (3) will have a concept of cause and effect relationships; (4) will make a habit of basing judgment on fact; and (5) will have the ability to distinguish between fact and theory (Davis, 1935).

Trefil (2008) stressed the importance of science to students and how it impacts their role as citizens. Trefil stated that linking the role of science education to informed citizenry is an important by-product of proper science education. Due to the changes that have altered the nature and practice of science, a global economy anchored by the advances in science and technology has emerged. With this change in the economy, a change in science education is needed (Trefil, 2008).

DeHart-Hurd (2000) claimed that little progress has been made to bring about a significant change in science teaching. He stated that although there has been quite a bit of discussion about reform—more rigorous classes, lengthening the school day/year, reducing class size, and more demanding homework—have been discussed, these actions do not reflect a coherent point of view, nor are they consistent with the changing culture and its demands on students (DeHart-Hurd, 2000).

DeHart-Hurd (2000) echoed the same argument as Trefil, stating that policies important for guiding decisions about the place of science and technology in society and politics that represent the integrative personal-social and social-civic aspects of today's science are needed.

Science is becoming more cross or trans-disciplinary, blending the natural and social science for planning human resources, such as agriculture, health, education and the environment (Hurd, 2000). Other fields of study have "absorbed" the world of biology, for example astrobiology, biochemistry, biophysics, and biogeochemistry to name a few (Hurd, 2000).

Science Education Reform: The Process

In McComas' (1998) book, *The Nature of Science in Science Education: Rationales and Strategies*, he stated the importance of changing the way science is taught. The idea of learning is to make a qualitative change in the way students think about a subject. Most science educators learned the process of the scientific method in the context of pure science research (McComas, 1998). The "new" science teachers are blending science and education to create a curriculum that will incorporate all learning styles, thinking patterns, and educational backgrounds. In order for students to obtain high quality learning, teachers must change the way they think about teaching (Ramsen, 1992). McComas stated that it is critical for teachers to understand the nature of science and how it relates to other disciplines.

Rycik (2007) focused on a recent study that suggests the actions by the federal government may be both helping and hindering the process of science education. The study outlined that the need for improving the level of education as a whole has taken time away from true science education. According to the report, the average time spent weekly on science instruction in elementary schools around the country has been reduced from 2.6 hours in 1999-2000 to 2.3 hours during the 2003-2004 academic year.

O'Fallon (2005) supported the idea of increasing science literacy. He stated that, with the fast-paced technological and scientific advances, the need to produce the next generation of scientists is needed now more than ever. O'Fallon referenced a National Center for Education (NCE) (2004) study that showed U.S. students were not faring as well in the sciences and mathematics as their counterparts around the world.

With this understanding, several innovative education research projects were developed to enhance the science curriculum. O'Fallon (2005) outlined five elements necessary for greater student achievement in science responsibility:

> (1) Improved student achievement—improve curriculum, especially for special needs students. (2) Revised curriculum which includes integrative curriculum will increase enthusiasm with students. (3) Increased understanding of environmental health—Increase student understanding regarding the link between human health and environment. (4) Teacher participation—Professional development for teachers. Projects that will highlight how to implement various curricula. (5) Social responsibility—Students use problem based learning to link real world experiences. Students learn how to identify questions, conduct research, analyze data and communicate recommendations. (p. 1)

Another group of educators explored the current state of science education (San Francisco State University, 2008). A team of California researchers conducted a comprehensive survey of college science educators and found that most of the faculty blended the two disciplines, for example, biology and physics, in order make science understandable to all students. However, the study found that these innovative teachers involved in the project considered leaving the department due to burn out and lack of institutional understanding and support of the process (San Francisco State University, 2008).

The American science educational system has been plagued by a fundamental confusion, a mismatch between goals claimed to be valued and the strategies used to achieve them (Feinstein, 2011). The United States claims to value civic engagement and science literacy, but the education system is more suited to producing a scientific workforce (Feinstein, 2011). The need for educational reform is critical; meanwhile, states are cutting back on teacher's salaries and educational tools, and classrooms are becoming more congested. These educational reforms are needed in all disciplines and at all educational levels (Feinstein, 2011).

In the field of science education, reform is needed now more than ever as Americans live in a global economy, with technology advancing each and every day, and the world of science impacting society on a daily basis. Additionally, as Ziman (2000) stated, the world of science is global, competitive, and multi-disciplinary.

According to the National Innovation Initiative (NII), large shifts in every field suggests an inflection point in history, whether examining demographics, science, culture, technology, geopolitics, economics or the biological state of the planet, major changes are underway (National Innovation Initiative Summit, 2004). With this type of educational and societal mutation underway, the United States educational system must change the way education is taught and processed by all students at all levels (Yager, 2000).

Student Demographics

Studies have found that student success in education in general, and science in particular, can be linked to certain critical characteristics of that student. This literature review includes several research studies that consider the elements that were linked to student success in science education, such as: gender, first-generation status, and the use of Supplemental Instruction (SI) as a tool to increase student success in an introductory science course.

Gender Identity

Scholars and administrators frequently look at the role gender plays in the world of education (Becker, 1989). Specifically, scholars are interested in how gender influences the understanding of basic science education. Frequently asked questions include: why do boys consistently outperform girls on standardized tests of achievement? Or, why does this "gender gap" in science achievement increase as students move through the educational pipeline (Burkam, Lee, & Smerdon, 1997)? Researchers have studied when the achievement gap begins and found that science achievement starts to favor boys as early as age nine (Burkam et al., 1997).

However, studies have shown that women are enrolling in college and taking the endeavor quite seriously. According to the National Center for Educational Statistics (2011), female college enrollment increased forty percent between 1999 and 2009, while male enrollment increased 35 percent during the same time. Van Harlingen (1981) focused on gender and the link to science and math education, once again comparing performance in an introductory physics course. The study included more than 500 students enrolling in a first semester calculus-based college physics course; of these, forty percent were female. All students who enrolled in the class were given a pre-test, which included various mathematical sections ranging from algebra to calculus and functional relationships. Understanding the pure nature of the world of physics, Van Harlingen not only looked at the mathematical applications associated with physics, but also took into consideration the reasoning, deductive and inductive, spatial rotation and visualization, and even propositional logic needed to truly understand physics. These independent variables were aligned to tell a story about the dependent variable: physics achievement.

In order to understand the relationships, Van Harlingen performed multiple regression and factor analysis to compare pre-test performance to physics achievement. The numbers for the entire group reflected that a 31 percent variance in physics achievement was explained by: trigonometry and geometry knowledge, SAT scores, logic questions, spatial visualization, and rotation. The group was then separated by gender and it was found that, for women only, trigonometry/geometry and high school SAT scores had significant beta weights (multiple regression analysis showed $R(2) = .27$). When GPA was added to the women's group, the $R(2)$ values rose to 0.44. This research showed that, the Adjusted R value (multiple correlation coefficient) was .27 or 27% of the variance in math achievement can be predicted from a combination of trigonometry/geometry and high school SAT scores. However, when adding in GPA to the combination, the value rose to .44 or 44% of math achievement that was predictable.

Van Harlingen continued to analyze the group using factor analysis and found that three factors were extracted: logical/verbal, spatial, and mathematical. These three factors explained 29% of physics achievement, with the largest factors being logical/verbal and mathematical. Van Harlingen narrowed the field once again and focused the factor analysis using data from the female participants, and found that the values were similar, but less distinct. SAT scores (logical/mathematical) once again were a factor; however, the mathematics factor alone was the most important factor in predicting physics success.

Van Harlingen (1981) then analyzed the male factors and found that the strongest variables were identified as spatial rotation and spatial visualization, and GPA; a multiple regression analysis was used to predict physics success at $R(`2) = 0.32$ or 32% of physics success can be predicted by the combination of spatial rotation, visualization and GPA. This research found that ability in all areas of mathematics appears to be a prerequisite for success in physics achievement, with conditional reasoning contributing to the success in physics. The study found that for women, the key for success is a strong mathematical foundation. Van Harlingen also noted that even when these differences were controlled statistically, a difference in physics achievement continues to favor males.

In a more recent study, Chen (2002) explored the issue of gender differences in science education, in general, and specifically in physics education. The study examined the attributive independent variables that may predict student outcomes in six different physics classes. The physics classes ranged from algebra-based introductory classes to calculus-based physics courses. The main variables of the study were the students': gender, mathematics and science academic preparation in high school, learning preferences, perceptions of the introductory college physics courses, and performance in the course. It was found that these independent factors accounted for 21.8 percent of the variance in performance in introductory physics classes. A total of 267 subjects participated in the study with 161 (60%) male participants and 106 (40%) female participants.

Chen (2002) found that more males than females enrolled in physics classes (255 to 151). Out of the six sections of physics examined, 200 students enrolled in algebra-based physics and 67 enrolled in calculus-based physics. Of the 200 students enrolled in algebra-based physics, 58 percent were male and 41.5 percent were female. In the calculus-based physics courses, 65.7 percent were male and 34 percent were female. Student performance in these classes reflected that males were more successful, with 22.7 percent of male participants receiving A's compared to only 8.7 percent of females. Conversely, 21.1 percent of female participants received D's while only 9.1 percent of the males received a D.

Three of the variables studied were found to have the greatest impact on success in physics: participant's educational goals; high school GPA; and mother's occupation in the area of science, engineering or computer technology (Chen, 2002).

Other recent reports have suggested that the science gender gap is disappearing. However, upon closer examination, data reveals that the decrease in the gender gap varies by the area of science, the level of education, and career attainment examined (Britner, 2008). Women have made academic strides in the world of life sciences, biology, ecology, etc. However, the situation is different in the physical sciences. The number of women earning physical science degrees has increased, however, the percentage of white males earning physical science degrees is still much higher (Britner, 2008).

The National Science Foundation provides statistical information regarding the lack of female students' participation in particular areas of science (2013). The report does not offer recommendations, policy or programs, but the report serves as a source of information (NSF 2013). The report found that in 2010, 77.1% of female science students were earning Bachelors' of Arts (BA) degrees in the area of psychology, and during the same year of 2010, 57.8% of female science students were earning BA degrees in the life sciences. However, the same study showed that in 2010, only 18.2% of female STEM students earned a BA in the area of computer sciences and 18.4% of women earned BA degrees in engineering (NSF, 2013). The report states that women entering the area of engineering and computer sciences remains below 30%.

The report added that female participation in science and engineering occupations is lower than it is in the United States workforce. The report stated that in 2011, 11.7% of women were working as engineers, and only 25% were working as mathematicians and computer scientists (NSF, 2013). Once again, the report found that women are hired as psychologists

(71.1%) at a greater rate; the report also found that women continue to constitute the vast majority of those employed in traditionally female occupations, such as nurses at 91.1% (NSF, 2013).

Ethnicity

It is important for everyone to understand the importance of science education. Historically, however, the aim to include or reach out to students of color in the world of scientific investigation has been limited. Women and non-Asian minorities are underrepresented in the STEM field workforce. In the late 1980s, women in the workforce steadily increased to nearly fifty percent; however, at that time, only fifteen percent were employed as scientists, mathematicians and engineers. At the same time, blacks and Hispanics in the workforce made up ten and five percent, respectively, of all employed workers, but only represented about two percent of the total scientific workforce (Oakes, 1990).

As stated in the NSF report, data shows that the tide may be turning for women in some STEM disciplines and more women are majoring the psychology and life science STEM fields (2013). In contrast to the positive trends for women, blacks and Hispanics have made little progress. Their lower and constant rates of participation are limited by their lower rates of degree attainment. This is coupled by the fact that few who do attain a degree pursue science and mathematics as majors in college (Oakes, 1990). Research has shown that even those who remain in the precollege pipeline fail to choose STEM fields at the same rate as whites (Berryman, 1983; Oakes, 1990).

Oakes' statistical analysis of minorities in STEM field employment is bleak, and the fact that some minority groups are not represented in the STEM work place outlines another important issue. These groups are not registering for STEM courses in college and if they enroll in STEM field courses, studies have shown that these students tend to not persist to graduation. Women, blacks and Hispanics are also underrepresented in preparing for careers in science (Oakes, 1990). Disproportionate percentages of minorities enroll in vocational or non-academic curriculum tracks (Ekstrom, Goertz, & Rock, 1988; Oakes, 1990; West & Gross, 1986).

A recent science report showed an increase in the enrollment of African American, Latino and Native American students in STEM undergraduate and graduate programs. However, the odds of remaining in science until degree completion are still currently very low; only 24 percent of underrepresented racial minority (URM) students and forty percent of white students who begin college as science majors complete bachelor's degrees in science (Center for Institutional Data Exchange and Analysis, 2000). Under-participation in these student populations can be attributed to their lower levels of achievement in mathematics during the pre-college years (Oakes, 1990).

The National Science Foundation's report highlights the role of women in the world of science and also looked at the role of minorities, black and Hispanic students. The NSF (2013) study found that since 1991, underrepresented minorities were earning degrees in sciences of psychology, the social sciences, and computer sciences. The study highlights that since 2000, underrepresented minorities earning degrees in engineering and the physical sciences have been flat, and participation in mathematics has dropped (NSF, 2013). The study stated that in 2010, 22.7% URM students earned BA degrees in Psychology, 12.6% earned BA in Engineering, and 11.7% earned BA in Mathematics. The study also found that the Science and Engineering workforce is composed of primarily white males at 51.0% of the workforce and the participation of Hispanics and blacks' is substantially lower in the overall United States workforce (NSF, 2013).

High School Preparation

Studies have shown that persistence in a science major has a direct correlation to science and mathematics in high school (Oakes, 1990). However, the United States has a science pipeline problem. This problem doesn't begin in college or even high school, but in elementary school. Studies have found that this age is the first and best chance to grab students' attention and keep them engaged and interested in science for a lifetime (Payne, 1996).

With this knowledge, educators need to be aware of this special stage of life, and should tailor the biological science curriculum to capture students' creativity and interest. The national science standards have sought to change the face of science education with the idea that science is something students do, using both hands-on activities and structured learning experiences (Payne, 1996). The science educators came to a consensus within the science community, and found a vision of science education that stakeholders could embrace (Wheeler, 2006). These basic scientific tenets include: learning science content through the perspectives and methods of inquiry, applying the knowledge, and the subject must be coherent and integrated (Wheeler, 2006).

Although exposing students to biological science in elementary school is important, studies have shown that science and math concentration during the high school years has an important effect on interest in biological science in college (Cassel, 1998). Other studies have found that the more complex courses, technically speaking, and the courses that provide the greatest challenges fall in several categories. For example, mathematically-based courses like algebra, geometry and calculus may lead to success in engineering, while courses in biology may lead to success in medicine (Cassel, 1998).

The relationship between high school preparation in biology and success in college biology was conducted using a multi-level modeling survey to investigate this relationship (Loehr, 2005). The study found that high school science courses and science instructional experiences have the largest impact on student achievement in the first introductory college biology courses (Loehr, 2005). In particular, these included high school Calculus and Advanced Placement Biology, along with biology curriculum that focused on developing a deep understanding of the topics (Loehr, 2005).

Maple and Stage (1991) used High School and Beyond national data to study the influences of several variables, including course taking, on choice of science and mathematics majors. They found that students who took more math and science courses in high school were significantly more likely to choose science and math majors in college. The study also focused on early academic performance, which had effects on students' high school program, high school grades and students' plan to pursue science and math majors.

The current workforce trend has led students towards the allied health care field. More dental techs, nurses, and medical techs are being employed every day. A health care industry report found that 49 percent of students entering two-year colleges and 57 percent of students entering four-year colleges pursued health related careers (Zavattieri, D'Anna, & Maillet, 2007). This shift toward science-based skill jobs may be pressured by external economic factors; however, it is important for students to have a strong affiliation for science and math, even in the early years of high school. With this understanding, it is important for high school educators to capture and engage the minds of their students at an early age and expose them to the various worlds of science and math. The love and interest in pursuit of scientific exploration should begin in middle and high school. One such program is a broad-based curriculum program that allows students to problem-solve, communicate with mentors, and most importantly, intern in their field of choice (Zavattieri et al., 2007). The importance of these programs are threefold: they foster a basic understanding of science, spark an interest in lifelong learning of the subject, and can then lead to a very rewarding work experience.

Many educational researchers take into consideration the students' GPA and SAT scores as clues that may determine success in college level science and math courses. As noted in the Van Harlingen (1981) study, SAT and GPA performances were analyzed to predict student success when it came to physics achievement. In that study, when women were analyzed and their GPA was factored in, the $R(2)$ value increased to 0.50, which indicates a strong relationship.

Sadler and Tai (1997) have also explored the role of high school preparation and how it may lead to future success in introductory science courses. Just as in Chen's (1997) research, Sadler and Tai also examined the applied science discipline of physics. Sadler and Tai noted that high school teachers and college physics professors differed in their beliefs about how high school courses, particularly physics courses, impact college physics success. The two groups of well-meaning educators have a different take on the experience. High school teachers feel that students are well prepared for future success, while college physics professors are finding students falling by the wayside in a class that has become unfortunately a "weed out" class. The pair surveyed 1,933 introductory college physics students and collected important demographic information, such as schooling factors and college grades, in order to gain a clearer picture of the academic historical background of the student. The researchers wanted to understand if demographic variables accounted for differences in performance and course taking behavior, three such variables were race, gender, and parents' educational history. Other factors were evaluated as well, such as high schools that offered physics, how many students had one to two years of physics prior to entering college, and students' high school GPA.

The study found that the majority of the students (63%) took calculus in high school and 87 percent of students took both chemistry and biology in high school; most of these students had excellent high school GPAs (Sadler & Tai, 2001). As for the participants' parental educational level, the study found that sixty percent of fathers had four or more years of college, and 45 percent of mothers had the same educational status. On the other side of the educational spectrum, only four percent of students came from a household where the parents had not completed high school. Most students self-reported that they had taken at least one year of high school physics; only 13 percent of the group stated that they had taken more than two years.

With this important demographic information in hand, Sadler and Tai (1997) simply separated the physics participants into two sets: those who had taken high school physics and those who had not taken the class. Their findings showed that students with some high school physics experience had a grade average of 82.1 on a traditional grading scale of 100. Students who had not taken physics had a grade average of 79.8. The *t*-test analysis showed significance, as the *p* value equaled .001. Although the researchers questioned students on their upbringing, they found that these variables had little to do with student success in class. The researchers concluded that more rigorous high school preparation in areas such as calculus, and two or more years of high school physics, had a greater positive correlation to success in college physics.

First-Generation Status

In the years since World War II, institutions of higher education have been called upon to educate an increasingly diverse student body with a variety of backgrounds and needs (McConnell, 2000). Many of these students come from low-income homes and are the first in their families to pursue post-secondary education (Levine, 1989).

As colleges and universities have become increasingly accessible to women, people of color, and students from low-income families, the landscape of the undergraduate student population has changed with respect to students' age, enrollment status, attitudes, family conditions, physical and psychological health, as well as gender and race/ethnicity (Terenzini, 1996). A large number of these "new students to higher education" are concentrated in community colleges (London, 1992). These first-generation students, who do not tend to experience the academic success of their peers, made up 45 percent of all undergraduates in 1995-96 and are certainly on the radar of community college leaders (McConnell, 2000). In 1994, 55 percent of all first-generation students attended public two-year colleges (ERI & IHEP, 1997; McConnell, 2000).

In a study conducted by Terenzini (1996), the personality traits and academic differences between first-generation students and traditional students were examined based on several questions: (1) Do the precollege characteristics of first-generation students differ from those of traditional students? (2) Do first-generation students' college experiences differ from those of other students? (3) What are the educational consequences of any differences on first-year gains in students' reading, math, and critical thinking abilities? (Terenzini, 1996). The study sample consisted of 825 first-generation and 1,860 traditional students. Researchers found that first-generation students differ from their traditional peers in both entering characteristics and college experiences (Terenzini, 1996).

Teaching Methodologies

Cooperative Learning

One important educational strategy that would allow for this type of open thinking and understanding is the idea of cooperative learning. Within cognitive development theory, the basic premise of cooperation must come before cognitive growth. Cognitive growth springs from looking at various ideas as people work to achieve common goals (Morgan, 2003). Morgan (2003) noted that the idea of cooperative learning is part of Piagetian theory. Piaget (1965) stated that the cooperation of individuals with the environment results in healthy socio-cognitive development, which then stimulates perspective-taking ability and cognitive development. Cooperative learning in college classes has roots in cognitive development and some research provides evidence that this type of learning method results in greater efforts to achieve, more positive interpersonal understanding and greater psychological health when compared to competitive or individualistic learning models (Johnson, Johnson, & Holubec, 1994).

Cooperative learning is a great educational model for students to understand the scientific process, scientific meaning, and talk with others to understand their perspective on the subject. According to Krank (2001), the use of cooperative learning activities has been traditionally successful. The anatomy of cooperative learning consists of teacher instruction that is delivered to a small group of students. Cooperative learning, or group instruction, is intended to be student centered, not teacher centered. Basic components that come from this type of instruction are individual accountability, interpersonal skills and group processing. With these positive cognitive and behavioral outcomes, Krank (2001) indicated that cooperative learning is a powerful and important learning tool that lends itself to enhanced critical thinking skills and heightened academic achievement in both major and non-major science courses.

Understanding how students learn, what drives student's to understand a subject, is half the battle (if not all). Once educators understand the way students learn, they can gear their classes to engage their students in an open dialogue and enhance understanding of the subject. One issue, however, is that most educators, especially science educators, are not clued into the basic foundation of cognitive development. These educators stick to what they feel is the "tried and true" teaching models of "chalk and talk" lecture only. With a basic understanding of cognitive theories and embracing various best practice teaching ideas, the world of science education can be modified to be a discipline that can excite and challenge the truly interested science major and even the forever-baffled non-science student.

Educational researchers are on a never-ending quest to understand how to educate the mind of the modern student. Today's college students are dealing with the influence of the Internet, workloads outside the classroom, and other outside pressures that modern students face each day. Mindful educators are looking for innovative and creative ways to inspire and educate their students, both in and out of the classroom. Common approaches to instruction are competition, cooperation, and individual work (Blosser, 1993). The concept of cooperative learning has been studied in great detail within the world of academia. Rutherford and Ahlgren stated:

> The collaborative nature of scientific and technological work should be strongly reinforced by frequent group activity in the classroom. Scientists and engineers work mostly in groups and less often as isolated investigators. (as cited in Blosser, 1993, p. 2)

Assuming this is true, one would then tend to believe that academic success comes from a collaborative learning style in the classroom.

The importance of changing the way science and math is taught is not only critical in changing the basic academic outcomes, but also in changing the student perceptions and attitudes about the subject. Chinese researchers Cheng and Chen (2008) studied the impact of cooperative learning and student attitudes toward accounting. They recognized that the competitive nature of the Taiwanese society has led to an educational culture of academic isolation. The two researchers profiled Johnson and Johnson's (1994) positive features of cooperative learning, such as positive interdependence, individual and group accountability, face-to-face interaction, collaborative skill, and group processing (as cited in Cheng and Chen, 2008). These are all also societal soft skill sets that are important and can be used outside of the academic realm.

In Cheng and Chen's study, the participants were students at a technical college in Taiwan. They were randomly assigned to either the experimental group (cooperative learning) or to the control group (sans cooperative learning). The researchers then assessed students' learning attitudes toward accounting by using a special 25-item five-point Likert scale survey that allowed them to assess how the students felt about the subject. The findings showed that the use of cooperative learning, which included class presentations, group study time, individualized quizzes, individual improvement, and team recognition, yielded a positive effect on student learning attitudes. Their analysis of the pre/post test scores of the experimental group showed that the student's average attitude towards accounting and learning accounting rose from 4.03 to 4.27 and from 3.46 to 3.68, respectively; the Cronbach's alpha ranged from 0.70 to 0.94, which suggests that the scales were sufficiently reliable.

Research regarding cooperative learning has also looked at the mathematical genre of college algebra. Curtis (2006) explored improving student attitudes regarding mathematics by exploring mathematics curriculum innovation. The study researched community college students' perceptions of mathematics, which included the nature of math, learning math, and how changing the way mathematics was presented could change these ingrained perceptions. Curtis identified the independent variable as teaching strategies, and the dependent variable as student attitudes toward mathematics. Curtis used an already established survey instrument to evaluate student attitudes towards mathematics: the Attitudes Towards Mathematics Inventory (ATMI). The instrument was originally a 49-item Likert scale instrument, shortened to forty items in this study that measured student confidence, anxiety, value enjoyment, and motivation, all of which contribute to student success in mathematics (Curtis, 2006).

The study's results showed that cooperative learning received high ratings from students who were working on word problems (69.6%, $n = 16$). Most students engaged in this teaching style found themselves involved with other classmates in solving the problems (65.2%, $n = 15$), working with others to learn, or assisting another student in learning the material. As in Cheng and Chen's (2008) study, the educational boondock of academic isolation is corrected with the use of cooperative learning. Other positive factors that stem from the use of cooperative learning came to light, such as the fact that over half of the students reported that this method was used to relate the topics being taught (57.1%, $n = 12$) and the students were able to integrate the concepts between chapters (47.6%, $n = 10$). This positive student engagement then led to important topic connections between previously discussed material and current content (33.3%, n = 7). Overall, Curtis' study showed that the use of cooperative learning enhanced student understanding of these mathematical concepts, reduced student anxiety, and students became more aware of instructional strategies, moreover, the students recognized the value of mathematics for job skills and personal business (Curtis, 2006).

How students learn biology stems from what types of interactions and or experiences they get in the classroom. They often find biological jargon tough to understand, labs difficult to finish, and lectures very one sided. With this, many students, both majors and non-majors, tend to fall behind, miss class, and then drop the class.

It is imperative that American science educators find a different way to dispense the information and capture students' imagination, while still maintaining the appropriate rigor. Some professors point to chronic student absenteeism, which leads to students falling behind in the material and frustration, and as a result many drop out of the class (Moore, 2004). Students often ask one basic question, "What can I do to succeed in this course?" Many professors answer, "Study hard and read the assigned chapters." In response, successful students often report that they did study hard and they did read the assigned chapters (Moore, 2004; Sappington, Kinsey, & Munsayac, 2002). Science professors and professors in other disciplines are often puzzled by students' low rates of class attendance.

Supplemental Instruction

Attitude is a key ingredient in how students confront educational challenges. Students' attitudes are influenced by a host of factors, including their: past experiences, sense of competence, need to acquire knowledge, motivation, goals, home backgrounds, school and classroom environments, biases of peer groups and students' perceptions of the rewards associated with learning (Gottfried, 1993). In order to change student attitudes towards science, science educators must take a different approach on science instruction. Supplemental Instruction is a peer-led cooperative learning program that encourages students to develop conceptual understanding by articulating both understandings and misconceptions in a think-aloud fashion (Lundeberg, 1990).

Arendale (2002) defined Supplemental Instruction (SI) as a student academic assistance program that increases academic performance and retention through its use of collaborative learning strategies. The SI program targets traditionally difficult academic courses (Arendale, 2002). The fear of science can create a mental block for students, which may lead to apprehension towards scientists and science related activities; the SI program is designed to help eliminate this fear (Gottfried et al., 1993).

Arendale (2002) stressed that the basic premise of SI avoids the stigma of remediation because it does not focus on high-risk students, but identifies high-risk classes. SI is open to all students in the targeted course and the program allows for more of a proactive assistance before problems occur. It is important for science educators to create an atmosphere of understanding, listening and open dialogue to capture students' interest and quell the fear of the subject. SI can be quantified by positive differences in student performance and retention rates.

Arendale (2002) outlined several factors most often mentioned by SI staff, students and participating faculty. He said that SI is: proactive rather than reactive, the service is directly attached to specific courses, SI leaders must attend all class sessions, SI programs do not carry the remedial stigma, SI sessions should promote a high level of student interaction and mutual support, and the program provides an opportunity for the course instructor to receive useful feedback from the SI leader.

As stated earlier, it is important for educators to allow students to explore the world of science. This open exploration and understanding creates informed attitudes regarding the nature of science. As educators attempt to recreate the classroom experience, this will allow students to gain a comprehensive appreciation of the nature of science and how it applies to their lives. In order for this type of transformational learning to occur, science educators must incorporate teaching methods that will excite and challenge all students.

Meanwhile, the popularity of peer-instruction methods has risen drastically within the educational community. Professors in the past demonized this type of instruction, claiming that peer leaders should be pursuing a graduate degree while tutoring (Walvoord, 2008). However, students who receive collaborative instruction by baccalaureate and post-baccalaureate students demonstrate the same level of subject matter mastery as students who receive instruction from graduate students; they also indicated greater levels of interest in science in general, and biology specifically (Walvoord, 2008).

The SI method has been shown to be effective in science. Lundeberg (1990) conducted a study that focused on Supplemental Instruction (SI) in chemistry. SI was offered for three hours a week outside of class for students enrolled in three classes of General, Organic, and Biological Chemistry. At the end of the semester, final grades in chemistry classes noted that this type of instruction was effective in increasing students' achievement in chemistry (Lundeberg, 1990).

Like in the Lundeberg (1990) study, SI has been used as an interactive learning approach to combat the features of traditional algorithmic chemistry teaching techniques, with the hope of increasing the conceptual knowledge and retention rate of introductory chemistry students. With this positive outcome, a reduction in attrition should follow (Lundeberg, 1990; Webster & Hooper, 1998).

Another study focused on the use of SI in an introductory biology class, the author used data collected from the National Science Foundation (NSF), which at the time, predicted a shortfall of 675,000 scientists and engineers within fifteen years (Holden, 1989). This study stated that participation in science by females and minorities is required to help offset the projected shortfall, and that private agencies were developing student scholarships and internship programs to attract and retain both groups (Shaya, Petty, & Petty, 1993). These programs focused on improving outdated teaching equipment; however, little attention was paid to instruction. The authors stated that a useful adjunct to the traditional lecture/lab classroom structure is supplemental instruction (SI). The researchers implemented this instruction method to students enrolled in a one-semester Basic Biology course at Wayne State University. A total of 1,116 students were enrolled in all sections of this course. The study compared sections that implemented SI with non-SI sections and found that the overall percentage of successful completions was 90 percent with SI treatment and 32 percent without SI treatment, a dramatic difference (Shaya et al., 1993). In order to increase success in science courses, supplemental instruction may be a valuable tool to help stem the tide of students, principally women and minorities, from leaving science (Shaya et al., 1993).

Successful Supplemental Instruction Characteristics

It is not enough for an educator to just throw together a science ”study group”; the idea of SI takes “buy in” from everyone involved, from the student leaders, the academic professionals, as well as the students. There must be a focused theme to all of the sessions, not just a haphazard barrage of questions. Academic accountability is also key, measures must be taken to insure that SI sessions are planned and there is follow through (Arendale, 2002). There are six ideas effective supplemental instruction leaders regularly employ: building relationships, examine meta cognition, give the participants a voice and a choice, leaders should show emotion, the sessions should be meaningful for both parties, and encourage the students (Saunders, 2009). The process of coordinating a successful SI program involves several players: the SI leader, the SI supervisor, and the course instructor (Arendale, 2002). The student leader is typically an undergraduate student who has successfully mastered course subject matter and has completed SI training (Webster & Hooper, 1998). The SI leader is a facilitator, not a mini-professor and their role is to provide structure to the study session (Arendale, 2002). Lockie and VanLanen's (2008) study focused on the impact of the SI experience on SI student leaders (SISLs). The researchers' qualitative analysis utilized Colaizzi's phenomenological approach to assess the SISLs experience in SI. The researchers asked 44 SISLs to write out their experiences and reactions while participating in the SI program. The researchers found four basic themes, with associated sub themes, to the students' experience in SI (2008). Their four themes were: (1) diversity of student learning needs, (2) enriching academic experiences, (3) enriching interpersonal experiences, (4) relationship with faculty (p. 2). In Lockie and Van Lanen's (2008) study, they found that SISLs gained a greater understanding of student academic abilities and a greater understanding of the diverse learning styles. They also found that SISLs gained a greater understanding of the material as well as increased leadership skills. This open exploration of science creates informed attitudes regarding the nature of science. As educators attempt to recreate the classroom experience, it allows students to gain a comprehensive appreciation of the nature of science and how it applies to their lives. In order for this type of transformational learning to occur, science educators must incorporate various teaching methods that will excite and challenge all students.

Community College of Denver/Metropolitan State University of Denver Supplemental Instruction (SI) Program

The remainder of this chapter will focus on this study's specific university location and the SI programs they have initiated.

In 2009, the Community College of Denver entered a partnership with Metropolitan State University of Denver (MSUD) to provide Supplemental Instruction (SI) to students enrolled in two-year community college science courses. This partnership utilized funds set aside from a long-standing NIH grant, Strides Towards Encouraging Professions in Science (STEPS). SI Student Leaders from Metropolitan State University and the introductory students were enrolled at CCD. The purpose for implementing an SI program on the Auraria campus was to: (1) increase retention in difficult courses that have historically large D, F, and Withdraw rates (often in excess of 30%); (2) improve student grades and comprehension of course content; and (3) increase graduation rates through successful completion of these (often pre-requisite) courses (Taylor, 2011).

The faculty members responsible for implementing this program met on a regular basis to coordinate a successful roll out of the program. Along with the principle faculty members, CCD science faculty were an important part of the process, since the SI student leaders would be part of their students' classroom experience. The first cycle of the CCD/MSUD SI program only had two sections, one introductory biology course and one introductory chemistry course. All SI Student Leaders received official SI training provided by Dr. Maureen Hurley, Ph.D., from the Center for Academic Development, University of Missouri-Kansas City (Taylor, 2011). The CCD and MSDU principle faculty members also attended this two-day official SI training session.

Since the first cycle of the program, CCD and MSUD have worked together to provide this important academic intervention to hundreds of students and worked to mentor dozens of MSUD Student Leaders. The expectation is that these peer leaders will facilitate student learning rather than tutor or re-teach course content (Taylor, 2011). The CCD/MSUD SI program had all the elements of a traditional SI program, an involved SI director that provided mentorship and leadership to the SI Student Leaders, an interested science faculty that was excited to be involved in a program that would assist students, and a dedicated principle leadership group that involved not only faculty, but academic Deans, Provosts, and Vice Presidents, all of whom wanted the program to succeed. The CCD/MSUD SI program served the CCD biology and chemistry courses, each SI supported section had a maximum of 24 CCD science students per professor. The SI Student Leaders were an integral part the everyday workings of the course. The leaders answered student questions during lecture group study sessions, they assisted the professor during laboratory activities, and of course facilitated in the SI workshop sessions.

The CCD/MSUD SI program was primary funded through NIH grant funds and was closely monitored by an external grant evaluator, Dr. M. Taylor. Dr. Taylor analyzed basic program policy, SI Student Leader Mentorship, and CCD student demographics.

Taylor's SI Analysis

Dr. Taylor's (2011) evaluation of the CCD/MSDU SI program analyzed the program during the academic years 2010 and 2011. The program included General Biology- Bio111 and Bio112, and General Chemistry-Che109, Che111, and Che112.

Taylor's analysis involved a mixed-method design. Qualitative data collection consisted of: (1) mid-term interviews with the Project Director, Course Instructors/Professors, and SI Leaders; (2) ongoing dialogue with the Project Director; and, (3) end of year dialogue with the Project Director and surveys of course instructors/professors and SI Leaders. Taylor's qualitative analysis yielded interesting results for CCD faculty and student data, as well as SI Student Leader insights.

The CCD science faculty was impressed with the new program and the level of professionalism displayed by the MSUD SI Student Leaders. SI Staff and course instructors/professors were more engaged and more satisfied with the SI support available to their students during the spring term. During the 2010-2011academic year, the SI Student Leaders found that participating in the SI program allowed them to gain a deeper understanding of science, as well as how to relay these concepts to fellow students. As the program progressed through the academic year, SI Student Leaders noted an increased CCD student attendance.

Tables 2.1 and 2.2, below, were part of Taylor's reporting of the SI program and data includes all schools that participated in SI (CCD, CCA and MSUD), as well as all courses that were part of the program. After the first cycle, in which CCD only offered two sections, the CCDSI program grew to twelve SI offerings. These classes averaged more than five students per session and the highest average was 14.9 students per session for one of the introductory biology classes at CCD (and another biology class averaged 10.4 students per SI session). The data noted that very few SI offerings experienced a decline in average attendance (Taylor, 2011).

Table 2.1: *SI Attendance in Introductory Science Courses for Fall 2010 and Spring 2011.*

Course	Total attendance	Total SI Sessions	Average Attendance
Bio111	**1127**	**128**	**8.8**
Bio 112	22	11	2.0
Bio202	202	26	7.8
Chem109	95	39	2.4
Chem111	**410**	**86**	**4.8**
Chem112	340	77	4.4

Taylor's evaluation of the program also quantitatively examined student academic success in each course. This evaluation of the 2010 and 2011 SI program examined the letter-grade and withdraws between SI and non-SI sections. Taylor assessed the SI-course letter-grade rate against the five-year historical data set. Taylor used a *t*-test to gain insight into whether the academic intervention was successful.

One of Taylor's statistical analyses examined the student completion rates and whether implementing the SI program improved completion/retention rates. Chi-square statistical analysis was used to compare combined sections with versus without SI for a recent comparable sample and a longitudinal historical sample (all comparable sections since Fall 2006) (Taylor, 2011). Table 2.2 shows the results.

Table 2.2: *Significant Differences in Completion Rates in Courses with SI Option (Chi-square results).**

Course	Recent ABCD	Recent ABC	Historical ABCD	Historical ABC
BIO111	**3.303**	**0.992**	**3.115**	**1.752**
BIO112	0.589	0.102	0.995	0.038
CHE109	2.775	5.897	7.578	9.105
CHE111	**0.500**	**0.590**	**0.543**	**1.885**
CHE112	4.050	4.050	1.210	0.492

_*Green shading = statistically significant differences (Chi-square □ = .05, reject if $x^2 \geq 3.418$); Yellow shading = The difference between groups would be statistically significant if Chi square□ = .10, $x^2 \geq 2.706$.

Taylor noted that the calculations utilized the statistical program Java Math using the Chi-square statistic ($x^2 = 3.418$), alpha level of significance (p = .05), and one degree of freedom (df =1) to reject the null hypothesis (null = there is no significant difference between sections "with SI option" vs. "without the SI option") (2011). Taylor's Chi-square results are listed above and cells shaded green identifies the courses with statistically significant differences between the sections with SI versus without SI (2011). The results of Taylor's evaluation of the CCD/MSUD SI program compared to the historical mean are listed in Table 2.3.

Table 2.3: *Student Performance Rates in Courses with SI Option (t-test results).*

Course	Recent	Historical
BIO111	**0.836**	**0.933**
BIO112	0.990	0.781
CHE109 (General, Organic and Biochemistry)	0.000	0.000
CHE111	**0.195**	**0.453**
CHE112	0.486	0.281

* Green shading = statistically significant differences (Student's t-test, *r* = .05).

Taylor's examination found a statistically significant difference (i.e., *r* = .05, or 95% confidence the differences are real) in one of the CCD SI courses: *General, Organic and Biochemistry* (2011). Once the recent/historical analysis was complete, Taylor continued the analysis by examining individual courses (SI vs. non-SI) and student grade success and course completion rates (SI vs. non-SI). Taylor's results are summarized below in Table 2.4.

Table 2.4: *Taylor's CCD/MSUD SI Program Conclusion.*

Purpose	Status
1) Increase retention in difficult courses that have historically large DFWINC[1] rates (often in excess of 30%).	There were statistically significant gains in ABC grades (i.e., fewer DFWINC grades) in four of the ten courses that offered the SI option (CHE109, CHE112, CHE3100, and Mat121)
2) Improve student grades and comprehension of course content.	Two of the ten courses (20%) that offered the SI option had higher mean course grades than comparable classes without SI (CHE109 and MAT121). Course instructors and SI Leaders anecdotal reports indicate improved understanding of subject matter, and better performance on in-class tests.
3) Increase graduation rates through successful completion of these (often pre-requisite) courses.	Too early to determine.

Conclusion

This literature review examined several major topics that influence science education: gender, high school preparation, parental influence, and cooperative learning techniques that include the idea of supplemental instruction. Science educators must be aware of these factors and attempt to structure the classroom experience to foster an appreciation and understanding of the subject. In Chen's analysis, gender issues were discussed and it was found that female participants were not enrolling in introductory physics classes at the same rate as males. It is up to educators and parents to try to shift this skewed statistic. One way to shift this demographic is to look at how these subjects are approached in high school. It is at this level that students explore and find an affinity for subjects, and educators can create positive feeling towards subjects by changing the way the subject is taught. The idea of cooperative learning and supplemental instruction creates an environment that allows the student to explore a challenging subject, while engaging the student to think differently.

As the world population becomes more linked, the effect of English as a Second Language and first-generation students' needs to be part of these student demographic factors. With this added information, educators can truly make science and math a part of the lives of all students, and all students will have a greater appreciation of the subjects.

The state of science and mathematics education in today's society is at a crossroads. With the use of more technology and less funding, more students are falling behind. Concerns have been raised about the nation's ability to continue its global technological edge in the future. It has been noted that American students are not adequately prepared, nor developing the important STEM skills necessary to become tomorrow's leaders (Information Technology Industry Council, 2010). Science and mathematics educators truly need to take a hard look at how science and math education subjects are being treated in the public schools, especially at the high school level, and make the necessary adjustments to strengthen these programs.

This review outlined the importance of changing the way students view science and mathematics the way in which the information delivered had an impact on student appreciation, retention, and overall understanding of these subjects. The delivery method is the way by which teachers impart the knowledge that will allow students to achieve a deeper understanding of important science concepts (Kurdziel & Libarkin, 2002). The change in process will expose students to the nature of science and mathematics, which in turn, will allow students to tackle the controversial topics in science and basic understanding of mathematical features (Kurdziel & Libarkin, 2002).

Educators in both mathematics and science challenge students to take what they have learned and think critically about important issues that impact society and how these disciplines impact on not only their world but also all of society. Students should question science, challenge science, and use mathematics to understand their everyday world (Kurdziel & Libarkin, 2002). Most of all, they need to continue to blend science and math, as well as the process of scientific inquiry into their everyday lives.

CHAPTER 3: METHODOLOGY

This research study examined the relationship between the use of Supplemental Instruction (SI), an academic enhancement program, and academic success in introductory biology and chemistry classes at a community college. The variables explored were the relationships between the use of SI and final grade achievement by gender (male, female), ethnicity (White Non-Hispanic, Black Non-Hispanic and Hispanic), and first-generation students. This research document examined the impact of Supplemental Instruction (SI) on student success in an introductory science course at a two-year community college on traditional underrepresented students in science.

In order to understand the impact of SI on overall student academic final grades in introductory science courses, a quasi-experimental research design was implemented. This type of design features the causal impact of an intervention on a targeted population (Gliner & Morgan, 2000). In this study, the causal impact is SI, and the target population is the science-student population at CCD. The research analyzed the difference in final grades between SI supported science course and non-SI supported science courses as well as the difference in final grades between the underrepresented student populations outlined in Chapter 2.

Rationale and Evidence for the Selected Methodological Approach

The proper research design must be constructed to accurately assess whether SI increases academic success in an introductory science course. Creswell (2009) stated that the research plan should include: the researcher’s worldview assumptions; procedures of inquiry or strategies; and specific methods of data collection, analysis, and interpretation. According to Creswell, a researcher’s worldview is shaped by the discipline, the beliefs of advisers and faculty in a student's area, and past research experiences (2009). Creswell added that a researcher's worldview tends to "color" the way they view research, conduct research, and analyze data. Personal beliefs held by individual researchers will often lead to embracing a qualitative, quantitative, or mixed-method approach to their research (Creswell, 2009).

In this study, Chapter 3 outlines the procedures of inquiry as well as methods of data collection in order to understand the impact of the SI program on URM community college science students' final grades.

Quantitative and Qualitative Data Sets

This research uses a sequential explanatory design mixed-method approach. One definition of mixed-method research design states that a project has a quantitative data set and a qualitative data set, where neither data set is inherently attached to one another (Creswell & Plano-Clark, 2011; Green, Caracelli, & Graham, 1989). Sequential explanatory design methods are traditionally QUAN -→qual in nature, and explain the results of the study giving overarching analysis of the study (Creswell & Plano-Clark, 2011). That is, the primary method of the study is quantitative, followed by qualitative analysis to explain the quantitative findings more fully. This research aligns with this design scheme; the quantitative data set, which analyzes the impact of SI on student final grades, and the insight of the SI Student Leaders (SISL), which provides the qualitative analysis, provided a holistic view of CCD/MSUDs SI program.

Over time, other mixed-method research designs have been used to gain a more insightful view of the research questions (Creswell & Plano-Clark, 2011). Quantitative data sets are objective, which indicates that the researcher can easily classify or quantify the participants' behaviors (Gliner & Morgan, 2000). The majority of this research examined quantitative data sets in the form of CCD students' final grades in an introductory science course. This research is a non-equivalent group design, which include an existing group receiving a proscribed treatment (SI supported sections) and the other group serves as a control or comparison group (non-SI supported sections). This analysis had an intervention treatment (SI) for one group and a control analysis for the second. According to Campbell and Stanley (1963), key authorities on experimental and quasi experimental analysis, the research design, Figure 3.1, method would only allow for one group (0) to participate in the intervention (X).

Group 1:	0	X	0
Group 2:	0		0

Figure 3.1: Experimental design.

Another outcome of this research was a qualitative measure of how SI influenced the SI Student Leader (SISL). By analyzing quantitative and qualitative data strands, it gives a richer insight into the use of SI and how student populations, CCD, and SISL benefit from the program.

This type of data gathering and analysis allows for data merging or integration of both the quantitative and qualitative data set, allowing for the best understanding of the research problem (Creswell, 2009). The intent of this mixed-method study is to understand the effects of Supplemental Instruction on student final grades. In this study, analysis of student final grades in introductory science courses was used to measure the differences between student demographics, student final grades, and the use of Supplemental Instruction in introductory science courses. This research exploration was, however, not a concurrent mixed-method analysis; the qualitative data set was gathered in 2012. The qualitative data measures the impact of Supplemental Instruction on the ever-important SI Student Leaders (SISLs). The qualitative data stream was provided by the SISLs through an end of semester reflective document. The reason for developing this mixed-method analysis was to better understand the holistic effects of Supplemental Instruction on all of the principle participants and develop recommendations for the program.

Independent Variable(s)

The analysis of the relationship between SI supported instruction and student final grade outcomes can be best determined by using a quantitative individual difference general approach and more specifically, a quasi-experimental analysis. One innate factor of a quasi-experimental analysis is that it examines causality, the presumed effect of the attributive independent variables (Creswell & Plano-Clark, 2011). This type of research inquiry is based on cause and effect. This study is based on a dichotomous independent variable (Supplemental Instruction), attribute independent variables (male/female, White Non-Hispanic, Black Non-Hispanic, and Hispanic and first-generation status), and random assignment (the investigator does not control the science course assignment or the SI supported course assignment).

The attribute independent variables were chosen because previous research in science education literature found that students in these student demographic groups tend to enter introductory science classes without the necessary background to be successful in science (DeBacker, 1999).

Dependent Variable(s)

According to Creswell (2009), dependent variables are measures that rely on the independent variables; the outcomes from the influence of the independent variables. Other terms for dependent variables are criterion, outcome, and effect variables (Creswell, 2009).

In academia, there are various methods of measuring student academic success, but in this study, student success in the introductory science course was measured by student final grades. The grade scale is the traditional grading scale of A, B, C, D, or F. Another possible outcome is Withdrawal or W**.** The literature regarding student achievement in introductory science classes factor in withdrawals due to the rapid student attrition in introductory science courses (Freeman, 2006).

Therefore, the study looks as follows. The independent variables were the dichotomous variable of SI-supported and non-SI-supported introductory Biology and Chemistry science courses, and the attribute-independent variables of gender (male/female), ethnicity (White Non-Hispanic, Black Non-Hispanic and Hispanic), and first-generation student status. The dependent variable was final course grade (A, B, C or D, F, W). In this research, the effects of SI on student grades were measured using statistical analysis, in order to examine the effects. The final grade dependent variable was coded: A = 5, B = 4, C = 3, D = 2, F = 1.

An additional important part of this research study examined how participating in the SI program affects the SI Student Leaders (SISLs). This outcome was measured by examining SISLs personal reflection documents, which was gathered at the end of the 2012 fall semester. SI sessions were provided by Metropolitan State University of Denver to CCD introductory biology and chemistry students. SI Student Leaders (SISL) attended classes with the students; this allowed the SISLs to know exactly what the professor covered in class and what the professor considered important. Adding to Student leaders' teaching confidence is another benefit of the SI program. As the SISL's communication skills and depth of subject matter understanding increases, student leader confidence should likely grow. Some SISLs were pursuing teaching careers, so this experience was very beneficial (Gable, 2010). According to Gable (2010), the SI

Student Leaders gain experience in several areas of teaching, such as facilitating group dynamics, challenging all academic levels, and developing various strategies that allow students to better understand the material.

Statistical Analysis

With the research philosophy, design, and method in place, researchers must correctly choose a proper statistical analysis method to provide creditable, insightful, and gainful information. The foundation of quantitative research is based on data driven statistical analysis that "tell a story" in numbers (Creswell, 2009). Investigators divide research questions into three broad types: difference, associational, and descriptive (Morgan, Leech, Gloeckner, & Barrett, 2007). According to Gliner and Morgan (2000), difference and associational questions explore the relationship between variables, while descriptive research questions merely describe or summarize data, without generalizing to a larger population of individuals (Morgan et al., 2007).

Once a general research approach has been established, an appropriate type of statistical analysis usually emerges. When using a quasi-experimental approach to understand relationships and compare groups, where the research questions are differential, then the statistical approach used is differential/inferential statistics (Gliner & Morgan, 2000). Differential/inferential statistics (e.g., *t*-test or analysis of variance, or chi-square analysis) are used for approaches that test for differences between groups (Morgan et al., 2007). In this research, differential inferential analysis was implemented to examine the effectiveness of SI on student grades within the various student groups.

As stated earlier, the study has several independent variables, a dichotomous variable (SI/Non-SI course sections), and three attributive independent variables: gender (male/female), ethnicity (White Non-Hispanic, Black Non-Hispanic and Hispanic), and first-generation student status. The students' class assignment, which determined whether they received SI, was random (the student enrolls in the class at will). In this research, the comparative factor was SI-section students versus Non-SI-section students. This type of approach falls under the quasi-experimental approach, which states the investigator, cannot randomly assign participants to groups.

Evaluation of the Quality/Validity of Methods Proposed for the Study

In order to ensure credibility, researchers must assess the threats to validity, both internal and external. Validity is the term most often used to judge the worth of a particular study (Gliner & Morgan, 2000) and the degree to which the instrument truly measures what it purports to measure (Roberts, 2004). The traditional criteria for validity find their roots in a positivist tradition, and to an extent, positivism has been outlined by systematic theory or validity (Golafshani, 2003). Gliner and Morgan (2000) divided research validity into four components: measurement reliability and statistics, internal validity, measurement validity and general ability of the constructs, and external validity.

Internal validity threats are experimental procedures, treatments, or experiences of the participants that threaten the researcher's ability to draw correct inferences from the data about the population in an experiment (Creswell, 2009). Internal threats raise questions about the experimenter's ability to conclude that the interventions affect an outcome and not some other factor (Creswell, 2009).

For example, history, time passing during an experiment, and maturation of research participants all can affect results. This SI research study has a set time, a sixteen-week academic semester, which does not limit the normal biological maturation (which, cannot be controlled) of the student, however, the academic maturation process may be viewed as successful completion of the course. On the other hand, diffusion of treatment may be a factor due to the fact that students in an SI section class may speak to a non-SI-section student and explain the SI process to the student. However, the Community College of Denver's policy against course credit exchange (student's cannot switch classes after the first week of class) should reduce this factor. Experimental mortality, another threat to internal validity, may be a factor; however, this was tracked by following the number of withdrawals (W) between SI and non-SI sections.

According to Gliner and Morgan (2000), internal validity is measured by reliability and statistics, which measures the reliability of the instruments, appropriateness of power, statistical techniques and interpretation of the analysis. Internal validity also takes into account the strength or soundness of the research design (Morgan & Gliner, 1997). Gliner and Morgan outlined the concept of internal validity based on Tuckman (1994) assessment of the concept. Tuckman examined instrumentation bias, participation bias and experience bias as factors that could hinder internal validity (Morgan & Gliner, 1997). In this research analysis, student instrumentation, participation and student experience biases are not a factor due to the fact that this research examined final grades of students in introductory science courses and student surveys regarding SI were not used. The second factor which could influence the internal validity of a study, student participation, and participation in SI was random and the students could gauge their participation and student experience, the third measure of internal validity may be a small factor in this research, due to the fact that students may have previous knowledge in the sciences.

Other internal validity components outlined by Gliner and Morgan (2000) were equivalences of groups, and control of extraneous experiences and environmental variables. In this research analysis, quantitative student sample group equivalence comes from a pure random course section assignment, which gives the study a high rating on the Gliner and Morgan Internal Validity scale. As for controlling extraneous experiences and environmental variables, this study has attempted to control other outside factors, such as non-SI students attending SI sections; however, students enrolled in non-SI sections may still seek other outside academic enhancement programs, e.g., tutoring, peer group work, or a combination of both. With this understanding of other outside factors, this study rates between low and medium on the Gliner and Morgan Internal Validity scale.

Threats to External Validity

Threats to external validity arise when experimenters draw incorrect inferences from the sample data to other persons, other settings, and past or future settings (Creswell, 2009). . Creswell (2009) outlined three types of threats to external validity: interaction of selection and treatment, interaction of setting and treatment, and interaction of history and treatment. According to Gliner and Morgan (2000), external validity is an aspect of research validity that depends in part on the quality of the sample. The two types of external validity highlighted by Gliner and Morgan question both the population sample and the ecological external validity, which focuses on the influences of the environmental conditions of the study. In this research analysis, these external threats are present, in that the population is skewed towards the non-SI supported sections, which may not give a statistically holistic review of the SI program but will allow a condensed snapshot of an academic intervention program in the beginning stages. This, then, leads to an understanding of how to change the program to support all students.

Participant Selection, Sample Size and Supplemental Instruction Summary

Participant selection and sample size includes multiple sections of biology and chemistry courses delivered during the 2010-2011 academic school years at the Community College of Denver. Students self-enrolled into an introductory science class (Biology or Chemistry). SI student leaders were assigned to a section(s) based on the student leader's personal school schedule and availability. Students who were enrolled in the SI supported sections had the option to attend and participate in SI workshops.

The SI program was guided by a dedicated director, who carefully monitored the SI Student Leaders, the curriculum surrounding the entire program as well as within each SI session and carefully took notes at SI meetings. These weekly meetings were held by the SI Director in order to discuss, curriculum development, classroom management styles and teaching methods (See Appendix). This enabled newly minted SI Student Leaders to express their thoughts and concerns in a supportive environment. Faculty academic freedom over course curriculum is an established practice at CCD, and in order to maintain consistent curriculum development, CCD developed a comprehensive standardized final exam for the Biology 111 course. A standardized comprehensive chemistry exam is currently in development. Another method to ensure student comprehension of the material was to deliver hands on laboratory activities and demonstrations, which supported the lecture topics discussed. The researcher took a long-range view of the impact of the program on students' grades and was not part of the day-to-day processes of the program. The only involvement the researcher had with the program was scheduling rooms for the SI workshops. The greatest threat to external validity is the fact that the data set analyzed was collected from one community college (CCD) and focused on a limited community college student population.

Data Collection

Data collected for this study included students' final course grades, and basic student demographic information—gender (male/female), ethnicity (White Non-Hispanic, Black Non-Hispanic and Hispanic), and students' first-generation status. CCD's Institutional Research Department (IRD) had the necessary information, which was coded to protect the identity of the student. CCD's IRD identified sections that participated in the SI program. Another measured outcome was the SISLs' personal observations of SI. This was collected through the SI Student Leaders' personal reflection document. Although the SI program ran for several semesters, this qualitative data set was only gathered during the Fall 2012 semester. SISLs were given a consent form and asked to provide a one or two-page personal reflective paper on their experience in the program.

Data Analysis and Form of Results

The essence of proper research revolves around investigating relationships between selected demographic variables (Chen, 2002). As with the other steps in the research process, a number of ethical issues arise during the data collection and analysis phases of research (Gliner & Morgan, 2000). Data analyses involve collecting data, based on asking general questions and developing an analysis from the information supplied by participants (Creswell, 2009). This research analysis examined the effectiveness of the SI in sections of CCD biology and chemistry courses. In order to understand the impact of SI on the overall student outcome (final grade) within the various attributive independent variables (student groups) it was necessary to ask questions that explored the relationship between the variables.

Difference questions were asked to understand the relationship between the various student groups and SI-supported and non-SI-supported science sections. To understand the relationships between students' characteristics, background, and performance, differential statistical analysis was used (Two Way Factorial ANOVA) (Morgan et al., 2007).

Descriptive Questions

Frequency distributions indicate how many participants are in each category; they may or may not be ordered (Gliner & Morgan, 2000). These data describe or summarize data without trying to generalize to a larger population of individual (Morgan et al., 2007). In this study, three main attributive independent variables (gender, ethnicity and first-generation status) were analyzed.

Difference Inferential Statistics

Difference inferential statistics were used to help answer difference research questions outlined in the study. Difference research questions compare scores of two or more different groups, each of which is composed of individuals with one of the values or levels on the independent variable (Morgan et al., 2007). Interpreting statistics is another important process, if the probability is less than the preset alpha level, usually set to .05, it is said that the results are statistically significant (Morgan et al., 2007).

Examining whether SI-supported science sections, increased the overall grade for students' taking an introductory science course at the community college level was at the heart of this research. Difference research questions attempt to demonstrate that groups are not the same on the dependent variable (Morgan et al., 2007). Every statistical test is based on certain assumptions; for example, the parametric statistics (*t*-test, ANOVA) have normality of a distribution as one of the assumptions and are measurable with interval or ratio scales (Gliner & Morgan, 2000). The attributive independent variables (gender, ethnicity and first-generation status), according to the literature, may have an impact on student success in college science courses. A common parametric statistic is one that compares two different groups by computing the ratio of the variance between groups to the variation within the groups (Gliner & Morgan, 2000). This type of statistical analysis is appropriate for this research study. It gives keen insight into the overall outcome (grades) between the two groups (SI and non-SI sections).

Summary

The literature review outlined the decline of academic science success based on gender, ethnicity, and first-generation status. The literature showed that a decline in student grades and student retention in these introductory science courses are problematic.

This research study examined the effect of the SI program on student grades at the community college level and specifically looked at the groups identified by the literature as struggling. The Community College of Denver, an urban school that educates a diverse student population was the source of the data generated. The measured research outcome(s) are the students' final grade at the end of the science course, and how participating in the SI program influences the SI Student Leaders.

The basic paradigm used in this study was positivist; the research design was primarily quantitative, specifically, using comparative analysis, but also included qualitative data from section leaders. Overall examination of student grades were compared between SI and non-SI sections, while also comparing the various student group subsets of gender, ethnicity, and first-generation status. The attributive independent variables highlight important questions regarding student academic success in science within these student groups.

CHAPTER FOUR: RESULTS

In order to examine the impact of the academic engagement method, Supplemental Instruction (SI) on student achievement, this research first examined the student population demographics by answering several descriptive questions that gave a statistical snapshot of CCD's science student population. In order to examine the impact of SI on introductory science courses at a two-year community college, a series of research questions were asked, which gave insight into how SI impacted each attributive independent group. This research also evaluated how SI impacts the SI Student Leaders. This qualitative measure examined the common pedagogical themes associated with Supplemental Instruction. Statistical data analyses were implemented to measure the effect of the SI program on two-year community college introductory science students. CCD/MSDU SI program was grant funded, and as stated earlier, the SI Grant evaluator, Taylor previously synthesized a statistical analysis. Taylor examined the overall grade outcome between SI supported vs. non-SI supported science courses, completion rates, historical grade outcomes, and course progression since SI was implemented at CCD. Taylor's findings were examined in Chapter 2. However, this research study goes further by taking into consideration the historically diverse student population of community colleges and examines the success rates of various student populations enrolled in a two-year community college science course.

A basic student demographic frequency table was synthesized in order to understand the two-year community college student population. Another set of quantitative statistical information examined the overarching outcome value, measured as the students' overall final grade in the introductory course. The data comparison analysis focused on whether the student was enrolled in an SI-supported biology or chemistry section, and the demographic make-up of the student (White Non-Hispanic, Black Non-Hispanic and Hispanic, male/female, and first-generation student status).

To answer the overall research question—is there a relationship between the use of SI and student achievement in science courses—Two-Way (Factorial) ANOVA was primarily used for statistical analysis of the data.

The qualitative analysis was generated from the SI Student Leaders (SISL), an important influences in the SI program. The SISLs were asked how the program influenced their perceptions of science education, community college students, and their own future academic aspirations. The qualitative measure was examined by asking SISLs to write an end of the year SI Reflective Document that outlined their overall view of the CCD/MSUD Supplemental Instruction program and how participating in this program changed their viewpoint of the state of science education in the United States. These questions and consent form were distributed to the SISLs in a survey format and participants were asked to answer them in a reflective documentation format. The results will be discussed after an analysis of the specific quantitative research questions.

Research Questions

The first set of statistical analyses outlined the CCD's student population demographics. The remaining research questions, evaluated student academic performance, based on student demographics, science course selection, and SI or Non-SI supported sections.

Demographics

During the 2010-2011 academic year, the Community College of Denver Introductory Biology course (BIO 111), had a total of 642 students, 74% of enrolled students were female, Table 4.1. According to Table 4.2, during the 2010/2011 academic year, the Community College of Denver's Biology course (BIO111) had 39.6% of enrolled students were minorities (Hispanic and Black Non-Hispanic). First-generation students made up 51.7% of enrolled students in the course (Table 4.3). Compared to CCDs Introduction to Biology course (BIO111) which had 642 students enrolled during this academic year, the Introductory Chemistry course (CHE 111); Table 4.4, had a total of 217 students, 55.8% of enrolled students were female. According to Table 4.5, CCDs Introductory Chemistry course (CHE 111) comprised 28.1% minorities (Hispanic and Black Non-Hispanic). According to Table 4.6, the Community College of Denver's First-generation student population comprised 36.9% of all students enrolled in the Introductory Chemistry course (CHE 111).

Table 4.1: *CCD Biology (BIO 111) Gender Demographics.*

Table 4.1: CCD Biology (BIO 111) Gender Demographics.	Frequency	Valid Percent	Cumulative Percent
Male	161	25.1	25.1
Female	481	74.9	100.0
Total	642	100.0	

Table 4.2: *CCD Biology 111 Ethnicity Enrollment Data.*

	Frequency	Percent	Cumulative Percent
Other	136	**21.2**	21.2
White Non-Hispanic	252	**39.3**	60.4

Black Non-Hispanic	95	**14.8**	75.2
Hispanic	159	**24.8**	100.0
Total	642	**100.0**	

Table 4.3: *CCD BIO 111 First-Generation Enrollment Data.*

	Frequency	**Percent**	Cumulative Percent
Unknown	93	**14.5**	14.5
First-generation	332	**51.7**	66.2
Not First-generation	217	**33.8**	100.0
Total	642	**100.0**	

Table 4.4: *CCD CHE 111 Student Enrollment Gender Data.*

	Frequency	**Percent**	Cumulative Percent
Male	96	**44.2**	44.2
Female	121	**55.8**	100.0
Total	217	**100.0**	

Table 4.5: *CCD CHE 111 Ethnicity Enrollment Data.*

	Frequency	Percent	Cumulative Percent
Other	70	**32.3**	32.3
White Non-Hispanic	86	**39.6**	71.9
Black Non-Hispanic	24	**11.1**	82.9
Hispanic	37	**17.1**	100.0

Table 4.6: *CCD CHE 111 First-Generation Enrollment Data.*

	Frequency	Percent	Cumulative Percent
Unknown	38	**17.5**	17.5
First-generation	80	**36.9**	54.4
Not First-generation	99	**45.6**	100.0
Total	217	**100.0**	

Difference Questions/Hypothesis

The remaining research analysis focused on the impact of SI on CCD science courses by answering a series of difference questions.

Research Question One

Are there differences between student academic performance (final grade) in SI and Non-SI supported sections?

The mean student grades and the standard deviations between NON-SI and SI sections are presented (Table 4.7). The *n*-value for Non-SI section was 589, while the SI sections were 270. More students were registered in Non-SI sections than SI sections. The mean student grade analysis between SI and Non-SI was 3.34 for SI-supported sections, and 3.04 for Non-SI-supported sections (Table 4.7). While the SI section's score was higher, there was a significant difference, or *d*-effect (d = .165) between SI and Non-SI supported sections. Table 4.8 shows the interaction between SI and Non-SI section grades (F=5.33) (p = .024), which was significant. The square of the means was significant (F = 5.33) (p = .024) either. The Eta, an index of association, was also very low (.006), indicating that .6% of students' academic performance can be predicted by SI/Non-SI supported science sections.

Table 4.7: *SI/Non-SI Grade: Mean.*

Variable/Stats	n	M	SD
Non-SI	589	3.04	1.781
SI	270	3.34	1.846
Total	859	3.14	1.806

Dependent variable: Grade

Table 4.8: *SI/Non-SI Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	16.661	5.133	.024	.006
Error	857	3.246			

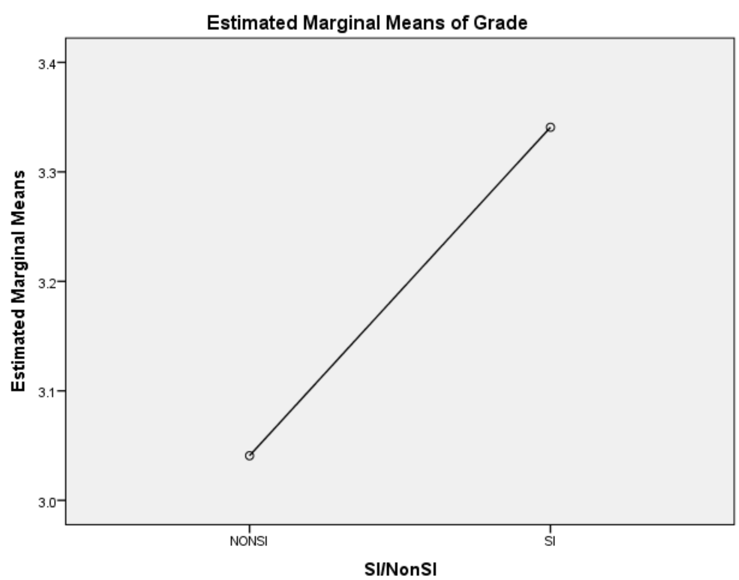

Figure 4.1: SI/Non-SI plot analysis. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in both introductory science courses. Note that the plotted means in Figure 4.1 shows that students enrolled in SI sponsored science course have a higher final grade means. The effect size within this data set was d= .165 . This analysis indicates a positive direction between the use of SI on overall student final grades. The interaction pattern between SI and student academic success is more apparent, which clearly displays an interaction between student final grade and SI supported science sections.

Research Question Two

Are there differences between student academic performance (final grade) in Fall and Spring academic semesters? Is there an interaction of SI and Non-SI sections and Fall and Spring academic semesters on student academic performance (final grade)?

The CCD/Metro SI program ran for two semesters, Fall 2010 and Spring 2011. Statistical analyses were implemented to understand the academic performance between the two semesters.

Table 4.9 shows the mean student grades and the standard deviations between Non-SI and SI sections. The *n*-value for Non-SI sections was 589, while the SI sections were 270. The *n*-value for Fall and Spring semesters were 433 and 426, respectively. The mean values for the Fall semester were 2.93 for Non-SI-supported sections and 3.30 in SI-supported sections. The mean values for the Spring semester were 3.14 in Non-SI-supported sections and 3.39 in SI-supported sections. Table 4.10 shows the effect size for the differences analysis of SI/Non-SI and Fall/Spring term. The effect sizes indicate that the strength of relationships were small. The research also did not indicate a significant interaction between SI and Non-SI section grades and semester term interaction ($F = .185$) ($p = .668$). The Eta, an index of association, (Table 4.10) showed that only .1% of students' academic performance was predicted by Fall or Spring semester SI/Non-SI supported science sections. The index also indicated that only .6% of student academic performance was predicted by students enrolling in SI or Non-SI-supported science sections.

Table 4.9: *SI/Non-SI Fall/Spring Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/Fall	272	2.93	1.789
Non-SI/Spring	317	3.14	1.771
Total	589	3.04	1.781
SI/Fall	161	3.30	1.803
SI/Spring	109	3.39	1.915
Total	270	3.34	1.846
Total/Fall	433	3.07	1.801
Total/Spring	426	3.20	1.810
Total	859	3.14	1.806

Dependent variable: Grade

Table 4.10: *SI/Non-SI and Fall/Spring Semesters Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	18.038	5.558	.019	.006
Fall/Spring Term	1	3.934	1.212	.271	.001
SI/Non-SI Section* Fall/Spring Term	1	.599	.185	.668	.001
Error	855	3.246			

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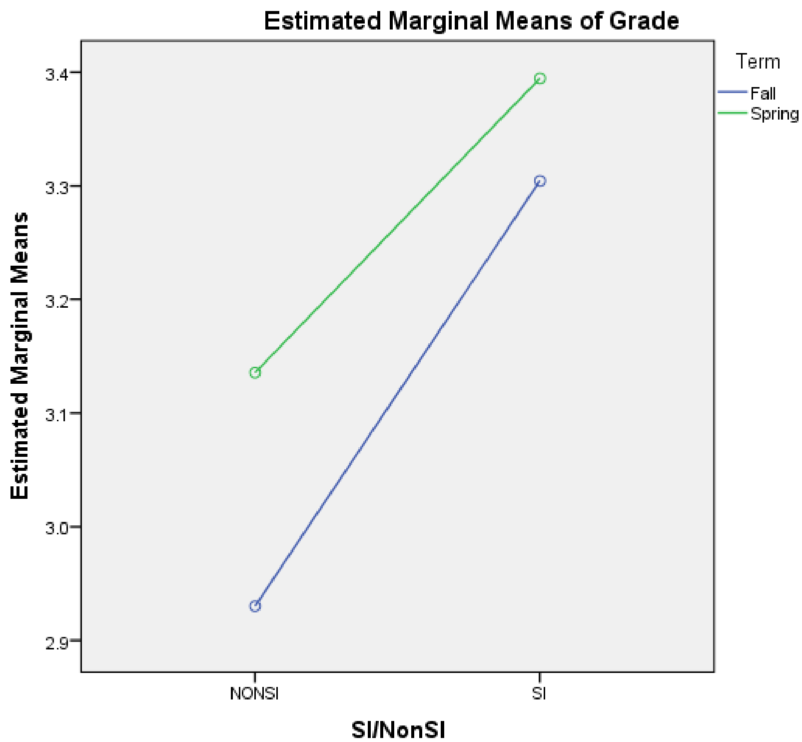

Figure 4.2: SI/Non-SI and Fall/Spring marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades for both introductory science courses, between Fall and Spring semesters during the 2010/2011 academic year. Note that the plotted means in Figure 4.2 indicates that students enrolled in SI sponsored science course have a higher final grade means in both semesters (Fall and Spring). The total effect size within this data set was d= .165. This analysis indicates a positive direction between the use of SI on overall student final grades. The Fall semester effect size was d= .206. This data set analysis indicates that in both semesters a positive direction between the use of SI on student grades was achieved.

Research Question Three

Are there differences between student academic performance (final grade) in Introductory Biology and Chemistry courses? Is there an interaction of SI/Non-SI-supported sections and Introductory Biology and Chemistry courses on student academic performance (final grade)?

Table 4.11 shows the *n*-value for the Non-SI section was 589, while the SI sections were 270. The *n*-value for Biology and Chemistry were 642 and 217, respectively. Statistical analyses showed the mean student grades and the standard deviations between Non-SI and SI sections.

The Non-SI sections had a student grade mean of 2.90 for Biology 111, and 3.85 for Chemistry 111. The SI-supported sections had a mean value of 2.92 in Biology 111, and slightly lower mean values of 3.81 for the Chemistry 111 section. Figure 4.3 depicts the marginal means between Biology and Chemistry SI and Non-SI sections. Table 4.12 shows that the relationship between SI/Non-SI (F= .006) (p = .941) was not statistically significant. The relationship between the introductory biology and chemistry courses, however, did show a statistical significance between the two courses (F=39.396) (p = .001). Meanwhile, there was not a significant interaction between SI and Non-SI section grades and biology/chemistry courses (F=.043) (p = .837). Table 4.12 showed the Eta index of association had a very small (.044 or 4.4%) association between students' academic performance and course selection**.**

To further understand the difference between SI/Non-SI and the two science courses, a cross-tabulation statistical analysis was performed for the total grade outcomes between the courses. These statistics indicate that out of the total number of students that withdrew, 86.5% were in Biology compared to 13.5% in Chemistry. The total percentage of F grades was also heavily in Biology (90.5%) compared to Chemistry (9.5%). However, among the total A grades, 64.8% were earned in Biology, while 35.2% were earned in Chemistry.

Table 4.11: *SI/Non-SI and Introductory Science Course Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
NonSI/BIO	500	2.90	1.794
NonSI/CHEM	89	3.85	1.466
Total	589	3.04	1.781
SI/BIO	142	2.005	2.92
SI/CHEM	128	3.81	1.525
Total	270	3.34	1.846
Total/BIO	642	2.90	1.841
Total/CHEM	217	3.83	1.498
Total	859	3.14	1.806

Dependent variable: Grade

Table 4.12: *SI/Non-SI and Biology/Chemistry Courses Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	.017	.006	.941	.001
Biology/Chemistry Course	1	122.489	39.398	.000	.044
SI/Non-SI Section* Biology/Chemistry Course	1	.132	.043	.837	.001
Error	855	3.109			

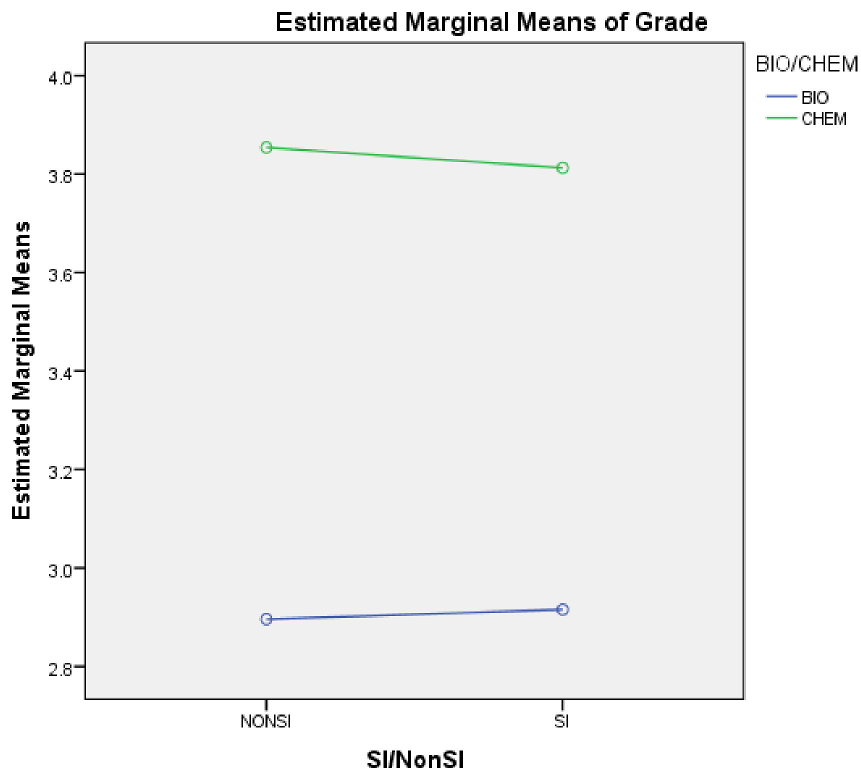

Figure 4.3: SI/NonSI Biology and Chemistry marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades both introductory science courses, between introductory science courses (Biology and Chemistry) during the 2010/2011 academic year. The overall effect size within this data set was d= 0.165. This analysis indicates a positive direction between the use of SI on overall student final grades and introductory science courses overall. The data indicates that use of SI in an introductory biology course, student final grade showed an effect size of d=0.015. This data indicates SI supported biology classes has an effect (positive direction) on overall final grades. However, SI supported introductory chemistry courses, showed a slight decrease (negative direction) in marginal means (d = -0.0267).

Research Question Four

Are there differences between student academic performance (final grade) and student ethnic demographics (White Non-Hispanic, Black Non-Hispanic and Hispanic)? Is there an interaction between the SI/Non-SI supported sections and student ethnic demographics on student academic performance (final grades)?

The *n*-values for White Non-Hispanic, Black Non-Hispanic, and Hispanic were 338, 119, and 198, respectively. In this analysis, Other (which accounts for other identified student ethnicities) was counted but not analyzed; the *n*-value for the Other student group was 206. Non-SI supported sections mean student grades for White Non-Hispanic students were 3.52; 2.41 for Black Non-Hispanic students; and 2.45 for Hispanic students. SI-supported science sections showed mean grades for White Non-Hispanic students were 3.69; 3.50 for Black Non-Hispanics, and 2.98 for Hispanics. Figure 4.4 depicts the marginal means between Biology and Chemistry SI and Non-SI sections and student ethnicity in science courses

Table 4.14 shows that the difference between ethnicities and SI/Non-SI sections was statistically significant (p = .002). The difference between student ethnicity and total grade was also statistically significant (F = 9.733) (p < .001). The data analysis showed a significant interaction between SI and Non-SI section grades and student ethnicity (F = 2.979) (p = .031). The Eta index of association (Table 4.14) found that student ethnicity was a slight factor in predicting student success in introductory science courses (.033 or 3.3%). Table 4.14 also indicates students' ethnicity and SI or Non-SI section selection cannot predict student success in introductory science courses (.010 or .1%). A Tukey Honest Significant Difference (HSD) post hoc analysis was used in order to understand the variances within a data set (Morgan et al., 2007). A Tukey analysis is similar to that of a t-test in except that it corrects for the error rate (Morgan, et al., 2007). Table 4.15 showed significant differences between Black Non-Hispanic (p = .093) and Other student population. Between the Black Non-Hispanic population and the Hispanic population (p = .873), the Tukey test showed that there was not a significant difference in the student's final overall grade performance in SI/non-SI science courses. The Tukey Homogeneous Subset analysis (Table 4.15) further illustrated the significant differences between the three ethnic subgroups. In this analysis, Black Non-Hispanic students and Hispanic students are featured in the same subset, which indicated that the final grade outcomes between the two groups were not significant. The same can be stated for White Non-Hispanic students and the student group Other (other student ethnicities and students who did not self-identify ethnicity) and Black Non-Hispanic and Other, these two student groups showed that the final grade outcome is slightly significant.

Table 4.13: *SI/Non-SI Student Ethnicity Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/White Non-Hispanic	240	3.52	1.726
Non-SI/Black Non-Hispanic	83	2.41	1.746
Non-SI/Hispanic	140	2.45	1.727
Non-SI/Other	126	3.21	1.670
Total	589	3.04	1.781
SI/White Non-Hispanic	98	3.69	1.796
SI/Black Non-Hispanic	36	2.98	1.483
SI/Hispanic	56	2.98	1.844
SI/Other	80	3.09	1.995
Total	270	3.34	1.846
Total/White Non-Hispanic	338	3.57	1.746
Total/Black Non-Hispanic	119	2.74	1.739
Total/Hispanic	196	2.60	1.773
Total/Others	206	3.16	1.799
Total	859	3.14	1.806

Dependent variable: Grade

Table 4.14: *SI/Non-SI and Student Ethnicity Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	28.357	9.223	.002	.011
Student Ethnicity	3	29.925	9.733	.001	.033
SI/Non-SI Section* Student Ethnicity	3	9.158	2.979	.031	.010
Error	851	3.075			

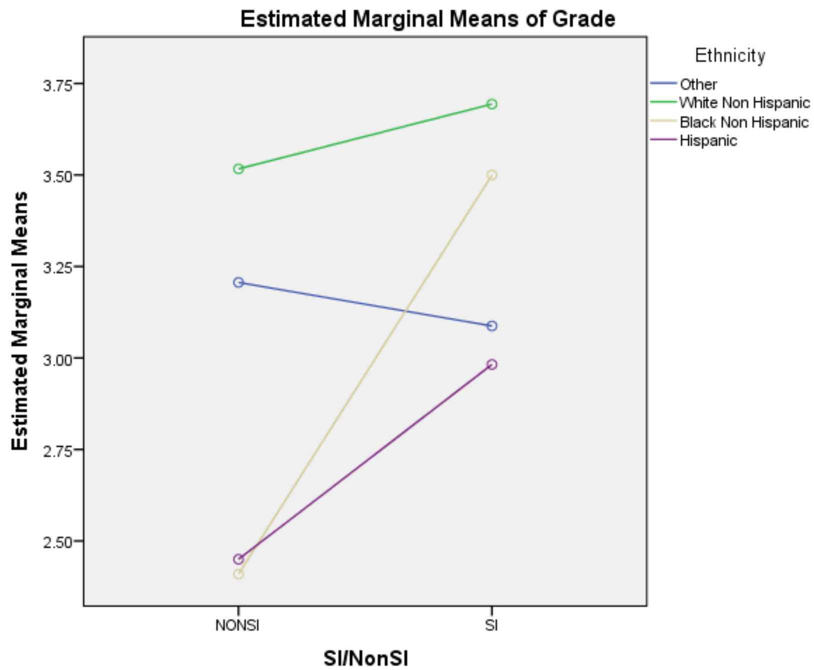

Figure 4.4: SI/NonSI Student Ethnicity marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades both introductory science courses (Biology and Chemistry), and student ethnicity. The overall effect size within this data set was d= 0.165. This analysis indicates a positive direction between the use of SI on overall student final grades and student ethnicity in introductory science courses. Note that the plotted means in Figure 4.4 indicated that Black Non-Hispanic students enrolled in SI sponsored science course showed a significantly higher final grade means. The data indicates that use of SI in an introductory science course, student final grade within the Black Non-Hispanic student population showed an effect size of d=0.339 . This data indicates SI supported introductory science courses and a greater effect (or positive direction) on Black Non-Hispanic overall final grades. White Non-Hispanic students enrolled in SI supported introductory science courses, showed a slight increase (positive direction) in marginal means (d = 0.096). Hispanic students enrolled in SI supported science courses, showed an increase (positive direction) in final grade outcomes d= .2966. This plot analysis indicates a statistical significance between student final grade and SI supported science sections, and student ethnic background.

Table 4.15: *Homogenous Subset Final Grade Analysis.*

Tukey HSD[a,b,c]

Ethnicity	N	Subset		
		1	2	3
Hispanic	196	2.60		
Black Non-Hispanic	119	2.74	2.74	
Other	206		3.16	3.16
White Non-Hispanic	338			3.57
Sig.		.873	**.093**	.110

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 3.075.
a. Uses Harmonic Mean Sample Size = 187.632.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Research Question Five

Are there differences between student academic performance (final grade) and student ethnic demographics (White Non-Hispanic, Black Non-Hispanic and Hispanic)? Is there an interaction between the Introductory Biology (BIO111) SI/Non-SI supported sections and student ethnic demographics on student academic performance (final grade)?

Table 4.16 examined the overall student mean grades for the evaluated student ethnic demographics. For the Non-SI Biology sections, the results were: White, Non-Hispanic, 3.39; Black, Non-Hispanic, 2.21; and Hispanic, 2.37. The SI-supported section showed student mean grades for the evaluated student ethnic demographics were: White, Non-Hispanic, 3.04; Black, Non-Hispanic, 3.38; and Hispanic, 2.58. Figure 4.5 depicts the marginal means between student ethnic demographics in SI and Non-SI supported Biology 111 sections. Table 4.17 shows there were no significant differences between SI/Non-SI Biology science supported sections (p = .171). The data analysis did show a significant difference between student ethnicity (p = .011).

The data indicated a significant interaction between SI and NON-SI section grades, student ethnicity, and BIO 111 courses ($p < .001$). The square of the means for this interaction was significant ($F = 6.053$) ($p < .001$). The Eta index of association (Table 4.17), which evaluated the effect of student ethnicity on biology achievement, found that 1.7% of the variance in biology grades could be predicted from the students' ethnic background. An additional post-hoc statistical analysis was performed to fully understand the interaction between SI/NonSI supported biology sections and student ethnicity. A Tukey Honest Significant Difference (HSD) post hoc analysis was used in order to understand the variances within a data set. A Tukey analysis is similar to that of a t-test in except that it corrects for the error rate (Morgan et al., 2007).

Table 4.17 showed significant differences between White Non-Hispanic students, Black Non-Hispanic ($p < .001$) and Hispanic ($p < .001$) student population. Between the Black Non-Hispanic population, Hispanic, and Other population ($p = .120$), the Tukey test showed that there was not a significant difference in the student's final overall grade performance in both introductory science courses. The Tukey Homogeneous Subset analysis, Table 4.18 further illustrated the significant differences between the three ethnic subgroups. In this analysis, Black Non-Hispanic students and Hispanic students are featured in the same subset, which indicated that the final grade outcomes between the two groups are not significant. The same can be stated for White Non-Hispanic students and the student group Other (students who did not self-identify ethnicity) and Black Non-Hispanic and Other, these two student groups showed that the final grade outcome is not significant.

Table 4.16: *SI/Non-SI, BIO 111 and Student Ethnicity, and Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/White Non-Hispanic	207	3.39	1.759
Non-SI/Black Non-Hispanic	72	2.21	1.711
Non-SI/Hispanic	126	2.37	1.729
Non-SI/Other	95	3.04	1.688
Total	500	2.90	1.794
SI/White Non-Hispanic	45	3.04	2.099
SI/Black Non-Hispanic	23	3.83	1.230
SI/Hispanic	33	2.58	2.047
SI/Other	41	2.54	2.099
Total	142	2.92	2.005
Total/White Non-Hispanic	252	3.33	1.824
Total/Black Non-Hispanic	95	2.60	1.747
Total/Hispanic	159	2.42	1.794
Total/Other	136	2.89	1.828
Total	642	2.90	1.841

Dependent variable: Grade

Table 4.17: *SI/Non-SI, Student Ethnicity and Biology 111 Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	6.007	1.882	.171	.003
Student Ethnicity	3	12.003	3.760	.011	.017
SI/Non-SI Section* Student Ethnicity	3	19.322	6.053	.001	.028
Error	634	3.192			

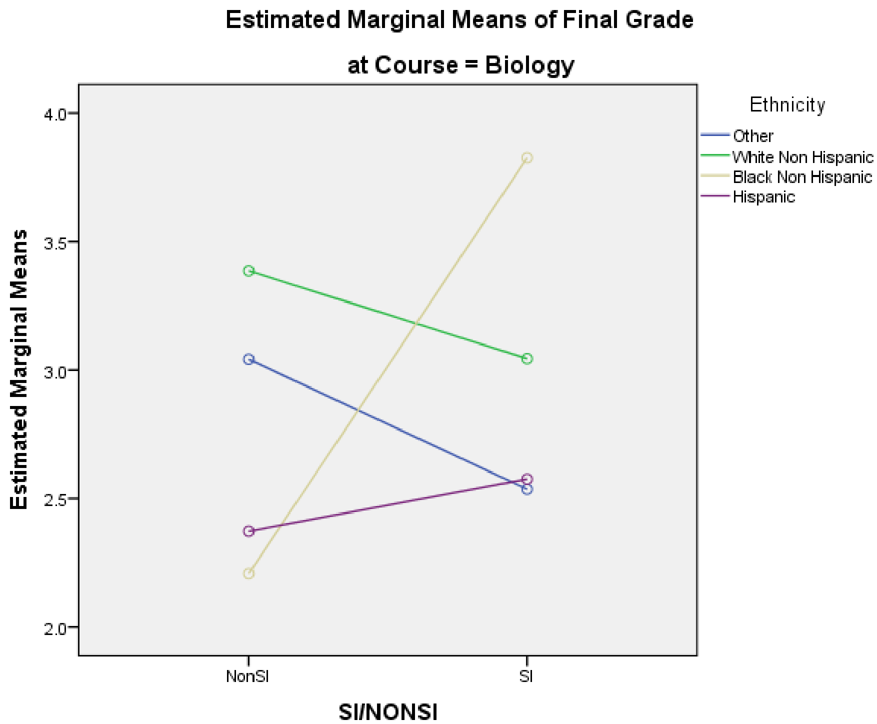

Figure 4.5: SI/NonSI, Student Ethnicity and Biology 111 marginal means of grades.This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in an introductory biology course, and student ethnicity. The overall effect size within this data set was d= 0.015. This analysis indicates a positive direction between the use of SI on overall student final grades and student ethnicity. Note that the plotted means in Figure 4.5 indicated that Black Non-Hispanic students enrolled in SI sponsored science course showed a significantly higher final grade means in the introductory biology course. The data indicates that use of SI in an introductory biology course, student final grade within the Black Non-Hispanic student population showed an effect size of d=1.087 . This data indicates SI supported biology classes and a greater effect (or positive direction) on Black Non-Hispanic overall final grades. However, White Non-Hispanic students enrolled in SI supported introductory biology course, showed a slight decrease (negative direction) in marginal means (d = -0.180). Hispanic students enrolled in SI supported course, showed a very slight increase (positive direction) in final grade outcomes (d= 0.11). The interaction pattern between SI and student academic success is more apparent in this plot, which clearly displays an interaction between student final grade and SI supported science sections. This plot analysis indicates clearly displays statistical significance between Black Non-Hispanic student population and student final grade and SI supported biology sections.

Table 4.18: *Homogenous Subset Final Grade Analysis.*

Final Grade

Tukey HSD[a,b,c]

Ethnicity	N	Subset	
		1	2
Hispanic	159	2.42	
Black Non-Hispanic	95	2.60	
Other	136	2.89	2.89
White Non-Hispanic	252		3.33
Sig.		.120	.177

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 3.263.
a. Uses Harmonic Mean Sample Size = 142.162.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Research Question Six

Are there differences between student academic performance (final grade) and student ethnic demographic (White Non-Hispanic, Black Non-Hispanic, and Hispanic)? Is there an interaction between the Introductory Chemistry (CHE111) SI/Non-SI supported sections and student ethnic demographics on academic performance (final grade)?

White Non-Hispanic students, Black Non-Hispanic students and Hispanic students who were enrolled in a Non-SI supported section of Chemistry 111, had final grade mean values of 4.33, 3.73, and 3.14, respectively. The same student demographics enrolled in a SI-supported section had final grade averages of 4.25, 2.92, and 3.57, respectively. Figure 4.6 depicts the marginal means between student ethnic demographics in both SI and Non-SI supported Chemistry 111 sections. Table 4.20 does not show a significant difference between SI/Non-SI supported Chemistry sections and grade (F = .316) (p = .575). But, it does show a significant difference between student ethnicity and grade (F = 5.070) (p = .002). There was not a significant interaction between SI and non-SI section grades, student ethnicity and CHE111 courses (F = .833) (p = .477). The Eta index of association (Table 4.20) indicates that 6.8% of students' academic performance can be predicted by the students' ethnic background. Table 4.21 showed significant differences between White Non-Hispanic students, Black Non-Hispanic ($p < .001$) and Hispanic ($p < .001$) student populations.

Between the Black Non-Hispanic, Hispanic population, and Other ($p = .603$), the Tukey test showed that there was not a significant difference in the student's final overall grade performance in both introductory chemistry courses. The Tukey Homogeneous Subset analysis, Table 4.18 further illustrated the significant differences between the three ethnic subgroups. In this analysis, Black Non-Hispanic students and Hispanic students are featured in the same subset, which indicated that the final grade outcomes between the two groups are not significant. The same can be stated for White Non-Hispanic students and the student group Other (which includes, other ethnicities and students who did not self-identify) and Black Non-Hispanic and Other, these two student groups showed that the final grade outcome is not significant.

Table 4.19: *SI/Non-SI Student Ethnicity and CHE111 Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/White Non-Hispanic	33	4.33	1.242
Non-SI/Black Non-Hispanic	11	3.73	1.421
Non-SI/Hispanic	14	3.14	1.610
Non-SI/Other	31	3.71	1.532
Total	89	3.85	1.466
SI/White Non-Hispanic	53	4.25	1.270
SI/Black Non-Hispanic	13	2.92	1.754
SI/Hispanic	23	3.57	1.343
SI/Other	39	3.67	1.722
Total	128	3.81	1.525
Total/White Non-Hispanic	86	4.28	1.22
Total/Black Non-Hispanic	24	3.29	1.628
Total/Hispanic	37	3.41	1.443
Total/Other	70	3.69	1.629
Total	217	3.83	1.498

Dependent variable: Grade

Table 4.20: *SI/Non-SI, Student Ethnicity and Chemistry 111 Between-Subjects Analysis.*

Variable and Source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	.675	.316	.575	.002
Student Ethnicity	3	10.835	5.070	.002	.068
SI/Non-SI Section* Student Ethnicity	3	1.780	.833	.477	.012
Error	209	2.137			

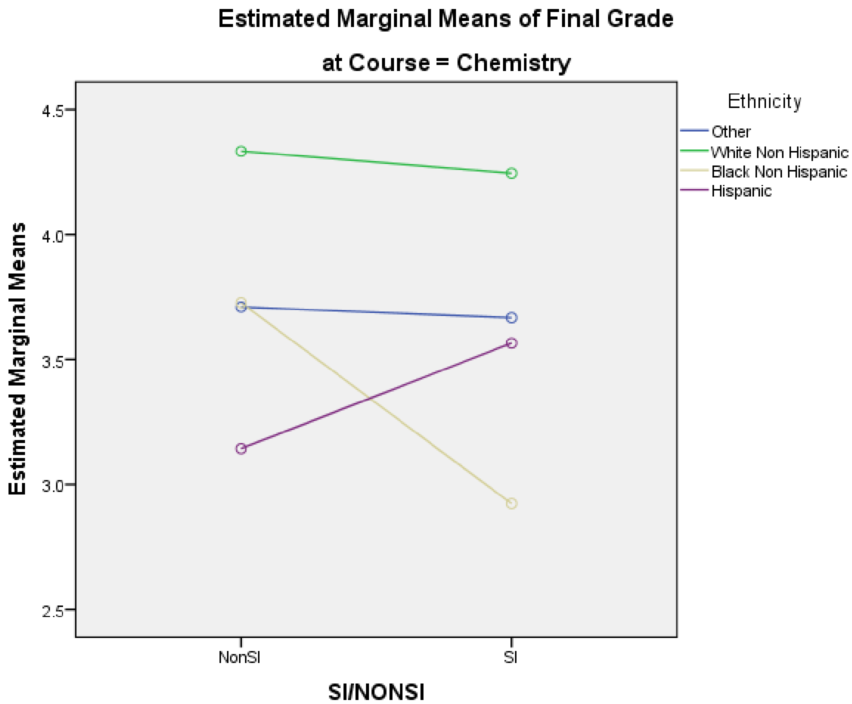

Figure 4.6: SI/Non-SI, student ethnicity and Chemistry 111 marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in an introductory chemistry course, and student ethnicity. The overall effect size within this data set was d= 0.026 . This analysis indicates a positive direction between the use of SI in an introductory chemistry course on overall student final grades and student ethnicity. Note that the plotted means in Figure 4.6 indicated that Black Non-Hispanic students enrolled in SI sponsored science course showed a decline in final grade means in the introductory chemistry course. The data indicates that use of SI in an introductory chemistry course, student final grade within the Black Non-Hispanic student population showed an effect size of d= - 0.5074. This data indicates SI supported chemistry classes had little effect (or negative direction) on Black Non-Hispanic overall final grades.

Table 4.21: *Homogenous Subset Final Grade Analysis.*

Final Grade

Tukey HSD[a,b,c]

Ethnicity	N	Subset	
		1	2
Black Non-Hispanic	24	3.29	
Hispanic	37	3.41	
Other	70	3.69	3.69
White Non-Hispanic	86		4.28
Sig.		.603	.246

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.137.
a. Uses Harmonic Mean Sample Size = 42.280.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

Research Question Seven

Are there differences between student academic performances (final grade) between genders in BIO 111? Is there an interaction between the Introductory Biology (BIO 111) SI/Non-SI supported sections and student gender demographics?

Table 4.22 shows that female students enrolled in a Non-SI-supported Biology 111 section had mean final grades of 2.85, while male students enrolled in a non-SI-supported section had final grades of 3.04. Female students enrolled in SI-supported Biology 111 sections had mean final grades of 2.83, while male students mean final grades were 3.21. Figure 4.7 depicts the marginal means between female and male student demographics in SI and Non-SI supported Biology 111 sections.

Data analysis (Table 4.23) did not show a significant difference between student gender and SI/Non-SI Biology (F = 1.974) (p = .161). The data also showed no significant interaction between SI and Non-SI section grades, student gender and Biology 111 courses (F = .222) (p = .638). The square of the means was also not significant; Eta index of association (Table 4.23) indicated that only .3% of students' academic performance in Biology 111 can be predicted by the students' gender.

Table 4.22: *SI/Non-SI, Student Gender and BIO111 Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/Male	128	3.04	1.741
Non-SI/Female	372	2.85	1.812
Non-SI/Total	500	2.90	1.794
SI/Male	33	3.21	1.850
SI/Female	109	2.83	2.050
SI/Total	142	2.92	2.005
Total/Male	161	3.07	1.759
Total/Female	481	2.84	1.866
Total/Biology	642	2.90	1.841

Dependent variable: Grade

Table 4.23: *SI/Non-SI, Student Gender and Biology 111 Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	.462	.136	.712	.001
Student Gender	1	6.701	1.974	.161	.003
SI/Non-SI Section* Student Gender	3	.754	.222	.638	.001
Error	638	3.395			

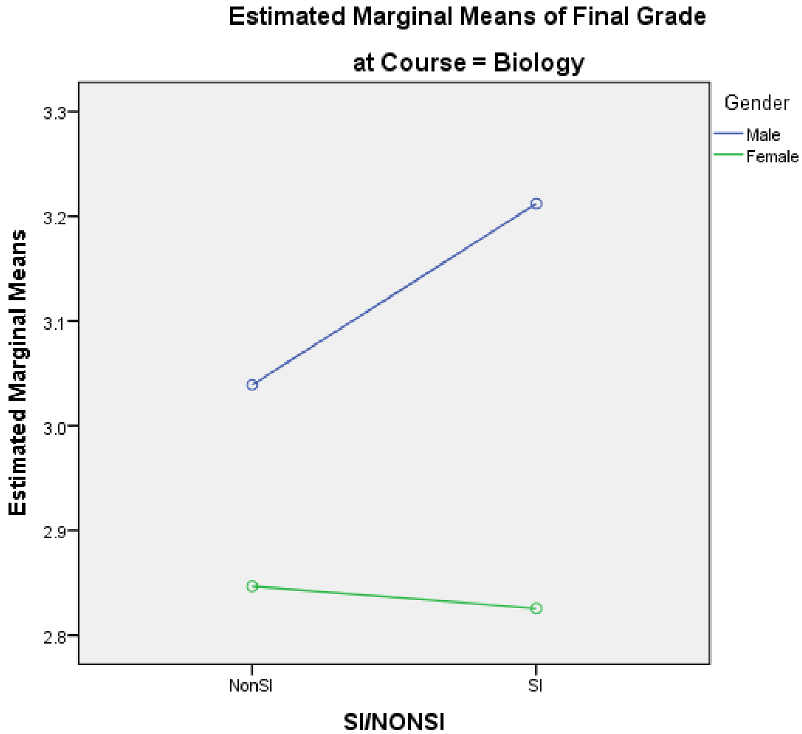

Figure 4.7: SI/Non-SI, Student Gender and Biology 111 marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in an introductory biology course, and student gender. The overall effect size within this data set was d= 0.0105. This analysis indicates a positive direction between the use of SI in an introductory biology course on overall student final grades and student gender. This plot analysis indicates clearly displays statistical significance between student gender and student final grade and SI supported introductory biology sections. The data indicates that use of SI in an introductory biology course, student final grade within the female student population showed an effect size of d= - 0.0103. This data indicates SI supported biology courses had little effect (or negative direction) on female student overall final grades. Male students enrolled in SI supported biology course, showed an increase in final grade outcomes. Male students enrolled in SI supported course, showed an increase (positive direction) in final grade outcomes (d=0.094). Note that the plotted means in Figure 4.7 indicated that female students enrolled in SI sponsored science course showed a slight decline in final grade means in the introductory biology course. While male students enrolled in SI supported introductory biology course, showed an increase in marginal means.

Research Question Eight

Are there differences between student academic performance (final grade) between genders? Is there an interaction between the Introductory Chemistry (CHE 111) SI/Non-SI supported sections and student gender demographics on academic performance (final grade)?

Female students enrolled in a Non-SI-supported Chemistry 111 section had mean final grades of 3.55, while males had final grades of 4.23. Female students enrolled in SI-supported Chemistry 111 sections had mean final grades of 3.86, while male students had final grades of 3.75. Figure 4.8 depicts the marginal means between female and male student demographics in SI and Non-SI-supported Chemistry 111 sections. Table 4.25 shows there are no significant differences between student gender and performance (F = 1.844) (p = .176). The data does not show a significant interaction between SI and Non-SI section grades and student gender in Chemistry 111 courses (F = 3.588) (p = .060). The Eta index of association indicated that only .9% of students' academic performance in Chemistry 111 can be predicted by gender.

Table 4.24: *SI/Non-SI, Student Gender, CHE111 Final Grade Mean Analysis.*

Variable/Stats	**n**	**M**	**SD**
Non-SI/Male	40	4.23	1.121
Non-SI/Female	49	3.55	1.646
Non-SI/Total	89	3.85	1.466
SI/Male	56	3.75	1.575
SI/Female	72	3.86	1.495
SI/Total	128	3.81	1.525
Total/Male	96	3.95	1.417
Total/Female	121	3.74	1.559
Total/Chemistry	217	3.83	1.498

Dependent variable: Grade

Table 4.25: *SI/Non-SI, Student Gender and Chemistry 111 Between-Subjects Analysis.*

Variable and Source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	.352	.158	.691	.001
Student Gender	1	4.106	1.844	.176	.009
SI/Non-SI Section* Student Gender	1	7.989	3.588	.060	.017
Error	213	2.226			

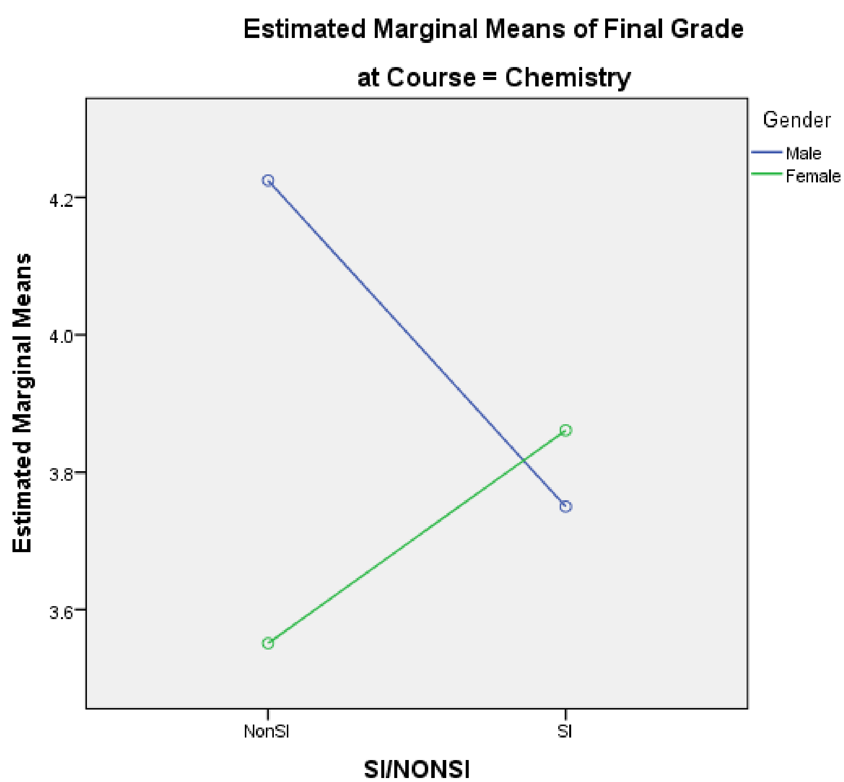

Figure 4.8: SI/Non-SI, student gender and Chemistry 111 marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in an introductory chemistry course, and student gender. The overall effect size within this data set was d= - 0.027. This analysis indicates a negative direction between the use of SI in an introductory chemistry course on overall student final grades and student gender. This plot analysis indicates clearly displays statistical significance between student gender and student final grade and SI supported introductory chemistry sections. The data indicates that use of SI in an introductory chemistry course, student final grade within the female student population showed an effect size of d= .197. This data indicates SI supported biology courses had an effect (positive direction) on female student overall final grades. Male students enrolled in SI supported biology course, showed a decrease in final grade outcomes. Male students enrolled in

SI supported chemistry course, showed a decrease (negative direction) in final grade outcomes (d= -0.351). Note that the plotted means in Figure 4.8 indicated that female students enrolled in SI sponsored chemistry course showed an increase in final grade means in the introductory chemistry course. While male students enrolled in SI supported introductory biology course, showed a decrease in marginal means.

Research Question Nine

Are there differences between student academic performance (final grade) between First-generation and non-First-generation students? Is there an interaction between the First-generation students and Not First-generation students?

The data showed that the overall number of first-generation students enrolled in introductory science courses was 412, while non-first-generation students' enrollment was 316. In SI supported sections, first-generation students had a mean grade average above 3.0 and non-first-generation students had mean grade average above 3.60. In non-SI supported science sections, first-generation students had a final grade mean above 3.0; while, non-first-generation averaged above 3.50. Figure 4.10 depicts the marginal means between first-generation student demographics in SI and non-SI supported sections. Table 4.27 showed there was not a significant difference between SI/non-SI science supported sections (F = 4.907) (p = .027). The data analysis showed there was a significant difference between grades of first-generation students and those who were not (F = 9.522) (p = .001). However, there was not a significant interaction between SI and non-SI section grades and first-generation/non-first-generation (p = .496). The square of the means was also not significant (F = .701) (p = .496). The Eta index of association (Table 4.27) indicated that 1.1% of a students' academic performance in Biology 111 can be predicted by the students' first-generation status.

Table 4.26: *Mean Analysis SI/Non-SI First-generation Student status.*

Variables/Statistics	n	Mean	Std. Deviation
Non-SI First Generation	293	2.76	1.765
Non-SI Non-First Generation	213	3.51	1.695
Non-SI Unknown	83	2.84	1.825
SI First Generation	119	3.11	1.921
SI Non-First Generation	103	3.60	1.921
SI Unknown	48	3.35	1.720
Total First Generation	412	2.86	1.816
Total Non-First Generation	316	3.54	1.781
Total Unknown	131	3.03	1.797
Total	859	3.14	1.806

Table 4.27: *SI/NonSI First-generation Between Subject Analysis.*

Variable/Statistical Analysis	df	Mean Square	F	Sig.
SI/NONSI	1	15.505	4.907	.027
First-generation/Non-first-generation Status	2	30.086	9.522	.001
SI/NONSI* First-generation/Non-first-generation Status	2	2.216	.701	.496
Error	853	3.160		

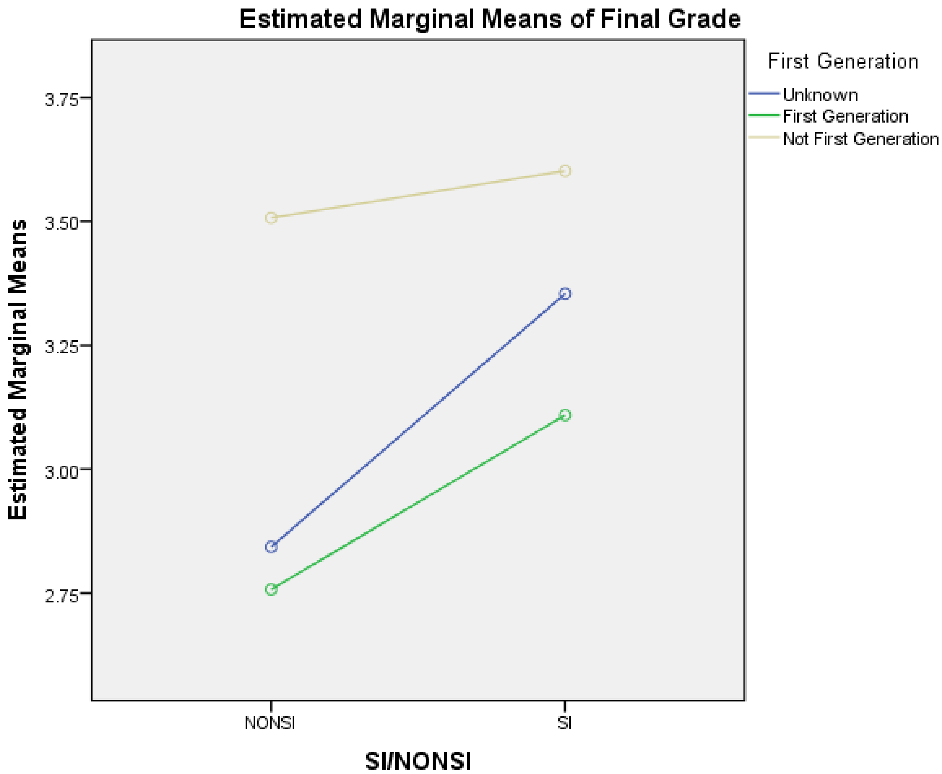

Figure 4.9: SI/non-SI first-generation marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in introductory science courses, and first-generation student status. This analysis indicates a positive direction between the use of SI in an introductory science course on overall student final grades and student first generation status. The data indicates that use of SI in an introductory science course, student final grade within the first generation student population showed an effect size of d= 0.1897. This data indicates SI supported science courses had an effect (positive direction) on First Generation student overall final grades. Non First Generation students enrolled in SI supported biology course, showed an increase in final grade outcomes. Non first Generation students enrolled in SI supported science course, showed an increase (positive direction) in final grade outcomes (d= 0.0496).

Research Question Ten

Are there differences between student academic performance (final grade) between first-generation and non-first-generation students? Is there an interaction between the Introductory

Biology (BIO 111) SI/Non-SI supported sections and first-generation demographic on academic performance (final grade)?

First-generation students in non-SI-supported Biology 111 had a final grade mean of 2.64; non-first-generation students had a mean of 3.37. SI supported Biology 111 sections; first-generation students in SI-supported Biology 111 had a final grade mean of 2.72; non-first-generation averaged 3.02. Figure 4.10 depicts the marginal means between first-generation student demographics in SI and non-SI supported Biology 111 sections. Table 4.29 showed there was not a significant difference between SI/non-SI Biology science supported sections (F = .349) (p = .555). The data analysis showed there was a significant difference between grades of first-generation students and those who were not (F = 3.614) (p = .027). However, there was not a significant interaction between SI and non-SI section grades, first-generation status and BIO 111 courses (p = .171). The square of the means was also not significant (F = 1.771) (p = .171). The Eta index of association (Table 4.29) indicated that only 1.1% of a students' academic performance in Biology 111 can be predicted by the students' first-generation status.

Table 4.28: *SI/Non-SI, First-generation and BIO111 Final Grade Mean Analysis.*

Variable/Stats	n	M	SD
Non-SI/First-generation	261	2.64	1.771
Non-SI/Not First-generation	171	3.37	1.739
Non-SI/Unknown	68	2.66	1.801
Non-SI/Total	500	2.90	1.794
SI/First-generation	71	2.72	2.051
SI/Not First-generation	46	3.02	2.005
SI/Unknown	25	3.28	1.882
SI/Total	142	2.92	2.005
Total/First-generation	332	2.66	1.832
Total/Not First-generation	217	3.30	1.800

Total/Unknown	93	2.83	1.832
Total	642	2.90	1.841

Dependent variable: Grade

Table 4.29: *SI/Non-SI, Student First-generation status and Biology 111 Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	1.156	.349	.555	.001
First-generation/Non-First-generation	2	11.976	3.614	.027	.011
SI/Non-SI Section* First-generation/Non-First-generation	2	5.869	1.771	.171	.006
Error	636	3.314			

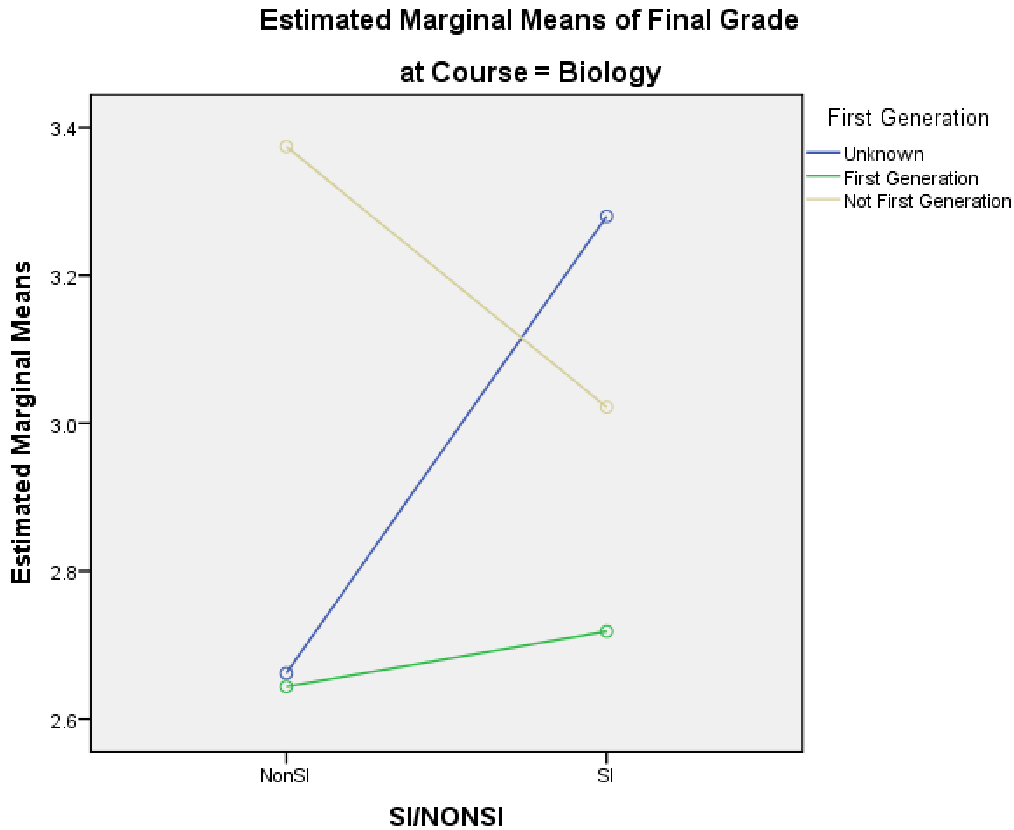

Figure 4.10: SI/Non-SI, first-generation status and Biology 111 marginal means of grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in introductory biology courses, and First Generation student status. The overall effect size within this data set was d= 0.0105. This analysis indicates a positive direction between the use of SI in an introductory biology course on overall student final grades and student first generation status. The data indicates that use of SI in an introductory biology course, student final grade within the first generation student population showed an effect size of d= 0.0417. This data indicates SI supported biology courses had an effect (positive direction) on First Generation student overall final grades. Non First Generation students enrolled in SI supported biology course, showed a decrease in final grade outcomes. Non first generation students enrolled in SI supported chemistry course, showed a decrease (negative direction) in final grade outcomes (d= -0.186). Note that the plotted means in Figure 4.10 indicated that First Generation students enrolled in SI sponsored biology course showed an increase in final grade means in the introductory biology course. While Non First generation students enrolled in SI supported introductory biology course, showed a decrease in marginal means. This plot analysis indicates that there is not a statistical significance between student first generation status and student final grade in SI supported introductory biology sections.

Research Question Eleven

Are there differences between students' academic performance (final grade) between first-generation and non-first-generation students? Is there an interaction between the Introductory Chemistry (CHE 111) SI/non-SI supported sections and students' first-generation status?

First-generation students had a final grade mean in non-SI-supported Chemistry 111 sections of 3.69, while those who were not first-generation had a 4.05. In SI-supported Chemistry 111 sections, first-generation students had a final grade mean of 3.69, and students who were not considered first-generation had a 4.07. Figure 4.12 depicts the marginal means between first-generation student demographics in SI and Non-SI supported Chemistry 111 sections. Table 4.31 shows there was not a significant difference between first-generation status and grade (F = 2.105) (p = .127). No significant interaction was also found between SI and non-SI section grades, first-generation status and CHE 111 courses (F = .101) (p = .904). The Eta index of association (Table 4.31) indicates that 2% of students' academic performance in Chemistry 111 can be predicted by first-generation status.

Table 4.30: *SI/Non-SI, First-Generation and CHE111 Final Grade Mean Analysis.*

Variable/Stats	**n**	**M**	**SD**
Non-SI/First-generation	32	3.69	1.424
Non-SI/Not First-generation	42	4.05	1.396
Non-SI/Unknown	15	3.67	1.759
Non-SI/Total	89	3.85	1.466
SI/First-generation	48	3.69	1.560
SI/Not First-generation	57	4.07	1.462
SI/Unknown	23	3.43	1.562

SI/Total	128	3.81	1.525
Total/First-generation	80	3.69	1.498
Total/Not First-generation	99	4.06	1.427
Total/Unknown	38	3.53	1.623
Total	217	3.83	1.498

Dependent variable: Grade

Table 4.31: *SI/Non-SI, Student First-Generation Status and Chemistry 111 Between-Subjects Analysis.*

Variable and source	df	MS	F	Sig	Partial Eta Squared
SI / Non-SI Sections	1	.215	.096	.757	.001
First-generation/Non-first-generation	2	4.727	2.105	.124	.020
SI/Non-SI Section* First-generation/Non-first-generation	2	.227	.101	.904	.001
Error	211	2.245			

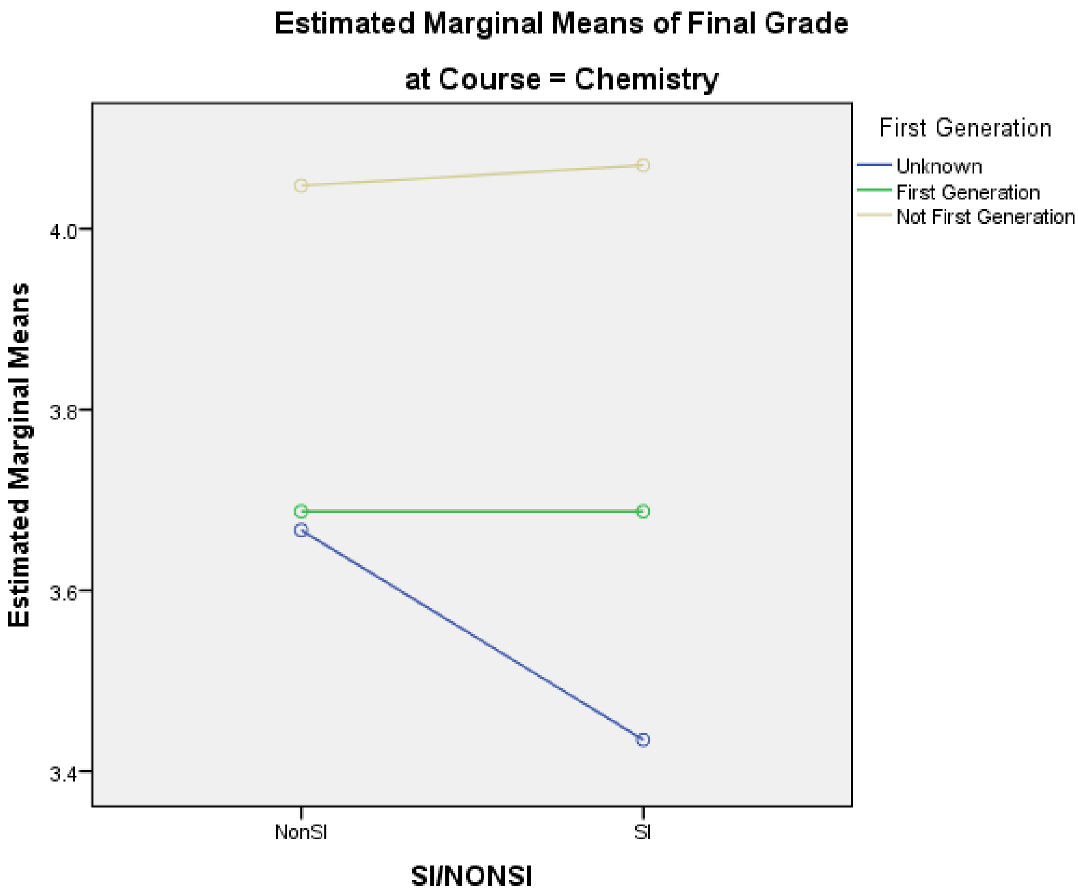

Figure 4.11: SI/Non-SI, first-generation status and Chemistry 111 marginal means grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in introductory biology courses, and First Generation student status. The overall effect size within this data set was d= - 0.0267. This analysis indicates a negative direction between the use of SI in an introductory chemistry course on overall student final grades and student first generation status. The data indicates that use of SI in an introductory chemistry course, student final grade within the first generation student population showed an effect size of d= 0.00 . This data indicates SI supported biology courses had no effect (positive or negative direction) on First Generation student overall final grades. Non First Generation students enrolled in SI supported chemistry course, showed an increase in final grade outcomes. Non first generation students enrolled in SI supported chemistry course, showed an increase (positive direction) in final grade outcomes (d= 0.0139). Note that the plotted means in Figure 4.11 indicated that First Generation students enrolled in SI sponsored chemistry course showed no increase in final grade means in the introductory chemistry course. While Non First generation students enrolled in SI supported introductory chemistry course, showed an increase in marginal means. This plot analysis indicates that there is not a statistical significance between student first generation status and student final grade in SI supported introductory chemistry sections.

Multiple Regression Analysis

Multiple regression analysis predicts values of the dependent variable, on one or more independent variables, in order to determine an equation to identify the relationship between the two variables (Morgan et al., 2007). The dependent variable in this study (final grade) and the independent variables (SI/non-SI, student gender, first-generation, and BIO/CHEM Courses) were used to establish relationships or associations between the dependent and independent variable sets.

Research Question Twelve

How well does the combination of SI/Non-SI support, gender, and first-generation status predict student academic performance in CCD Science Courses?

A Multiple regression analysis was used to understand the association between the dependent variable final grade and a combination of Independent Variables; Gender, SI/non-SI supported science sections, science course selections (Biology or Chemistry) and first-generation status. The simultaneous multiple regression analysis was conducted in order to understand the best predictors of final grade. Dummy variable protocol was used to gain a clearer understanding of how SI affected student success in introductory science courses. Table 4.32 outlines the standard deviation analysis of the means. The intercorrelation analysis (Table 4.33) found that the combination of variables analyzed showed a significance level of correlations with final grade (F (4, 859) = 15.38; $p < .001$). The beta coefficients (Table 4.31) showed that gender (p = .002), first-generation status (p = .001) and science course selection, Chemistry (p = .000), significantly predicted final grade outcome. The adjusted R-squared value, Table 4.33, was .063 or 6.3% of the variance in final grade. According to Cohen (1998), this is a moderate effect (Morgan et al., 2007).

Table 4.32: *Multiple Regression Mean Analysis.*

	Mean	Std. Deviation	N
Grade	3.14	1.806	859
SI/Non-SI	1.31	.465	859
Gender	1.70	.458	859
First-Gen	1.22	.689	859
BIO/CHEM	1.25	.435	859

Table 4.33: *Dependent Variable, Final Grade, Independent Variables, SI/Non-SI, Gender, First-Generation Status and Science Course Correlation Analysis.*

		Grade	SI/NonSI	Gender	First-generation	BIO/CHEM
	Grade	1.000	.077	-.096	.132	.224
	SI/Non-SI	.077	1.000	-.045	-.011	.345
Pearson Correlation	Gender	-.096	-.045	1.000	-.039	-.182
	First-generation	.132	-.011	-.039	1.000	.056
	BIO/CHEM	.224	.345	-.182	.056	1.000
	Grade	.	.012	.002	.000	.000
	SI/Non-SI	**.012**	.	.094	.369	.000
Sig. (1-tailed)	Gender	**.002**	.094	.	.125	.000
	First-generation	**.000**	.369	.125	.	.052
	BIO/CHEM	**.000**	.000	.000	.052	.

Table 4.34: *Multiple Regression Model Summary Analysis.*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	**.259**[a]	.067	**.063**	1.748

a. Predictors: (Constant), BIO/CHEM, First-generation, Gender, SI/NonSI

b. Dependent Variable: Grade

Table 4.35: *Multiple Regression ANOVA Analysis.*

Model	Sum of Squares	df	Mean Square	F	Sig.
a. Dependent Variable: Grade					
Regression	**188.141**	**4**	**47.035**	**15.389**	**.000[b]**
Res	2610.194	854	3.056		
Total	2798.335	858			

b. Predictors: (Constant), BIO/CHEM, First-generation, Gender, SI/NonSI

Table 4.36: *Multiple Regression Coefficients.*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.150	.343		6.276	.000
Gender	-.222	.133	**-.056**	**-1.671**	**.095**
First-generation	.172	.050	**.115**	**3.463**	**.001**
BIO/CHE	.867	.149	**.209**	**5.828**	**.000**
SI/NONSI	.007	.137	.002	.054	.957

Qualitative Analysis

The SI program involves a number of principle members, including the academic administrator, department faculty, SI director and the SI Student Leaders (SISL). The SISL, along with the faculty, have the most contact with the students. They can not only shape how the introductory student feels about the subject, but become a peer mentor to struggling introductory science students.

SISLs for the sections studied were asked to complete an open-ended SI reflective document that highlighted their thoughts about participating in the CCD/MSUD SI program.

Although the number of SISL responses was not a large as the Lockie and Van Lanen (2008) study, important insights into SISLs' experiences can still be explored. The qualitative data outlined below was gained from an end of the semester SISL reflection document.

What are the Supplemental Instruction Student Leaders (SISLs) overall impressions of Supplemental Instruction, and has it changed the way they view education in general and Science education specifically?

Theme 1: The Diversity of Student Learning Needs

The SI Student Leaders who participated in this academic enhancement program had a very different academic profile than the community college students. This type of educational division could lead to some misunderstandings regarding students' learning needs. The SISLs' reflective documents noted the educational divide. One of the SISL's reflective statements on student educational diversity were:

> The SI program changes the way SI leaders think. All of the leaders are good students who catch on to biological concepts quickly. Most of the SI students attending SI sessions do not, and as a leader you must be prepared to explain concepts several different ways, more than once, and in a different way than you learned.

Another SISL response noted the importance of creating students who developed a love of learning, "Our aim as an SISL was to develop lifelong learners. Students were encouraged to test their knowledge, reflect on their misunderstandings, study methods and make adjustments."

The joy participating in the SI program and educating science students was a major theme in most of the SI reflective documents. Three examples were:

> I really like the ideas and principles behind the SI Leadership program. I really like the group study aspect of learning; and as a senior student, I enjoy helping the younger students.

> Students are not just vessels waiting to be filled, but are active participants in the learning process.
>
> The purpose of education is to get students interested, enjoy the process and at the end of the day think critically, not just memorize facts.

Theme 2: Enriching Academic Experiences

Another common theme throughout the SISLs' reflective papers was the SISLs' increased understanding of the material, and the ability to communicate science concepts with the community college students**.** For example, one SISL noted in her SI Reflective Document:

> Relearning basic concepts connecting the dots. Cellular Respiration and Photosynthesis difficult concepts to learn, but by participating in the SI program, I was able to "connect the dots" and I understand these basic principles of cell function.

Theme 3: Enriching Intrapersonal Experiences

Most of the SISLs found great satisfaction in the area of intrapersonal experiences. One SISL commented on her future in academia, "Grateful and found my future life work as a professor." Another SISL found that it allowed for thinking about science on a different level, "This program teaches the SI Leader how to teach, engage students, and flexibility." The same SISL found that being part of the program was an important part of any undergraduate educational experience, "Being part of the SI was an incredible experience for any undergraduate student who wants to go to graduate school."

Another SISL found the responsibility of being a SI leader challenging, "Working as an SI Leader was challenging, but rewarding. Challenges ranged from SI room assignments, session planning, to keeping students focused and organized." The SISL added:

> Despite the challenges, the students made it all worthwhile. They gave me a lot of feedback and were supportive of me throughout the entire process. I find what I'm doing helps them and I feel a delight that can only be experienced through teaching.

A different SISL, who participated in the program for two years, discussed how the program gave greater perspective in teaching methodologies:

> Developed invaluable educational skills, such as developing educational worksheets, practice quizzes and exams, but also provided an opportunity to mature my methodology as an instructor. SI grew within me an educator, one with a strong epistemology and teaching methodology and for this I'm forever grateful.

The same student leader went on to explain the importance of how participating in the program led them to a richer understanding of student learning, and even allowed them to develop a teaching philosophy:

> My job was to guide students through Vygotsky's zone of proximal development. Students left this course with a mastery of the subject, stronger study skills and greater control of their own development. With collaborative learning - problem solving, students were able to work with others and develop their critical thinking skills.

Another SISL commented on the various pedagogy techniques discussed in the weekly SISL meetings:

> During the weekly SI meetings, SISLEADERS discussed student centered instruction techniques, scaffolding techniques using Bloom taxonomy, and student meta cognition (i.e. thinking about thinking).SI taught me to respect students and share my love of the sciences

Theme 4: Relationship with Faculty

The relationship between the SISL and the faculty could be an important faculty/student mentorship opportunity. Among all of the SISLs' reflective documents, not one of the SISLs commented on their interaction(s) with the CCD Science faculty, which may indicate a lack of interaction between two key principle SI collaborators, the faculty and SISL.

The SISLs felt they gained greater insight to student learning, leadership skills, as well as knowledge on discipline.

CHAPTER FIVE: DISCUSSION

The purpose of this study was to focus on how Supplemental Instruction (SI), a form of peer learning, contributed to students' academic success in an introductory science course at a community college. The research examined the use of SI on the dependent variable, students' final grades. The research also explored demographic variables regarding the use of SI and its impact on students' overall final grade: male/female (gender), White Non-Hispanic, Black Non-Hispanic, and Hispanic (ethnicity), and first-generation status. The research also examined the use of SI in community college introductory biology and chemistry science courses and its impact on final grades. In order to explore this relationship between SI and its effect on students' overall grades, the research used difference inferential statistics to understand the relationship (interaction) of SI on the various independent groups.

This research first examined the student population demographics by examining several descriptive questions that gave a statistical snapshot of CCD's science student population. The next set of research questions asked a series of difference questions, which gave insight into how SI impacted each attributive independent group (Table 5.1). This research also evaluated how SI impacts the SI Student Leaders. This qualitative measure examined the common pedagogical themes associated with SI. The final research question examined how the qualitative and quantitative data streams formulate recommendations for the use of SI in community college introductory science courses.

Table 5.1: *Research Question Summary.*

Questions	Statistically Significant	Statistical Interaction
Q. 1 Are there differences between student academic performance (final grade) in SI and Non-SI supported sections?	Yes	Yes
Q.2 Are there differences between student academic performance (final grade) in SI and Non-SI supported sections?	Yes	
Are there differences between student academic performance (final grade) in Fall and Spring academic semesters?	No	
Is there an interaction of SI and Non-SI sections and Fall and Spring academic semesters on student academic performance (final grade)?		No
Q. 3 Are there differences between student academic performance (final grade) in SI and Non-SI-supported sections?	No	
Are there differences between student academic performance (final grade) in Introductory Biology and Chemistry courses?	Yes	
Is there an interaction of SI/Non-SI-supported sections and Introductory Biology and Chemistry courses on student academic performance (final grade)?		Yes
Q.4 Are there differences between student academic performance (final grade) and student ethnic demographics (White Non-Hispanic, Black Non-Hispanic and Hispanic)?	Yes	
Is there an interaction between the SI/Non-SI supported sections and student ethnic demographics on student academic performance (final grades)?		Yes
Q. 5 Are there differences between student academic performance (final grade) and student ethnic demographics (White Non-Hispanic, Black Non-Hispanic and Hispanic)?	Yes	
Is there an interaction between the Introductory Biology (BIO111) SI/Non-SI supported sections and student ethnic demographics on student academic performance (final grade)?		Yes

Q. 6 Are there differences between student academic performance (final grade) in Introductory Chemistry (CHE 111) SI and Non-SI supported sections?	No	
Are there differences between student academic performance (final grade) and student ethnic demographic (White Non-Hispanic, Black Non-Hispanic, and Hispanic)?	Yes	
Is there an interaction between the Introductory Chemistry (CHE111) SI/Non-SI supported sections and student ethnic demographics on academic performance (final grade)?		No
Q.7 Are there differences between student academic performance (final grade) in Introductory Biology (BIO 111) SI and Non-SI supported sections?	No	
Are there differences between student academic performances (final grade) between genders in BIO 111? Is there an interaction between the Introductory Biology (BIO 111) SI/Non-SI supported sections and student gender demographics?		No
Q. 8 Are there differences between student academic performance (final grade) in Introductory Chemistry (CHE 111) SI and Non-SI supported sections?	No	
Are there differences between student academic performances (final grade) between genders?	No	
Is there an interaction between the Introductory Chemistry (CHE 111) SI/Non-SI supported sections and student gender demographics on academic performance (final grade)?		No
Q.9 Are there differences between student academic performance (final grade) in SI and Non-SI supported sections?	No	
Are there differences between student academic performance (final grade) between First-generation and non-First-generation students?	Yes	
Is there an interaction between the First-generation students and Not First-generation students?		Yes
Q.10 Are there differences between student academic performance (final grade) in Introductory Biology (BIO	No	

111) SI and Non-SI supported sections?		
Are there differences between student academic performance (final grade) between First-generation and non-First-generation students?	Yes	No
Is there an interaction between the Introductory Biology (BIO 111) SI/Non-SI supported sections and First-generation demographic on academic performance (final grade)?		
Q. 11 Are there differences between student academic performance (final grade) in Introductory Chemistry (CHE 111)	No	
Are there differences between students' academic performance (final grade) between First-generation and non-First-generation students?	No	
Is there an interaction between the Introductory Chemistry (CHE 111) SI/Non-SI supported sections and students' First-generation status?		No

Supplemental Instruction Data Analysis and Research Recommendations

This section provides an analysis of the data organized by research question and also gives recommendations for possible future research.

Question 1: SI/Non-SI

The research found that overall student grades in the SI sections were 3.34 and 3.04 in Non-SI supported sections. Further statistical analysis showed that, overall, SI did have a significant difference in student overall grade outcome. This research analyzed the statistical interaction between SI and Non-SI supported sections, and found that there was a significance ($p = .024$). The literature outlines the SI program as a voluntary, non-remedial and non-threating, program (Arendale, 2002). These qualities are all important characteristics for the SI program, however, in order to gain a greater statistical significance and reach more community college science students, perhaps faculty could require students to attend a number of sessions early in the semester to monitor student participation, student retention and increased academic success. Timing may be the key to the success of SI, in an article by Peters, the idea of starting SI sessions as soon as the semester in order to gain a handle on the information, as well as outlining student study skills needed to be successful in the course (1987).

Question 2: Fall and Spring semesters

This research evaluated the SI delivery for both academic semesters, Fall 2010 and Spring 2011. The research showed no statistical significance between the two academic semesters and no statistical interaction between academic semesters, SI/Non-SI and student final grades.

Question 3: Introductory Science courses (Biology and Chemistry)

The research has shown that SI is an effective academic intervention tool for high-risk courses, such as biology and chemistry (Arendale, 2002). This study showed a statistical significance between the two courses ($p = .001$). The student grades between the two course offerings were significantly different. The research showed that final grades given in the Biology courses were significantly lower than that of Chemistry courses. Perhaps the data is highlighting a missing component in the STEM education. Most scientific endeavors require science processes such as data interpretation, data analysis and problem solving (Coil, 2010). According to Coil, these foundational scientific skill sets should be fostered early on in a students' education career (2010). This statistical difference between the two courses may be due to a number of factors, such as: faculty academic freedom, student demographics or student STEM education background. In order to understand how these external measures (both faculty and students measures) impacts the delivery of SI, continued monitoring of SI is necessary.

Questions 4, 5, & 6: Student Ethnicity

The literature states that the term Science, Technology, Engineering and Math (STEM), had its origin in the 1990s at the National Science Foundation (NSF), and has been used as a generic label for any event, policy, program or practice that pertains to one or several STEM disciplines (Bybee, 2006). Clarifying STEM literacy and establishing this as a fundamental purpose of school programs is a first step in advancing STEM education (Bybee, 2006). The literature indicates that minority students, with the exception of Asians, are severely underrepresented in the STEM fields at the national level in the United States (Slovacek et al., 2011). The research study by Slovacek et al. (2011) related to SI on minority performance in STEM courses and found that over a six-year period, minority students that participated in STEM SI programs were more likely to pass the corresponding course as opposed to students who did not participate in the academic enrichment program.

This research found a statistically significant ($p = .002$) difference in ethnicity demographics of White Non-Hispanic, Black Non-Hispanic and Hispanic science students and student overall grades in science courses. This statistical finding is consistent with the literature. This research examined the student final grade performance, the use of SI-supported science sections, and student ethnicity. Specifically, this research found a significant interaction between the use of SI and academic performance of Black Non-Hispanic students ($p = .031$). The research found a significant difference between student performance in Biology ($p = .011$), and a significant interaction between the use of SI in Biology and student ethnicity ($p = .001$).

The data revealed in this research is consistent with the literature which indicates that the proper use of SI in STEM focused courses, can lead to an increase in academic performance of URMs (Slovacek et al., 2011). There was also a significant difference between White Non-

Hispanic students and Black Non-Hispanic and Hispanic students, which is consistent with the STEM education literature.

This research does not show a significant difference between SI-supported sections and non–SI-supported sections in Introductory Chemistry courses ($p = .575$). This may be due to the limited SI sections available. However, this research found that there is a significant difference between student ethnicity and final grade ($p = .002$), which again aligns with the literature regarding URMs and academic success in STEM science courses (Slovacek et al., 2011). The interaction between SI and Non-SI supported Introductory Chemistry sections, and student ethnicity was not significant ($p = .477$) in this analysis. One way to address the issue of STEM gap between ethnic groups at the community college level would be to adopt some of the major intervention strategies used by some four-year universities. These intervention strategies, outlined by Tusi (2007) include: STEM summer bridge programs, STEM focused mentoring programs, research experiences, extensive tutoring opportunities for URM STEM students, career counseling and awareness, STEM focused learning centers as well as STEM workshops and quality STEM academic advising. Tusi's research included an extensive literature review that indicated these academic enhancement programs positively supported URM student achievement in STEM fields (2007).

While STEM academic advising has been in place at the Community College of Denver, the other proposed academic enhancements, and interventions could be adopted at the community college level, but in order for the measures to be of value, a strong STEM focus should be emphasized.

Questions 7, 8, and 9: Gender

This research showed that student academic performance (final grade) had no statistical significance for gender in either biology or chemistry courses. This research data aligns with an Assessing Women and Men in Engineering (AWE) study that found female students tend to perform better on areas of standardized science assessment that addresses the human application of science, such as the life sciences (2009). Female students have demonstrated that they are just as capable as their male counterparts of comprehending science concepts and knowledge (Ingels & Dalton, 2008). In the realm of higher education, more women than men pursue a post-secondary degree in the U.S.; however, fewer females pursue an undergraduate degree in science and therefore do not enter into science, technology, engineering, and math (STEM) related careers at the same rate as males.

The literature also states that while the educational gender gap within STEM education is disappearing, upon further analysis of the academic gender gap with STEM showed that this decrease was dependent on area of study, level of student education and career attainment (Britner, 2008). The reviewed literature clearly states that persistence in a science major in college has a direct correlation to science and mathematics in high school (Oakes, 1990). Perhaps STEM initiatives similar to the ones outlined for URM STEM success should be reviewed for women who would like to enter into the STEM field at the community college level. As the literature stated, women are making inroads in the areas of life sciences, biology and chemistry, however, they are not entering into the other avenues of STEM education, engineering and physics for example (Britner, 2008). In order to engage the interests of female STEM students, it is important to have STEM support systems, such as the ones listed above, in place for women to feel welcomed in this highly dominated male field of study. This further strengthens the importance for community colleges to understand their students' demographics, not only ethnicity and gender, but also high school academic success in STEM field courses.

Questions 10 and 11: First-generation Status

The study examined the difference between first-generation students' final overall academic performance in SI/non-SI science sections. The data showed a significant difference between SI/non-SI science sections (.027) and between first/non-first-generation students ($p = .001$). This data aligns with the current literature stating that students who have family member(s) who have experience in the world of higher education (non-first-generation students) have a tendency to differ from their first-generation peers in both characteristics and experience in college (Terenzini, 1996). However, the interaction between SI/non-SI sections and first-generation status was not significant; this could be due to the number of SI sections available during the year. This research examined the difference between academic performance for the two science courses examined, and found that first/non-first-generation students had a significant difference in Biology course grades and no significant difference between academic performances in Chemistry. The interaction between SI and the college courses (Biology and Chemistry) showed no significant interaction in this group.

Research Question 12: Multiple Regression Analysis

A multiple regression analysis was used in order to understand the association between the dependent variable final grade and a combination of independent variables: Gender, SI/non-SI supported science sections, science course selections (Biology or Chemistry) and first-generation status. In Van Harlingen's research, a multiple regression analysis was performed in order to compare pre-test performance to physics achievement. In that research, the numbers for the entire group reflected a 31 percent variance in physics achievement was explained by:

trigonometry and geometry knowledge, SAT scores, logic questions, spatial visualization, and rotation. The group was then separated by gender and it was found that, for women only, trigonometry/geometry and high school SAT scores had significant beta weights (multiple regression analysis showed $R(2) = .27$). When GPA was added to the women's group, the $R(2)$ values rose to 0.44. That research showed the Adjusted R value (multiple correlation coefficient) was .27, meaning that 27% of the variance in math achievement could be predicted from a combination of trigonometry/geometry and high school SAT scores. However, when adding in GPA to the combination, the value rose to .44 or 44% of math achievement that was predictable. In this research, past academic history was not a factor, however. This research found that the intercorrelation analysis showed that the combination of variables analyzed had a significant level of correlations with final grade ($F(4, 859) = 15.38$; $p < .001$). The p value interactions showed that gender ($p = .002$), first-generation status ($p = .001$) and science course selection, Chemistry ($p = .000$), significantly predicted final grade outcome. The adjusted R-squared value was .063 or 6.3% of the variance in final grade. The beta coefficients analysis showed that gender had a significant negative weight, while the other variables tested showed positive regression weights.

Student Supplemental Instruction Student Leaders (SISLs)

A research analysis by Lockie and Van Lanen (2008) focused on the impact of the SI experience on SI student leaders (SISLs). The researchers' qualitative analysis utilized Colaizzi's (1978) phenomenological approach to assess the SISLs' experience in SI. Lockie and Van Landen asked 44 SISLs to write out their experiences and reactions while participating in the SI program. The researchers found four basic themes, with associated sub themes, to the students' experience in SI. Their four themes were: (1) diversity of student learning needs, (2) enriching academic experiences, (3) enriching interpersonal experiences, and (4) relationship with faculty (p. 2).

This research examined how Supplemental Instructors impacted the SISLs, and found that similar important themes were found in the reflective documents. SISLs are extremely important stakeholders in the process of running a successful SI program and the examination of SISLs' interaction with the students and the faculty were important to gain a holistic analysis of a properly run SI program.

Research Limitations

This research examined a small population of students in order to fully understand how SI impacts student success in community college introductory science courses. An important research limitation that affected the full comprehension of how this program impacts the academic success of students was the high number of student demographic unknowns or other variables. In the student ethnicity and first-generation analysis, high rates of student unknowns or other variables impacted the full understanding of how SI impacts all groups of students (Tables 5.2 and 5.3). These two student variables (unknown and others) were retained for analysis due to the high numbers of unreported student demographic information. It is important for community college leaders to fully understand their students' demographics in order to develop curriculum strategies to best meet the needs of all student populations.

Another research analysis regarding aligning student demographics and creating curriculum strategies had an opposite view point. The study interviewed community college faculty who stressed in interviews that they did not place an emphasis specifically on developing strategies to enhance engagement with students of any particular racial or ethnic group. Rather, they placed attention on engaging all students (Harris, 2009). However, in order to understand how students learn, community college leaders must gain insight into the student population that they serve. This could be gained by a collaborative effort between community college student services and academic leaders to create a comprehensive student intake document(s), which would better outline student demographic, academic, and motivational backgrounds. This could be used to understand the ever-changing community college student population. Another important student demographic not featured in this study is the STEM preparation in high school. As stated earlier, the literature outlines a direct correlation to exposure and academic success in high school to persistence in college-level STEM disciplines. A research study conducted by Cassel (1998) concluded that, although exposing students to biological science in elementary school is important, studies have shown that science and math concentration during the high school years has an important effect on interest in biological science in college.

Other studies have found that the more complex courses, technically speaking, and the courses that provide the greatest challenges fall in several categories. For example, mathematically-based courses like algebra, geometry and calculus may lead to success in engineering, while courses in biology may lead to success in medicine (Cassel, 1998). This program in its current form had some limitations, such as not knowing the numbers of science students who regularly attended SI sessions and how long they stayed at the session. Another limitation involved not knowing how attending these sessions positively motivated the student toward science education. In order to address these limitations, continued use of this academic intervention program would allow a clearer view on how to help all students understand the world of science. While understanding community college students' science preparation is important in order to craft an engaging curriculum for students, this data could also be used to understand the primary and secondary school system's science curriculum. This could lead to a clearer understanding of basic principles discussed in primary and secondary classes, but also how the teachers at this level engage the students to develop a respect and interest in the sciences.

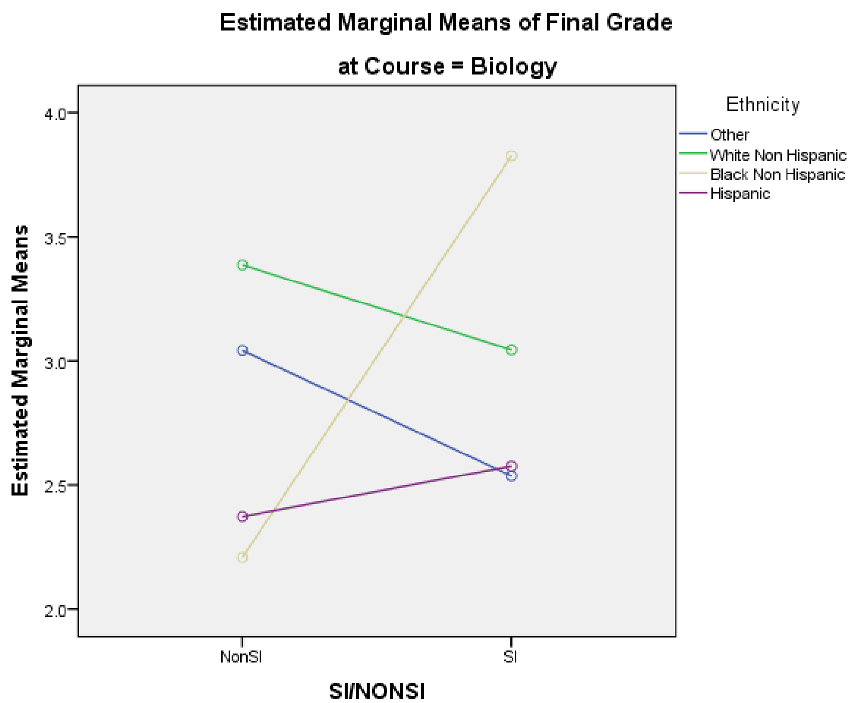

Figure 5.2: SI/NonSI, Student Ethnicity and Biology 111 Marginal Means of Grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in an introductory biology course, and student ethnicity. This analysis found that if factoring in the student population, Other, the effect size, d= -0.265 (negative direction). This data set states that the impact of SI in an introductory biology course as a negative effect on Other student population.

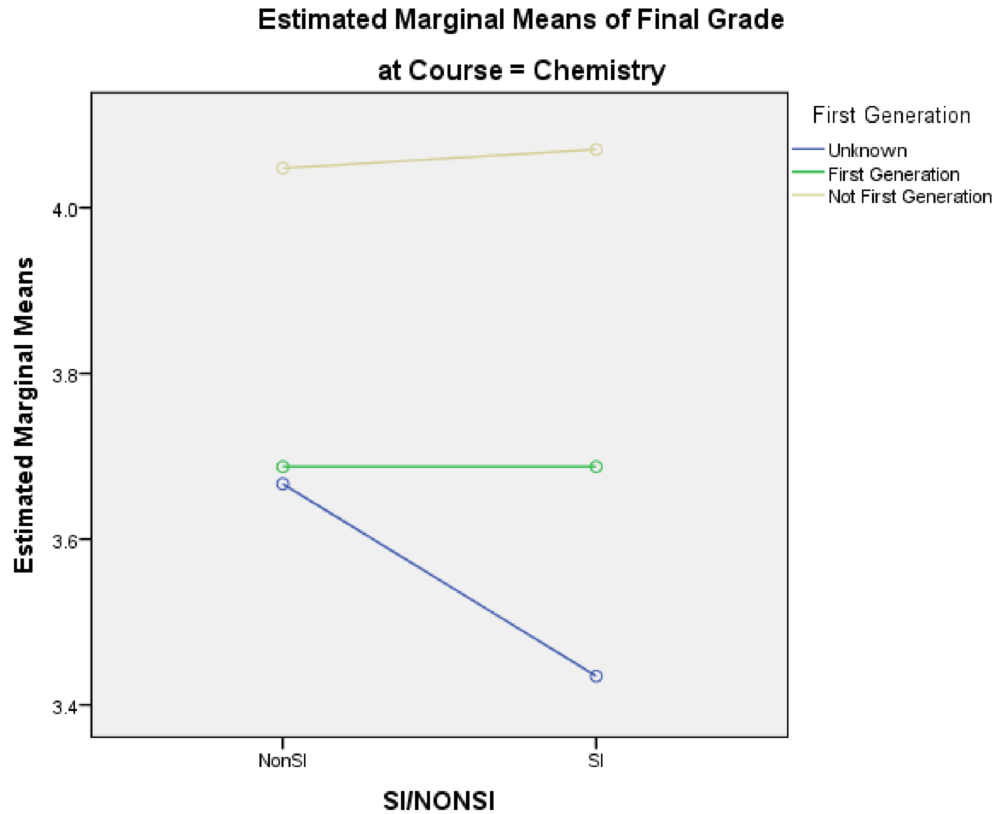

Figure 5.3: SI/Non-SI, first-generation status and Chemistry 111 marginal means grades. This Marginal Means plot analysis examined the impact of Supplemental Instruction (SI) on student grades in introductory biology courses, and First-generation student status. This analysis found that if factoring in the student population, Other, the effect size, d= -0.144 (negative direction). This data set states that the impact of SI in an introductory chemistry course as a negative effect on Unknown student population.

Personal Reflections

As stated earlier, the importance of science educators to allow students to gain a richer understanding of the world of science is imperative. This open exploration and understanding of science, in my opinion, creates informed attitudes regarding the nature of science. As educators attempt to recreate the classroom experience by using various pedagogical and curriculum techniques, it will allow students to gain a comprehensive appreciation of the nature of science and how it applies to their lives. In order for this type of transformational learning to occur, science educators must incorporate teaching methods that will excite and challenge all students.

I have a strong connection to the subject of creating a citizen of science. My professional career has taken me from the research lab, to the clinical lab, to the classroom. My experience as a graduate student teaching assistant helped me to understand that not all students grew up feeling a deep understanding and love for science. I had to change the way that I interpreted the subject, break it down to the necessary components, and rebuild it in a way that the students could then come away with an experience and understanding of the material that would last a lifetime. It was at that time in my career that I decided to pursue teaching at the college level so that I could bring my experiences from both research and clinical lab work to the classroom. I understand the importance of creating an open, engaging, accessible classroom environment, which allows students at all academic levels to ask questions, learn about the scientific process, and become citizens of science.

In order to create students who understand and appreciate the intellectual nuisances of science, educators must try new strategies to engage science students. I believe that Supplemental Instruction (SI) could be the educational key to students' academic success in traditionally difficult STEM courses. The SI structure is not a tutoring or remedial program, but an innovative and inspiring way to engage students to work together in group sessions with peer mentors. This type of academic intervention model allows students to understand course content and improve study skills and grades (Ramos, 2012). SI could help students pass gateway courses, which are traditionally difficult courses with high failing rates. The SI program helps to improve academic performance, increase retention and graduation rates in STEM majors and encourages students to pursue careers in STEM disciplines (Ramos, 2012).

Research Recommendations

As stated in an earlier section, research conducted by Tusi (2007), outlined several effective educational and intervention strategies to help four-year university STEM students. Tusi included: STEM summer bridge programs, STEM focused mentoring programs, research experiences, extensive tutoring opportunities for STEM students, career counseling and awareness, STEM focused learning centers as well as STEM workshops and quality STEM academic advising. Tusi's study focused on URM students; however, these programs could benefit all student demographics within the STEM fields.

With most community colleges operating on a limited budget, and a very focused workplace mission, it is important for community college STEM educators to get the message about the importance of developing interactive STEM activities, such as the ones outlined by Tusi, which have proven successful at four-year institutions. These programs will allow community college students to successfully transfer to four-year institutions with the academic confidence needed for success in the STEM field.

Another important recommendation stated in an earlier section was to create a more comprehensive student intake document. This would provide, not only community college student services leaders, but also academic leaders, with a clear understanding of the student population, academic background, demographics, and academic motivation.

Conclusions

SI provides an efficient and convenient opportunity for students to meet both academic as well as social agendas (Arendale & McLaren, 2000). The literature states that students who have not received a strong STEM background in a high school setting may not have the academic tools to successfully complete college science courses (Sadler & Ta, 1997). SI could be an important academic treatment for these students. This academic intervention method should not only be used for students who need academic support for traditionally difficult courses, but it could be used as a student's source to gain academic social support. Students with a strong social support system within the academic realm may enhance networking peer support. These strong academic and networking support systems, may give the student powerful academic and social capital needed to succeed in the ever-changing academic and workplace realm.

This research outlined how the implementation of SI increased student success (final grades) in community college introductory courses; however, the next research path should examine how SI increases the STEM student's social capital, which will give students the confidence to question important STEM concepts. The literature stated that during SI sessions, a student leader was chosen from the biology students participating in the sessions, this allowed for an open cooperative learning environment, which provides students with learning and study skills necessary for academic success (Shaya, Petty, & Petty, 1993). Maxwell (1998) examined how SI has been adapted in the community college setting as a learning community strategy for non-traditional students. The study found substantial evidence that within the community college realm, supplemental instruction can enable low-income students to independently interact with each other in their studies and coursework outside the classroom (Maxwell, 1998).

CCD's campus is a commuter campus, where students' primary focus may not be academics, but also external life issues. This type of academic and other externally focused environment is not uncommon for community colleges around the nation. With a clear understanding of this type of academic student demographic snapshot, it is then important for community college educators to supply other academic support systems that will help students feel a strong connection to not only the material, but to form a strong support system with peers and faculty. This type of support may allow introductory science students to ask questions, interact with students with similar interests and form a strong academic social capital, which will allow them to move forward with confidence. Further research should continue to understand and to create strong academic connections, which in turn could yield higher retention rates, but more importantly, a deeper understanding, and a stronger connection to the world of science for community college students.

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APPENDIX A: CCD – CHEMISTRY SYLLABUS

The Community College of Denver-
The Center for Arts & Sciences, Math & Science Department
South Classroom 306, (303) 556-2460, fax (303) 556-2174
General College Chemistry I – CHE 111

I. Course Information

Course Title: General College Chemistry I
Course Prefix, Number CHE 111
Credits: 5
Course Description: (This must be the description in Common Course Numbering & the CCD Catalog.) Focuses on basic chemistry and measurement, matter, chemical formulas, reactions and equations, stoichiometry and thermochemistry. This course covers the development of atomic theory culminating in the use of quantum numbers to determine electron configurations of atoms, and the relationship of electron configuration to chemical bond theory and molecular orbital theory. The course includes gases, liquids, and solids and problem-solving skills are emphasized through laboratory experiments.

Prerequisite(s)/Co-requisites:
Semester and Year:
Meeting Location, Times and Days:
Start Date: Check your class roster to be certain this is correct! End Date: Check your class roster to be certain this is correct!

II. Instructor Information

Name:
Voice Mail:
Fax:
e-mail:
Office Location:
Office Hours:

I. Required Course Materials

(List the books and other materials a student must purchase. Identify those that are optional.)

Course Outcomes/Competencies:

(Please list here all that are in the Course Curriculum Guide. Others may be added by individual instructors.)

Upon completion of this course, the student should demonstrate knowledge and/or skill in the following areas.

I. Apply scientific notation and significant figures in measurement and stoichiometric calculations. I,IV, V, VII
II. Apply atomic theory to the periodic table to explain various kinds of chemical principles and concept. II, III
III. Illustrate polarity, geometry, bond angle, hybridization, physical and chemical properties of different compounds using Lewis structures. III
IV. Interconvert masses, moles, numbers of particles, and volume. II
V. Interpret the computed outcome of a chemical calculation to determine its validity. I, II, IV, V, VII
VI. Connect real world applications to chemical models. II, III, IV, V, VI, VII
VII. Compare and contrast the basic bonding theories of valence shell electron pair repulsion theory, valence bond theory and molecular orbital theory, pointing out the strengths and weaknesses. III
VIII. Classify the basic types of chemical reactions and predict the projects for a given set of reactants. IV
IX. Conceptually and graphically illustrate the relationships of pressure, volume, mole quantity and temperature for a gas at ideal conditions. V
X. Predict the states of matter based on intermolecular forces of attraction. VI
XI. Apply the first law of thermodynamics to thermal systems. VII
XII. Identify strong and weak electrolytes. IV
XIII. Identify oxidation, reduction half reactions and oxidizing and reducing agents in a redox reaction. IV
XIV. Be able to name compounds from formula or write formula from names. II
XV. Read, analyze, and apply to new situations, written material related to the study of chemistry.
XVI. Write and speak clearly and logically in presentations and essays about topics related to chemistry.
XVII. Demonstrate the ability to select and apply contemporary forms of technology to solve problems or compile information in the study of chemistry.

CCD Critical Skills addressed in this course :

The critical skills addressed in this course are: reading, writing, computer literacy, speaking/listening, and
valuing diversity.

Reading 3 -- Analyze and synthesize the information as presented in the textbook
Writing 3 -- Define, explain, analyze and synthesize class and laboratory information
Math/Reasoning 3 -- Analyze chemical operations and reactions mathematically
Computer Literacy 2 -- Access and use course information on web-site and through online searches
Speaking/Listening 3 -- Demonstrate knowledge of chemistry through oral presentations
Explain, apply and analyze lecture material

Valuing Diversity 1 -- Explain different perspectives and theories in chemistry

IV. CCD Policies and Procedures

Student Code of Conduct and Academic Integrity Admission to the Community College of Denver implies that you agree to respect the rights of others and observe moral and civil laws. Interference with the normal processes of education in the classroom or elsewhere on the campus will be regarded as unacceptable conduct, warranting suspension or dismissal. Complete Student Code of Conduct is at this web site: http://ccd.rightchoice.org/Student_Life/COC.html.
Americans with Disabilities Act Students with a documented disability who need reasonable accommodations to achieve course objectives should notify the instructor and apply for services at the Center for Persons with Disabilities within the first week of classes. More information is available at http://ccd.rightchoice.org/EPAC/disabilities.html.

Grade of Incomplete
Incomplete: An "I" indicates that the course objectives are not yet fulfilled. It is the responsibility of the student to request, if needed, the assignment of an incomplete grade. The instructor's decision to authorize or not authorize an incomplete grade is final. The student must have completed 75% of the class with a C or better, and must complete the rest of the work with the same instructor. Arrangement for the completion of the course must be made with the instructor prior to the assignment of the "I" grade. This agreement must be written on a Contract for Incomplete Grde Form. The instructor may allow up to one full semester for the student to complete missing requirements. "I" grades not changed by the end of the following semester will automatically become failing grades (F).

V. Course Policies and Procedures

Attendance Policy (List clearly and concisely any attendance requirements for the course, and state that attendance will be taken daily.)
Grading Scale
(Adjust where necessary.) The grading scale most often used is:

A	90-100%	Superior mastery or achievement.
B	80-89%	Better than average mastery or achievement.
C	70-79%	Acceptable mastery or achievement.
D	60-69%	Less than acceptable mastery or achievement.
F	Below 60%	Fails to demonstrate achievement of course objectives.

Assignment Weight List
Exam Makeup List
Late Work List
Cheating/Plagiarism Plagiarism is grounds for failing an assignment or course and/or disciplinary action from CCD. DO NOT PLAGIARIZE. Plagiarism means copying passages directly from the text of study guide or any other source, without quotation marks and citations. Summarize or paraphrase the information. If you paraphrase by rearranging the order of a sentence or words, then give credit for the source. No credit will be given for plagiarized papers.

VI. Topic Outline/Calendar/Assignments: (Must include the Topical Outline from the Course Curriculum Guide. Additional material may be added by the individual instructor, who must include a calendar for the semester showing what students will be doing and what the assignments are, session by session.)

Date Topics/Assignments

I. Foundations of Chemistry

A. Measurements
B. Dimensional Analysis
C. Matter, Classification of Matter, Physical and Chemical Changes, Properties of Matter
D. Scientific Method

II. Atomic Theory and Structure

A. History of the Atom
B. The Modern Atomic Theory - Quantum Mechanics Approach
C. Electronic Configuration and Orbitals of Atoms
D. Periodic Table and Periodicity
E. Nomenclature of Inorganic Compounds

III. Chemical Bonding and Molecular Geometry

A. Types of Chemical Bonding
B. Periodic Table and Chemical Bonding
C. Polyatomic Ions
D. Octet rule, Exceptions to Octet Rule
E. Lewis Structure
F. VSEPR and Molecular Geometry
G. Molecular Geometry and Polarity

IV. Stoichiometry

A. Chemical Equations
B. Types of Chemical Reactions
C. Balancing Chemical Equations
D. The Mole
E. Stoichiometry and Limiting Reactants
F. Determination of Molecular and Empirical Formulas
G. Solution Calculations
H. Concentrations of Solutions
I. Solution Stoichiometry

V. Gases

A. Description of Gas State
B. Kinetic Molecular Theory
C. Gas Laws
D. Gas Stoichiometry

VI. Condensed States (Intermolecular Forces)

A. Description of Liquid State
B. Description of Solid State
C. Intermolecular Forces
D. The Phase Diagram

E. Vapor Pressure
F. Crystal Solid
VII. Thermochemistry
A. Thermochemistry terminology
B. The First Law of Thermodynamics
C. Calorimetry
D. Hess's Law

VII. Other Information

(Use this area for other information the program chair/coordinator and the individual instructor wants students to have. You might put in a piece about teaching philosophy. You might want to add your expectations or concerns, or a list of emergency information. You also might want to include statements about contacting instructors, or information about computer lab, the Writing Center, or tutoring through Academic Support Services. The number to call to see if the campus is closed due to bad weather is (393) 556-2400.)

APPENDIX B: CCD – BIOLOGY SYLLABUS

The Community College of Denver
The Center for Arts & Sciences, Math & Science Department
South Classroom 306, (303) 556-2460, fax (303) 556-2174
General College Biology – BIO 111

I. Course Information

Course Title: General College Biology with lab

Course Prefix, Number & Section: BIO 111

Credits: 5

Course Description: (This must be the description in Common Course Numbering & the CCD Catalog.) Examines the fundamental molecular, cellular and genetic principles characterizing plants and animals. Includes cell structure and function, and the metabolic processes of respiration, and photosynthesis, as well as cell reproduction and basic concepts of heredity. The course includes laboratory experience.

Prerequisite(s)/Co-requisites: Grade of "C" or better in ENG 090 and MAT 090 or minimum college level English and Math assessment scores.

Semester and Year:

Meeting Location, Times and Days:

Start Date: Check your class roster to be certain this is correct! End Date: Check your class roster to be certain this is correct!

II. Instructor Information Name:
Voice Mail:
Fax:
e-mail:
Office Location:
Office Hours:

I. Required Course Materials

(List the books and other materials a student must purchase. Identify those that are optional.)

IV. Course Outcomes/Competencies:

(Please list here all that are in the Course Curriculum Guide. Others may be added by individual instructors.)

Upon completion of this course, the student should demonstrate knowledge and/or skill in the following areas.

I. Recognize terminology, specific facts, experimental methodologies, and general concepts related to the basic chemistry, cell structure and function, cell reproduction, bio-energetics, and genetics.

II. Read, analyze and apply the concepts learned to interpret new situations.

III. Distinguish between the principles and purposes of procedures and techniques introduced in the laboratory.

IV. Inspect the role of research in the biological sciences and become aware of its impact on society.

V. Employ the "scientific method" to the extent of formulating a hypothesis, designing a set of experiments with controls, analyzing results, and deriving conclusions.

VI. Experience interpretation and manipulation of data in a variety of formats, such as graphs, tables, and charts.

VII. Demonstrate the ability to select and apply contemporary forms of technology to solve problems or compile information.

VIII. Write and speak clearly and logically in presentations and essays.

V. CCD Critical Skills addressed in this course :

The critical skills addressed in this course are: reading, writing, computer literacy, speaking/listening, and valuing diversity.

Reading 3 -- Summarize information as presented in the biology course

Writing 3 -- Interpreting, analyzing and evaluating biology based concepts

Math/Reasoning 2 – utilize mathematic principles inherent to scientific research and analysis of biological concepts.

Computer Literacy 2 – Access and use course information on web-site and through online searches.

Speaking/Listening 3 – Demonstrate, select and analyze biological concepts and communicate results to others using oral and written techniques.

Valuing Diversity 2 -- Represent and explain biological concepts from the perspective of diverse groups.

VI. CCD Policies and Procedures

Student Code of Conduct and Academic Integrity Admission to the Community College of Denver implies that you agree to respect the rights of others and observe moral and civil laws. Interference with the normal processes of education in the classroom or elsewhere on the campus will be regarded as unacceptable conduct, warranting suspension or dismissal. Complete Student Code of Conduct is at this web site: http://ccd.rightchoice.org/Student_Life/COC.html.

Americans with Disabilities Act Students with a documented disability who need reasonable accommodations to achieve course objectives should notify the instructor and apply for services at the Center for Persons with Disabilities within the first week of classes. More information is available at http://ccd.rightchoice.org/EPAC/disabilities.html.

Grade of Incomplete

Incomplete: An "I" indicates that the course objectives are not yet fulfilled. It is the responsibility of the student to request, if needed, the assignment of an incomplete grade. The instructor's decision to authorize or not authorize an incomplete grade is final. The student must have completed 75% of the class with a C or better, and must complete the rest of the work with the same instructor. Arrangement for the completion of the course must be made with the instructor prior to the assignment of the "I" grade. This agreement must be written on a Contract for Incomplete Grade Form. The instructor may allow up to one full semester for the student to complete missing requirements. "I" grades not changed by the end of the following semester will automatically become failing grades (F).

VII. Course Policies and Procedures

Attendance Policy (List clearly and concisely any attendance requirements for the course, and state that attendance will be taken daily.)

Grading Scale

(Adjust where necessary.) The grading scale most often used is:

A	90-100%	Superior mastery or achievement.
B	80-89%	Better than average mastery or achievement.
C	70-79%	Acceptable mastery or achievement.
D	60-69%	Less than acceptable mastery or achievement.
F	Below 60%	Fails to demonstrate achievement of course objectives.

Assignment Weight List

Exam Makeup List

Late Work List

Cheating/Plagiarism Plagiarism is grounds for failing an assignment or course and/or disciplinary action from CCD. DO NOT PLAGIARIZE. Plagiarism means copying passages directly from the text of study guide or any other source, without quotation marks and citations. Summarize or paraphrase the information. If you paraphrase by rearranging the order of a sentence or words, then give credit for the source. No credit will be given for plagiarized papers.

VIII. Topic Outline/Calendar/Assignments: (Must include the Topical Outline from the Course Curriculum Guide. Additional material may be added by the individual instructor, who must include a calendar for the semester showing what students will be doing and what the assignments are, session by session.)

Date Topics/Assignments

I. Introduction
A. Nature of the Scientific Enterprise
B. Science and Society
C. Unifying Concepts
II. Fundamentals of Chemistry
A. Atoms, Molecules, Bonding
B. Biologically Important Molecules
C. Water and pH
III. Cell Structure and Function
A. Prokaryotic and Eukaryotic

B. Techniques of Study
C. Organelles
D. Membrane
E. Transport Mechanisms
IV. Cell Reproduction
A. Mitosis
B. Meiosis
V. Bio-energetics
A. Laws of Thermodynamics
B. Anaerobic, Aerobic Respiration
C. Photosynthesis
VI. Genetics
A. Classical
B. Chemistry of Heredity
C. Development D.

IX. Other Information

(Use this area for other information the program chair/coordinator and the individual instructor wants students to have. You might put in a piece about teaching philosophy. You might want to add your expectations or concerns, or a list of emergency information. You also might want to include statements about contacting instructors, or information about computer lab, the Writing Center, or tutoring through Academic Support Services. The number to call to see if the campus is closed due to bad weather is (393) 556-2400.)

APPENDIX C: SI WORKSHOP PLANNING GUIDES

Planning the SI Session

Session Date & Day of Week Mon Oct 25 SI Leader [redacted]

Course Bio 111 Course Instructor [redacted]

Objective: What are the one or two most difficult concepts that the students need to work on today?

Genetic disorders / inheritance, family trees & Pedigree

Beginning reminders:
1. Arrange seats in a circle
2. Hand out *Participation Log*
3. Set agenda with group
4. Remember to relax and be flexible!

Content to cover:	Processes to use*:
Recessive / Dominant inheritance	Punnet square percentages of dominant or recessive disorders
Family tree / pedigree	determine inheratance in family trees, discuss expected percentages & outcomes
European Royal family workshop	ask group questions on Hemophilia in European Royal family.

***Possible processes to use:** Informal Quiz, Matrix, Reciprocal Questioning, Paired Problem Solving, Turn to Your Partner, Note Processing, Problem Solving Rubric, Formal Definitions (or ID's), Text Review (Divide and Conquer), Pictorial Representations, Sequencing

Possible closure technique: Predict next lecture, Summarize session, Informal Quiz, One-Minute Writing

After session comments/thoughts:

Planning the SI Session

Session Date & Day of Week 1/26/11 **SI Leader** [redacted]

Course Bio 111 **Course Instructor** [redacted]

Objective: What are the one or two most difficult concepts that the students need to work on today?

Bonds

Beginning reminders:
1. Arrange seats in a circle
2. Hand out *Participation Log*
3. Set agenda with group
4. Remember to relax and be flexible!

Content to cover:	Processes to use*:
Ionic bonds	use the periodic table to explain valence shell e⁻ & trends.
Covalent bonds	Break into groups of around 3 or 4 and work on determining
polar vs. non-polar	bond types. Each group writes their problem on the board &
Hydrogen bonds	explains it to the rest of the class.

***Possible processes to use:** Informal Quiz, Matrix, Reciprocal Questioning, Paired Problem Solving, Turn to Your Partner, Note Processing, Problem Solving Rubric, Formal Definitions (or ID's), Text Review (Divide and Conquer), Pictorial Representations, Sequencing

Possible closure technique: Predict next lecture, Summarize session, Informal Quiz, One-Minute Writing

After session comments/thoughts: Students appear to be struggling with fundamental concepts. It seems easier for students to grasp concepts from boardwork rather than from power point.

Chapter 10 Photosynthesis Concept Sheet

Photosynthesis-The conversion of light energy to chemical energy

Autotrophs vs. Heterotrophs

- Producers vs. consumers

Sites of Photosynthesis

- Stomata (mouth): Pores in the leaf where CO_2 enters and O_2 exits
- Mesophyll: Tissue in the interior of the leaf where chloroplasts are found
- Chloroplasts: Organelle in plants that absorbs sunlight
- Stroma: Fluid within the chloroplast
- Thylakoids: Intermembrane sacs within the chloroplast that contain chlorophyll
- Chlorophyll: Green pigment located within chloroplast that absorbs light energy

$6\ CO_2 + 12\ H_2O$ + light energy ------> $C_6 H_{12}O_6 + 6\ O_2 + 6\ H_2O$

2 Stages of Photosynthesis

- Light reactions
  - $NADP^+$
  - photophosphorylation
- Calvin cycle
  - Carbon fixation

Nature of Sunlight

- Wavelength
- Electromagnetic spectrum
- Visible light
- Photons
- Spectrophotometer
- Absorption spectrum
- Action spectrum

Chlorophyll *a*

Chlorophyll *b*

Carotenoids

Structure of Chlorophyll

- Porphyrin ring
- Hydrocarbon tail

A Photosystem

- Reaction-center complex

Chapter 10 Photosynthesis Concept Sheet

Photosynthesis-The conversion of light energy to chemical energy

Autotrophs vs. Heterotrophs
- Producers vs. consumers

Sites of Photosynthesis
- Stomata (mouth): Pores in the leaf where CO_2 enters and O_2 exits
- Mesophyll: Tissue in the interior of the leaf where chloroplasts are found
- Chloroplasts: Organelle in plants that absorbs sunlight
- Stroma: Fluid within the chloroplast
- Thylakoids: Intermembrane sacs within the chloroplast that contain chlorophyll
- Chlorophyll: Green pigment located within chloroplast that absorbs light energy

$6\ CO_2 + 12\ H_2O$ + light energy ------> $C_6 H_{12}O_6 + 6\ O_2 + 6\ H_2O$

2 Stages of Photosynthesis
- Light reactions
  - $NADP^+$
  - photophosphorylation
- Calvin cycle
  - Carbon fixation

Nature of Sunlight
- Wavelength
- Electromagnetic spectrum
- Visible light
- Photons
- Spectrophotometer
- Absorption spectrum
- Action spectrum

Chlorophyll *a*

Chlorophyll *b*

Carotenoids

Structure of Chlorophyll
- Porphyrin ring
- Hydrocarbon tail

A Photosystem
- Reaction-center complex