SOLID GEMS CHEMISTRY: PEDAGOGICAL INFLUENCE ON FIRST-YEAR EOF STUDENT SUCCESS IN THE SCIENCES

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ABSTRACT OF THE DISSERTATION

Solid GEMS Chemistry: Pedagogical Influence on First-Year EOF Student Success in the Sciences

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The purpose of this study is to examine the influence of Solid GEMS Chemistry pedagogical practices on Rutgers School of Environmental and Biological Sciences (SEBS) Educational Opportunity Fund (EOF) first year student success and persistence in the sciences. An additional objective of this study is to explore how student attitudes towards the sciences are shaped by their experiences in introductory science coursework and how those experiences impact subsequent enrollment in science courses. The student sample for this study includes 613 first-year students enrolled at Rutgers SEBS and School of Arts and Sciences (SAS) through the EOF program during the 2012 and 2013 academic years, as well as 2,928 graduates enrolled from 1997 - 2006. In addition, the study includes information from two faculty members who teach General Chemistry. This mixed methods study examines student course placements, grades, course registration, college GPA, SAT scores, and interview and classroom observation data. Using a mixed methods design, the researcher used Dedoose to identify Solid GEMS pedagogical practices, and SPSS software was used to examine the data. The results of this study suggest that student enrollment in Solid GEMS Chemistry does impact student success and attitudes towards the sciences. The findings reveal that initial mathematics course enrollment and mathematics SAT scores influence student success and persistence. Additionally, the data showed that EOF students had a greater likelihood of success, which is likely due to their increased likelihood of enrollment in Solid GEMS Chemistry.

Keywords: success, persistence, solid gems chemistry, STEM majors, EOF, attitudes, underrepresented

Dedication

This document is dedicated to seven people who have been my life's cheerleaders.

Sarah, my mother, who has guided me through all of life's trials with a smile, spirituality, and helping hand. No words that I put on this page can pay homage to your many sacrifices for me and my baby girl. Your unselfish compassion for others encouraged me to pursue a career in education.

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Chapter I

Background

Although the U.S. higher education system remains globally competitive, America is not keeping pace with other countries in developing a citizenry to meet the needs of a highly technical workforce (NCES, 2009; Maltese & Tai, 2011). While American students are technologically savvy, they lack the critical thinking and analytical skills necessary for in depth learning and transference of knowledge which hinders pursuit and completion of postsecondary school education, particularly science, technology, engineering and mathematics (STEM) majors (Arum & Roksa, 2011). Academic, personal, financial and social challenges encountered while completing initial science coursework make many students shy away from STEM majors early in their academic careers, producing high attrition rates for many science professional schools (Adelman, 2006; Good, J., Halpin, G., & Halpin, G., 2002.; Griffith, 2010; Halpin, 1990; May & Chubin, 2003; Seymour & Hewitt, 1997; Tinto, 1993, 1999).

Research studies show that student success and retention in the sciences is predicated on many factors – including student confidence, cultural and academic background, instructional practices, socioeconomic status, and more (Adelman, 2006; Faye Carter, 2006; Good et al., 2002; Griffith, 2010; Kokkelenberg & Sinha, 2010; Pascarella, 1986; St. John, Hu, Simmons, Carter & Weber, 2004). A substantial percentage of students who enter college determined to succeed in a STEM major change their chosen career path sometime after they arrive on campus. More generally, a study conducted by the National Center for Education Statistics (NCES, 2009) found that of the first-time full-time freshmen enrolled at four-year institutions during the fall of 1995, 27% left college without a degree. The American Council on Education (ACE) suggests that while students are entering college with high expectations, many students struggle during their first year (Anderson & Kim, 2006). To maintain America's global competitiveness, U.S. colleges and universities must enhance its retention of talented individuals in STEM fields.

The Rutgers School of Environmental and Biological Sciences (SEBS) admits approximately 750 to 850 freshmen each year; most are aspiring doctors, veterinarians and scientists. SEBS offers a quality educational experience for students interested in pursuing STEM career paths. Focused on teaching, research and community outreach, SEBS is dedicated to educating students using collaborative teaching pedagogy to address current and future societal problems through analytical and critical scientific analysis. To achieve its goals, the college must ensure that academic and administrative policies facilitate a sustained pipeline of students enrolling in and graduating with STEM majors.

In 1981, an administrative review of student performance in science and mathematics coursework highlighted high attrition and failure rates in the entry-level chemistry course sequence, General Chemistry 161 and 162, unveiling an institutional problem. This problem was more pronounced for Educational Opportunity Fund (EOF) Program[1] students, given their academic, social, cultural, and financial backgrounds. With a large African American and Latino population, EOF students enhance the diversity of most New Jersey's college and university campuses. Notwithstanding the access and opportunity afforded students through the EOF program, the low number of EOF students enrolled in STEM courses and pursuing STEM majors is a concern for EOF, college, and university administrations. Some EOF students arrive on campus with mathematics and English deficiencies that require remediation, which threatens their successful completion of STEM coursework (Adelman, 1999, 2006). Additionally, EOF students, like many other students, may lack the abstract reasoning skills necessary for success in

[1] EOF is a New Jersey funded program designed to encourage and support low income and first generation students' access to and completion of undergraduate degrees at New Jersey colleges and universities.

science courses. Upon highlighting the effect of academic deficiencies and limited abstract reasoning ability on EOF student success in the sciences, institutional leaders initiated the development of the Solid GEMS (General Education in Mathematics and Science) Chemistry course instructional model.

Solid GEMS was conceptualized in 1982 and implemented in 1986 by Dean Frager Foster, EOF Director, and Dr. Carol Sauers, then Associate Professor of Chemistry, after a review of the academic preparation of incoming SEBS, then Cook College, students to identify potential threats to student success in the sciences. Focused on General Chemistry, a required course for science majors, Foster and Sauers met with Dr. J. W. Carmichael, creator and director of Xavier University's Stress on Analytical Reasoning (SOAR), to discuss the success of Xavier's science bridge program and how to transfer that success to Rutgers students. SOAR was a national model for student retention in the sciences. Given its success, Foster and Sauers sought to bring the SOAR education model to Rutgers. Noting student mathematical ability and abstract reasoning skills deficiencies as a possible focus for student failure in General Chemistry 161 at Rutgers, Foster and Sauers proposed to enhance student success with their version of Project SOAR - Solid GEMS.

In its initial design, Solid GEMS was to become a twelve-month academic sequence of coursework for EOF students focused on integrating chemistry, mathematics, vocabulary, and cognitive skills development to support student learning necessary for science success. Failing to convince mathematics and English department chairs of the benefits of this integrated learning approach, the Solid GEMS model was not adopted as originally planned. While the mathematics and English departments did not embrace the Solid GEMS model, the chemistry department supported the implementation of a summer chemistry course for underrepresented students.

With modifications to the initial program design, the Solid GEMS model was initiated as a summer bridge program in 1986 with 20 participants enrolled in the introductory General Chemistry course. Since then, the model has been adapted to an academic year course offering for all university students using innovative instructional methodology to support their success in the sciences.

This study seeks to examine what role, if any, the Solid GEMS Chemistry instructional model plays in EOF first-year student success in the General Chemistry 161 and 162 course sequence. Additionally, this study explores the potential relationship between student success in the General Chemistry 161 and 162 course sequence and student persistence in the sciences. The study has seven sections. The first section provides an overview of Rutgers SEBS, EOF, and Solid GEMS Chemistry. The second section explains the purpose of this study and presents specific research questions. The third section discusses the theoretical framework used to analyze the data and present findings. The fourth section reviews the literature to situate the study within the current research on student retention and success in STEM majors. The fifth section outlines the research design, site, and participant selection process, as well as data collection and analysis procedures. The sixth section highlights ethical considerations, role of the researcher, and identifies potential concerns or biases with research methods. The final section presents research findings and possible implications for policy and future research. This study offers insight to Rutgers University, SEBS, and other science curriculum administrators into how pedagogical practices may influence student success in the sciences and how to promote institutional development of new pedagogical models that enhance student learning through innovative science instruction.

SEBS, EOF, and Solid GEMS Chemistry

SEBS: An Historical Perspective

In 1862, President Lincoln signed the Morrill Act creating American Land Grant institutions. The government surrendered thousands of acres of land to generate support for agriculture and science education. Institutions receiving land were challenged to establish educational programs that would enhance agriculture, engineering, and other science fields. The land allocated through the Morrill Act created the Rutgers Scientific School in 1864.

After a series of name changes, the Rutgers Scientific School became SEBS and remains one of 105 land grant colleges in America. Today, SEBS continues to enhance its prominence as a land grant institution, graduating students in agriculture and science fields. To preserve its status, SEBS must continue to support academic policies that promote its majors and sustain a pipeline of students who enroll in and graduate from its degree programs. An ongoing analysis of first and second year course enrollment statistics identified several challenges that must be addressed to achieve retention goals, one of which is first-year student success in introductory science courses, particularly student success in General Chemistry 161 and 162.

From SEBS' emergence as New Jersey's land grant college, school administrators have demonstrated a commitment to science education and institutional change to promote the development of scientists. Of the 25 degrees conferred by SEBS, 20 require completion of the introductory chemistry course sequence – General Chemistry 161 and 162. If students do not successfully complete this course sequence, their persistence at SEBS and/or in a STEM major is highly unlikely. Therefore, student completion of General Chemistry 161 and 162 is of great concern for SEBS and EOF administrators.

The Educational Opportunity Fund (EOF) Program

The Civil Rights Movement created several legislative acts to ensure egalitarian educational experiences for U.S. citizens. During this time, many postsecondary institutions were inundated with students who were the product of "separate but equal" secondary schools. While education had progressed from the days of exclusionary practices, the historical impact of long-term educational deprivation and the variation in secondary education curricula created a differential level of preparedness. A student body ill-prepared to meet the challenges of a college curriculum was generated requiring colleges to develop supplemental instructional methods to address skills deficiencies (Delpit, 1988).

As a result of the Civil Rights Movement, in 1968 New Jersey enacted legislation that created the Educational Opportunity Fund (EOF) Program. EOF operates to ensure access and opportunity for low-income first-generation students who are New Jersey residents and first-time full-time freshmen, to attend New Jersey colleges and universities. Access is provided by assessing individual student potential for success, notwithstanding educational background and standardized test scores. Once arriving on campus, EOF students face the challenge of obtaining a college degree despite their socioeconomic status or high school preparation. EOF programs offer students a variety of academic, social, and financial services designed to mitigate educational and sociocultural deficits to support their personal and intellectual development while prompting degree attainment.

In 1979, Rutgers Cook College, now SEBS, established an EOF program on its campus. The Civil Rights Act of 1964, changing U.S. demographics, and the creation of EOF programs necessitated a commitment of resources towards the development of scientific skills for underrepresented student populations. Recognizing that student retention is predicated on student success in the introductory chemistry course sequence, EOF and SEBS administrators embarked upon a journey to provide academic enrichment for EOF students and facilitate their success in college level chemistry; and in 1981 the Solid GEMS Chemistry instructional model was conceptualized then implemented in 1986.

Solid GEMS Chemistry: An Emergent Concept

The impetus for Solid GEMS rests upon the fundamental ideals of progressive era reforms. Viewing problems in education through dichotomous lenses of social justice and business efficiency models of instruction, progressive ideologies transformed American education. While social justice ideologies focus on human interactions and the development of individual social consciousness for civic engagement, business efficiency models promote education that develops intellectual and physical capital necessary to support national production interests (Tyack & Cuban, 1995). Although both ideological constructs encourage learning and offer valuable insight into education matters, their divergent views of the purpose of education challenges educators to develop more inclusive curriculum models. Changes in the United States demographics necessitate curricula designed for cosmopolitan populations and require the implementation of educational practices that integrate social justice and business efficiency ideas. Although most curricula focus on one design, effective instruction involves the convergence of both models.

Focused on student academic preparedness and Piaget's (1964) theory of cognitive development, EOF administrators determined that EOF students arrived on campus lacking abstract reasoning skills necessary for higher order thinking required by science coursework. According to Piaget, a student's ability to process and analyze information affects their learning which can hinder successful completion of coursework. Piaget's teachings focus on how a student comes to know what he knows and the stages through which cognition is enhanced. A study conducted by Harper, Etkina, and Lin (2003) suggests that student questioning is an important factor in student success in large physic courses. In their study, Harper et al. posited that the inability to ask specific questions, which requires higher order thinking skills, hinders student success in science coursework. Informed by the teachings of Piaget, Dean Foster and Dr. Sauers began to examine the academic preparation of all incoming SEBS students to identify specific characteristics necessary for student success in General Chemistry 161. Review of enrollment data and course grades facilitated the tracking of General Chemistry 161 course success/failure rates. Discussions with Rutgers and non-Rutgers science faculty pointed to abstract reasoning skills deficiencies as one possible focus for student failure in General Chemistry courses. Taking from Piaget the notion that what a student knows and his inability to think in abstract terms hinders success in chemistry, the administration employed progressive era reform strategies to design the Solid GEMS Chemistry model. The model focused on integrating science, mathematics, vocabulary, and cognitive skills development to support student construction of knowledge necessary for science success.

EOF students were the intended Solid GEMS Chemistry population. Students enrolled in the course engaged in classroom activities that used concrete operational methods (such as building models and factor dimensional methods) to assist students in gaining formal operational skills. To enhance student understanding and learning of chemistry concepts, classroom sessions used everyday language, mathematical operations, and chemistry models (Piaget, 1964). For example, a teaching session focused on Stoichiometry[2] would include a discussion of the

[2]Stoichiometry is the calculation of the quantities of chemical elements or compounds involved in chemical reactions to combine elements.

meaning of a mole as Avogadro's number[3] of atoms, molecules, or eggs. Using a common item such as eggs provided a concrete reference to assist with student cognition. Additionally, students learned to balance equations and calculate molecular weight using models and everyday language references. These practices incorporate student academic and cultural knowledge to create an inclusive curriculum that supports learning chemistry concepts and transitive inference necessary for deductive reasoning skills required of most science coursework Using these and other instructional practices, Solid GEMS offers innovative instruction designed to support student success in General Chemistry 161 and 162. The Solid GEMS Chemistry evolutionary timeline is outlined in Appendix A.

As with many reform efforts, the Solid GEMS Chemistry program does not represent a new concept. From Dewey's Laboratory Schools to Cubberley's advocacy for vocational training, similar educational reform efforts have been recycled and adapted to meet societal needs. Since enrolling its first class in 1986, Solid GEMS has enrolled over 4,000 students and continues to serve as a model for innovative science curriculum design at Rutgers. According to Dean Foster, the success of the Solid GEMS concept has led to the adoption of its model in the Introductory General Physics course curriculum – Extended General Physics. As of fall 2013, the biology department has revamped its curriculum to include some of the Solid GEMS pedagogical practices – extended class time. Focused on student achievement through the pursuit of excellence, Solid GEMS Chemistry is designed to offer pedagogical practices that enhance the delivery of instructional content to support student learning and understanding.

Solid GEMS Chemistry celebrated its 25th anniversary in 2011 and administrators are interested in examining its historical context and potential impact on EOF student success in

[3] Avogadro's number is the number of carbon-12 atoms in 0.012 kg of carbon-12, which is approximately 6.022×10^{23} particles/mole.

Chemistry 161 and 162. To date, the SEBS EOF program boasts of over 1,600 graduates, some of whom have continued their studies earning graduate and professional degrees in science and other fields. One of Solid GEMS most notable participants is Dr. Paulette McRae, an EOF student who is the first African American to earn a Ph.D. in Neurobiology from Yale University. A Non-EOF student, Jacques Karcnik who enrolled in the course during the fall of 2009 states, “The more Solid GEMS Chemistry lectures I attended, the more chemistry became demystified and the more I wanted to know about the subject I was studying. … I became aware that the topics I was learning held water – they were relevant to my life.” Ms. Karcnik is currently studying chemistry at the University of Florida International REU at the Universidade de Säo Paulo in Brazil. Another EOF student states, “After four tough years at Cook, the hard work has finally paid off. I have just been hired as a chemist in the Analytical, Physical, and Biochemical Research division of American Cyanamid. Without the Solid GEMS Chemistry, my success would have never happened.” Many other students express similar views of how Solid GEMS has influenced their experiences, success, and attitudes towards the sciences.

Purpose of the Study and Research Questions

All Rutgers students must complete the General Chemistry 161 and 162 sequence to earn a science degree. General Chemistry 161 and 162 serve as gatekeeper courses for science majors, restricting student major declaration as well as degree completion (Eagan & Jaeger, 2008). A review of the fall of 2012 General Chemistry 161 course data revealed that 33% of the students enrolled in the class earned a grade of “D”, “F”, “Incomplete” or withdrew from the course. While a “D” is considered a passing grade, most departments define successful completion of coursework as students earning a letter grade of “C” or better. Additionally, students may not officially declare a STEM major without earning a “C” or better in the introductory science coursework. Students who struggle with the General Chemistry course sequence often opt to "get through" the courses earning a "D" and then change their major to something that does not require chemistry or any other science courses. This trend is most notable for EOF science majors. During an interview with *Black Issues in Higher Education*, Dean Foster stated, "[in 1984] 50% of those [minority students] who passed the course earned a "D" (Barnes, 1993, p.44). This statistic compelled SEBS and EOF administrators to address underrepresented student systematic failure in General Chemistry 161, specifically EOF student failure rates as most minority students enrolled at the college were enrolled in the EOF program. With aspirations of becoming doctors and scientific researchers, when encountering General Chemistry 161, EOF and most SEBS students become discouraged, turning away from STEM majors or leaving the college. Enrollment and success in General Chemistry 161 significantly affects SEBS and first-year EOF student retention rates, as student success in this introductory science course typically predicts persistence to graduation with a science major (Eagan & Jaeger, 2008; Leppel, 2001).

EOF students enrolling at SEBS face many challenges during their first year of enrollment. Notwithstanding the socioeconomic challenges, lack of academic preparation hinders their performance in science coursework (Maltese & Tai, 2011; Myers & Fouts, 1992). This mixed methods study examines the potential influence of the Solid GEMS Chemistry pedagogical practices on student success in the General Chemistry 161 and 162 course sequence. Additionally, this study explores how Solid GEMS Chemistry pedagogy influences first-year EOF students' attitudes, perceptions, and persistence in science majors. In this study, success is defined as earning a letter grade of "C" or better. Persistence is defined by subsequent enrollment in Organic Chemistry 307 immediately following General Chemistry 162 which suggests continued interest in the sciences. These measures of success and persistence were chosen because first year attrition from STEM is pronounced when students are unsuccessful in introductory science coursework, earning less than a "C" in the course. Students who do not earn the "C" or better in the General Chemistry course sequence will not register for Organic Chemistry during the next term of enrollment which may suggest a departure from STEM studies. The underlying assumption of this study is that the Solid GEMS Chemistry pedagogical practices influence student success in introductory chemistry, which potentially supports student persistence to enrollment in Organic Chemistry. Viewed through a constructivist lens of student learning and guided by principles of student persistence theory, this study addresses the following research questions:

1. How do SEBS EOF students perceive Solid GEMS Chemistry pedagogical practices to influence their grades in General Chemistry 161 and 162?
2. Do Solid GEMS Chemistry pedagogical practices influence student attitudes towards the sciences?
3. What is the impact of Solid GEMS Chemistry on student enrollment in Organic Chemistry 307?
    a. Does Solid GEMS Chemistry influence SEBS EOF student subsequent enrollment in Organic Chemistry?
    b. What factors differentiate those who enroll (persisters) and those who do not enroll (non-persisters) in Organic Chemistry?

Theoretical Framework

Students enrolling in the Solid GEMS Chemistry course attend class five days per week, instead of four days per week. Solid GEMS students participate in smaller lecture and recitation sessions, take more quizzes and exams, and engage in socially integrated learning experiences. These interactions allow students to merge chemistry concepts with everyday activities to enhance retention and transference of chemistry content knowledge (Lave, 2009; Piaget, 1964; Vygotsky, 1978; Wenger, 2009). Notwithstanding the student's academic preparation, Solid GEMS is designed to engage students in educational practices that encourage learning and understanding of chemistry concepts, support student commitment to educational goals, as well as foster positive experiences that change attitudes towards education, eliminate fear of science courses, alter perception of individual abilities, and change feelings regarding institutional commitment towards student success.

The Solid GEMS pedagogical model offers General Chemistry 161 and 162 instructional practices that enhance a student's exposure to chemistry concepts and classroom experiences. In contrast to the non-Solid GEMS General Chemistry sections, students are engaged with chemistry 5-days per week versus 4-days per week. Solid GEMS lectures are 80-minutes versus the 55-minute non-Solid GEMS lectures. Students enrolled in the Solid GEMS sections participate in smaller classes and recitation sections, allowing for close contact with faculty and teaching assistants. Solid GEMS students are given additional testing opportunities which allows for formative assessment of student learning. The introduction of relevant life examples engages students in experiential learning experiences. The designers of the Solid GEMS model hoped that these practices would enhance student learning and understanding of chemistry concepts, support commitment to educational goals, and promote positive experiences inside and outside the classroom. The general goal is increase the number of students who successfully complete General Chemistry 161 and 162 with subsequent registration in Organic Chemistry 307, to encourage students to persist in the sciences. An illustration of the conceptual model for this study is presented in Figure 1.

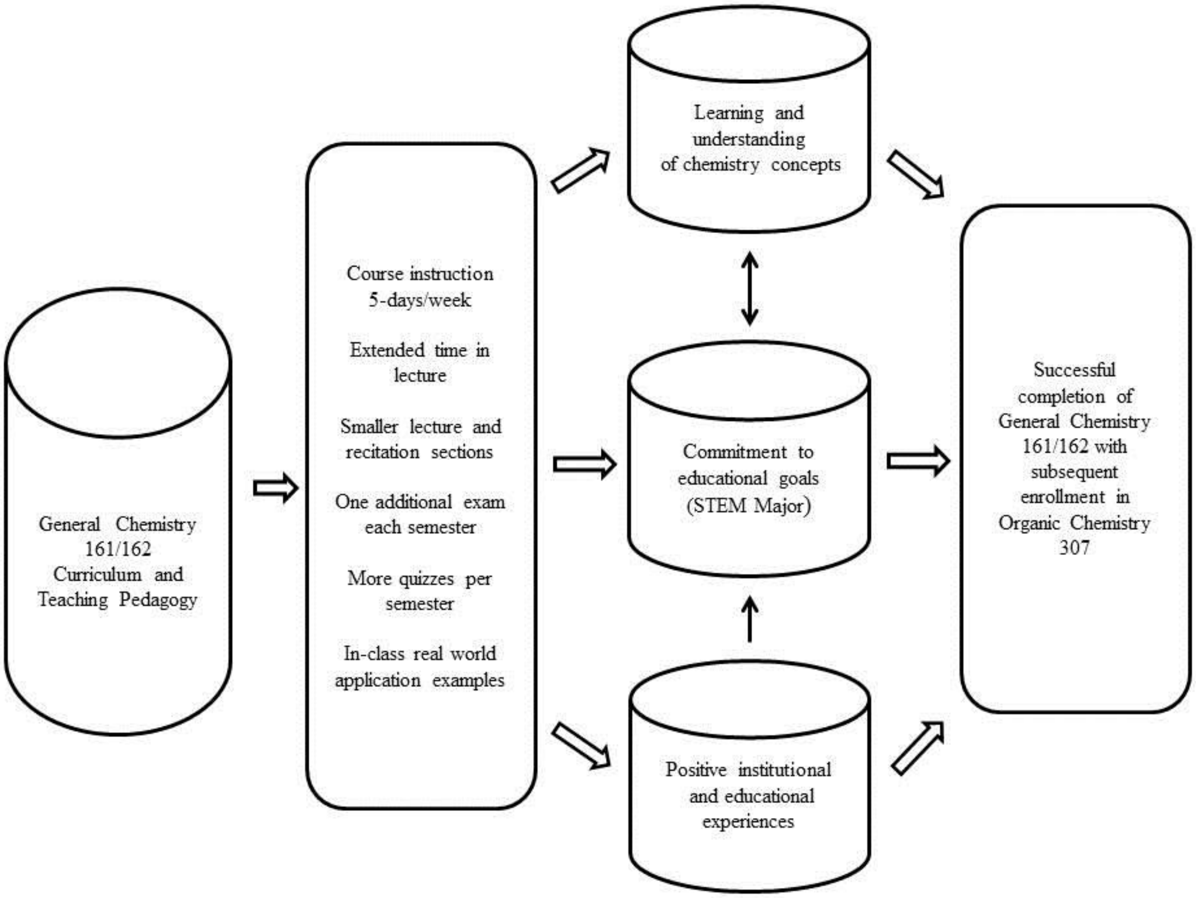

Figure 1. Solid GEMS Conceptual Model

Two theoretical perspectives guide this study: student persistence theory (Tinto, 1993, 1997) and social constructivist theory (Vygotsky, 1978). As this study seeks to examine the influence of Solid GEMS Chemistry instructional pedagogy on first year EOF student success in introductory chemistry at Rutgers and explore the potential effects on student persistence in STEM fields, using both persistence and constructivist theories encouraged in-depth understanding of student experiences. This study hypothesizes that the pedagogical practices of Solid GEMS Chemistry enhance student institutional and educational experiences while supporting learning and understanding of chemistry. Asserting that student experiences in Solid GEMS foster a deeper commitment to success and persistence in STEM majors, this research integrates constructivist and persistence theories as a way to understand and interpret student experiences in Solid GEMS and its impacts on their academic success to clarify and support research findings. The next section explains each theory as applied to this study.

Student Persistence Theory

Vincent Tinto’s (1993, 1997) theory of persistence offers the fundamental principles that guide the exploration of student success and experiences in the Solid GEMS Chemistry course. In 1993, Tinto identified three main areas that influence a student's decision to leave college: academic difficulty, personal and social challenges to achieving academic goals, and institutional climate. In his model, Tinto (1993) argued that students arrive on campus with goals, expectations, and academic abilities that lead them to make specific educational commitments. Tinto (1993) posited that, once on campus, students are confronted with a campus climate that shapes their educational experiences, and if students do not become actively engaged with the campus culture their academic coursework suffers and hinders persistence. While this theoretical explanation of student persistence is widely accepted, its critics suggest that Tinto’s broad focus on academic and social integration fails to address specific factors that affect persistence – psychological, economic, and cultural (Metz, 2004).

In response to challenges to his initial research, Tinto (1997) examined the college classroom as the center of student persistence. While his previous study focused on student integration with institutional culture and change from the student perspective, his 1997 study explored the potential effect of educational encounters on student retention. In subsequent research, Tinto (2003) examined institution structures identifying six factors that support student success: commitment, expectations, feedback, support, involvement, and learning. Institutional commitment towards student success is especially important for underrepresented groups. Students who feel that the institution is vested in their success persist more often (Pascarella, 1986; Seymour, 2001; Tinto, 2003). High expectations and faculty feedback are crucial to setting standards for success in the sciences. Instructional practices that set high expectations for students, directing them to academic support services when necessary encourage student success. Ongoing feedback from faculty and administrators helps to encourage persistence in those who consider leaving (Tinto, 2003). Tinto (2003) argues that, "Students are more likely to persist and graduate in settings that foster learning" (p. 5).

Although researchers (Braxton, Milem, & Sullivan, 2000; Guiffrida, 2006; Metz, 2004) challenge Tinto's (1975, 1993) early theoretical models, the six factors identified in his most recent studies (Tinto, 1997, 2003) serve as a framework for studying the effects of the Solid GEMS Chemistry pedagogy on student success and persistence. While not focused on STEM student persistence, Tinto's (1997, 2003) model provides a broader context and perspective that assists in answering the research questions.

Constructivist Theory

Piaget (1964), Vygotsky (1978), and all learning theorists assert that students heavily rely on prior experience and knowledge to construct their own understanding when learning. Effective educational practices take into account an individual student's prior experiences. Solid GEMS Chemistry instructional practices are guided by Piaget's (1964) analytical reasoning model engaging students in learning modules that integrate academic disciplines and stimulate cognitive development as students construct knowledge about chemistry and its relationship to the world around them. Vygotsky's social constructivist theory asserts that student social experiences and the assignment of meaning to those experiences, as they interact with others and the environment, facilitate learning. These constructivist paradigms view knowledge and learning through social, cultural, and political lenses. This view suggests that learning is a process of making meaning out of individual and group experiences shaped from social experiences and personal retrospection (Duffy & Jonassen, 1992). Human and environmental interactions stimulate assignment of meaning to experiences based upon prior knowledge, beliefs, and values from which individuals generate knowledge and understanding that supports learning.

Social constructivism places the student at the center of learning and challenges traditional institutional practices related to first-year introductory science courses. On most college campuses, introductory science courses are taught in large lecture halls with a focus on instruction and teaching (Eagan & Jaeger, 2008). Pedagogical practices that place instruction before learning can deter students' successful completion of coursework and possibly hinder college completion (Griffith, 2010; Maltese & Tai, 2011), particularly for STEM majors. The traditional model of General Chemistry 161 and 162 enrolls 300 to 350 students in a lecture classroom environment. As most first-year students, particularly EOF first-year students, have limited experience in large classroom instructional environments and have not been exposed to chemistry concepts since their sophomore year in high school this can be an intimidating experience. The Solid GEMS Chemistry course enrolls less than 200 students in each lecture and uses an instructional model that focuses on abstract reasoning, problem solving, and hands-on approaches to foster student learning. Using real world examples to present chemistry concepts, the Solid GEMS pedagogy attempts to engage and enhance student abstract reasoning skills through the integration of chemistry course content with real world examples that relate to students' personal experiences. Additionally, the smaller lecture size is less intimidating and supports student learning, success, and persistence (Biddle & Berliner, 2007; Borland, Howsen, & Trawick, 2005; Eagan & Jaeger, 2008; Finn & Achilles, 1999).

Solid GEMS pedagogical practices are designed to promote retention in the sciences through the facilitation of student success in the General Chemistry 161 and 162 course sequence. Using problem-based instructional methods to encourage student learning, Solid GEMS builds on Piagetian methodological practices to enhance student abstract reasoning skills using a cycle of student learning, Figure 2 illustrates the Solid GEMS philosophical tenets on learning.

Focused on enhancing student abstract and critical reasoning skills, Solid GEMS instructional pedagogy supports a four stage cycle of student learning – new problems, exploration, inventory, and application. Following Piagetian theory, Solid GEMS introduces students to rudimentary chemistry concepts to engage their sensorimotor and preoperational modes of thinking. As the curriculum progresses, students are exposed to conceptual ideas that build upon relationships using real world examples to connect chemistry with the students' everyday experiences. Instruction modules introduce chemistry related problems and encourage students to explore those problems using real life examples to ask probing questions. Using food and technology analogies, the instructor attempts to engage the students' concrete operational modes as they move towards developing the abstract reasoning skills necessary for studying science.

During an atomic structures lecture, the instructor uses magnets to demonstrate positive and negative charges. The instructor demonstrates the basic structure of an atom by showing students the image of a single atom. Using student familiarity of magnets, the instructor explains the properties of protons (positive charges), electrons (negative charges), and neutrons (neutral charges). Explaining how the positive and negative charges are attracted to one another, the instructor explains that this attraction keeps the electrons from floating away to maintain the structure of the atom. The use of magnets draws students' attention to commonly used childhood play toys drawing on prior knowledge to encourage application of practical knowledge to chemistry problems. Encouraging student use of personal experiences and everyday reasoning, the professor poses questions to assess students' supposition and reasoning skills. The professor continues to ask questions until the students have demonstrated sufficient understanding of the topic.

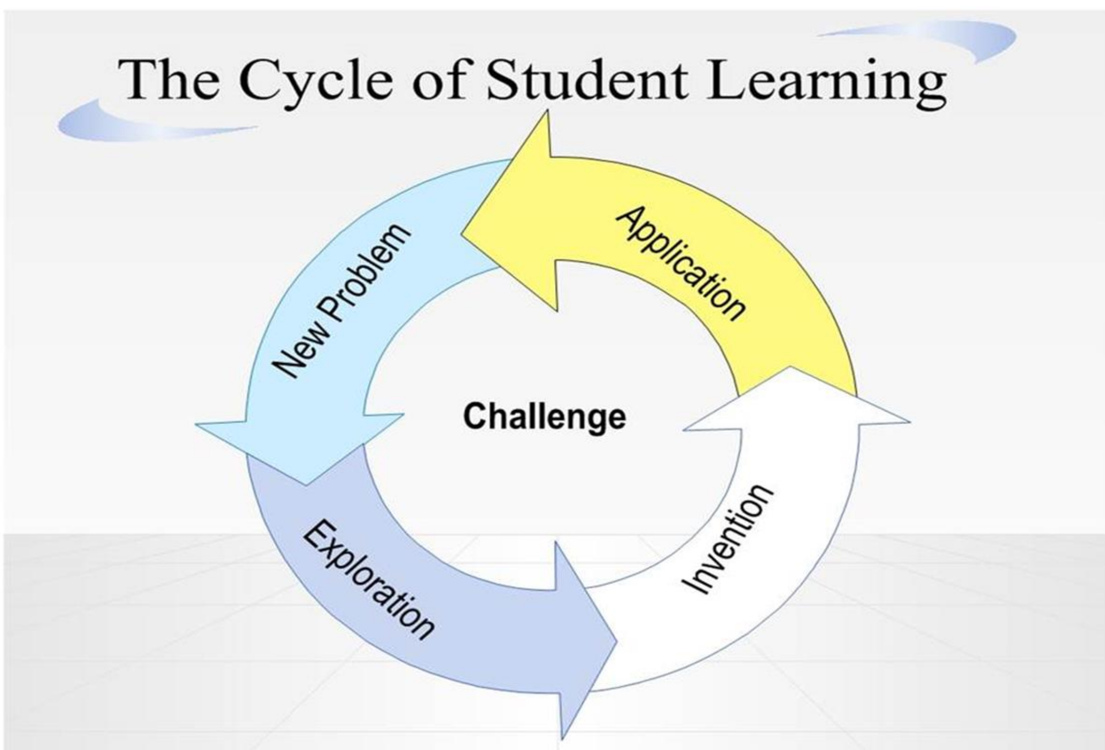

Figure 2. Cycle of Student Learning

While the course does not engage students in experiments, the lectures use this process for guiding students through understanding chemistry. 'New Problems' arise from student questioning that requires instructional staff to engage students in discussion that about chemistry concepts. The instructional staff member addresses the problem through interactive exchange of thoughts (exploration) moving students towards answering their own questions (invention). Real world examples of the problem are introduced to allow ‘application’ and new questions generate new problems. The process of introducing new challenges, exploring those challenges, inventing solutions, and applying new knowledge are principal to the Solid GEMS methodology. This interaction is repeated throughout each lecture and designed to facilitate student progression to Piaget’s formal operational stage promoting learning and success in the General Chemistry course sequence.

Significance of the Study

While there are voluminous studies focused on student success and persistence in STEM fields, the research is limited in its examination of science classroom pedagogy’s influence on student attitudes towards science (Astin & Astin, 1992; Daempfle, 2003; Duschl & Gitomer, 1997; Salta and Tzougraki, 2004; Seymour, 2002; Seymour & Hewitt, 1997; Whalen & Shelley, 2010). Most studies focus on a single student-level factor such as academic preparation, economic background, race, gender, or on a single institution-level factor such as class size, faculty engagement, or pedagogy. Astin and Astin (1992) examined student choice of science majors post participation in minority science retention programs at large public institutions. Focused on student level factors, the researchers found that student participation in minority science program had no significant impact on student major selection. In a study focused on science education trends, Seymour (2002) examined various institutional practices related to teaching science. Looking to determine how science education reform efforts are implemented, this study highlighted actions taken by educators to improve science teaching. Although this study focused on institutional factors, Seymour (2002) found that science education reform requires integration of institutional and student level improvements. These, and other studies, have failed to address the complexity of student success and persistence which is evident as there are consistent challenges to current research findings. From Tinto's (1975) original retention theory, which focused on student satisfaction to Bean's IEO model, there have been repeated challenges to the literature (Bean, 1980, 1981; Bean & Metzner, 1985; Pascarella, 1986; Pascarella & Terenzini, 1991). Recognizing the lack of research on classroom instructional practices, Duschl and Gitomer (1997) conducted a study to assess science classroom instruction. In this study, the researchers suggest changing instruction to include "assessment conversations" that assist with assessing, not testing, student understanding. The researchers found that conversation between teacher and students, and use of a portfolio instruction and assessment model enhances student science learning.

Lotkowski, Robbins, and Noeth (2004) presented examined the role of academic and non-academic factors on student retention. Focused on exploring student persistence at four-year postsecondary institutions, this study found the academic factors that most impact college student retention are high school GPA, ACT scores, institution selectivity, and financial support. Additionally, the researchers highlighted several non-academic factors that contributed to student college persistence such as self-confidence, achievement motivation, and social support. This is one of a limited number of studies that examine student and institution factors that hinder student persistence. This study seeks to add to the literature by examining student-level variables, attitudes and perceptions, together with an institutional variable, classroom pedagogy, to explore student success and persistence in introductory science course work. Focused on General Chemistry, an introductory course required by most institutions' general education requirements, this study looks across student-level and institution-level factors to understand how pedagogical practices may stimulate and sustain student enrollment in STEM majors. The data presented offers insights for educators and policy makers that can help them to critically examine current instructional practices and develop curriculum to support a sustained pipeline of citizens to meet future demand for a highly scientific and technical workforce.

Chapter II

Literature Review

Online research tools, such as EBSCOhost and Google Scholar yielded voluminous research focused on student retention using search terms that included science education, academic preparation, degree completion, retention, attrition, and career aspirations (Adelman, 1999, 2006; Atwater, 2000; Borland, Howsen, & Trawick, 2005; Good, Halpin, & Halpin, 2002; Braxton, Milem, & Sullivan, 2000; Chubin, May, & Babco, 2005; Enman & Lupart, 2000; Maltese & Tai, 2011; Griffiths, 2010; Pascarella, 1986; Pascarella & Terenzini, 1991; Seymour, 2001; Seymour & Hewitt, 1997; Tinto, 1975, 1987, 1993, 1997, 2002, 2003; Wood & Turner, 2011). The first section of this review highlights research on first-year student attrition, which is a focus of this study. The second section briefly examines high school experiences as a factor that affects college retention rates, specifically how those experiences influence student preparation and commitment to graduation. The third section examines research on underrepresented students in STEM fields highlighting studies regarding pedagogical practices that support STEM enrollment and positively influence the success of underrepresented students in STEM fields. This is important as this study focuses on the EOF population which consists of historically underrepresented students. The fourth section presents an overview of the research on educational practices in STEM majors. The final section addresses the limitations of existing research pointing to the need for this study.

First-Year Student Attrition

Using data from the National Center for Education Statistics report on higher education science and engineering enrollment (NCES, 2012), the National Science Foundation noted that of the first-time full-time students enrolled in America's four year colleges and universities from

1975 to 2010, more than one-third entered college with the intent of pursuing a science or engineering (S/E) degree. This report also indicated that 54% of students intending to major in S/E completed academic coursework in that major during their first year of enrollment. Researchers have found that of the first-year students entering college with the intention of majoring in engineering, between 30% and 60% will graduate with an engineering degree (Astin & Astin, 1993; Besterfield-Sacre et al., 1997; Fortenberry, Sullivan, Jordan, & Knight, 2007). While the proportion of freshman students intending to pursue S/E degrees has increased to 38% for that period and students appear to remain committed to their choice during the first year, many will change their major by their second year (Besterfield-Sacre, Atman, and Shuman, 1997; Georg, 2009; May & Chubin, 2003; Springer, Stanne, & Donovan, 1999; Tinto, 1987).

During the period from 1970 – 1988, Seymour and Hewitt (1997) noted a large decline in mathematics (from 4.6% to 0.6 %) and physical sciences (from 3.3% to 1.5%) degree enrollment. Reasons for the declining enrollment are plentiful with researchers examining single-level and multi-level student and institutional factors. The most notable student factors are academic preparation, socioeconomic status, expectations, and experiences. Institutional factors include campus environment, curriculum design, and faculty interactions. This phenomenon has stimulated active discourse regarding student success in higher education, highlighting factors that discourage pursuit of STEM career fields.

Various theories exist of student success and factors influencing their decision to leave postsecondary education (Adelman, 2006; Leppel, 2001; Tinto, 1997; Trenor, Yu, Waight, Zerda & Sha, 2008). Theories of academic preparation, early career aspirations, time to degree completion, faculty interactions, gender, and ethnicity permeate the literature offering insight to this phenomenon (Adelman, 2006; Atwater, 2000; Chubin, May, & Babco, 2005; Enman &

Lupart, 2000; Maltese & Tai, 2011; Terenzini & Pascarella, 1977; Tinto, 1997). Most models of student success examined the phenomenon using the exemplary frameworks posited by Tinto (1975) and Adelman (2006). While Tinto's (1975) seminal work theorized that campus interactions precipitated student satisfaction thus influencing individual success, Adelman's (1999, 2006) *Toolbox* and *Toolbox Revisited* suggested that high school preparation was an equally influential aspect of student success.

In his initial research, Tinto (1975) highlighted the importance of student satisfaction with an institution as a measure for dropout proneness. He explained that students who were not socially integrated into the campus climate had a less than satisfactory experience on campus and thus were more prone to drop out (Tinto). The campus climate included peer and faculty interactions as well as access to academic support and financial resources. Tinto and Goodsell (1994) believe that social acceptance during the first year of college impacts the student's desire to leave or stay. Students who were unable to adapt to the institutional climate found themselves' lost and unable to successfully navigate administrative, academic, and social situations and thus were more prone to drop out. Taking a closer look at student departure from higher education, Tinto (1999) wrote a paper which he delivered at a national forum for academic affairs administrators at California State University, entitled "Taking Student Success Seriously: Rethinking the First Year of College." In this paper, Tinto warned institutions to refrain from addressing student attrition problems with "add-on" services, encouraging administrators to consider institutionalizing student success strategies that integrate students into the campus culture and classroom pedagogy. According to Tinto institutions that enhanced a student's overall experiences would increase student satisfaction and classroom learning which promoted retention.

In *Answers in the Tool Box: Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment*, Adelman (1999) highlighted specific variables that supported student retention. This longitudinal study focused on student enrollment in college considering academic preparation, high school grades, socioeconomic status, and institutional commitment to examine degree completion patterns for a cohort of students graduating from high school in 1982. One finding of the study noted that students who arrived on campus in need of remediation in three or more areas were less likely to be retained after the second year. This suggested that high school academic preparation influenced first year attrition. This should not be surprising, as students with weak academic skills may find college coursework challenging and not perform well in first year courses. Notwithstanding this discovery, it must be noted that Adelman also discovered that student aspirations and experiences in gateway courses, among other areas, were factors in student retention.

In *The Toolbox Revisited: Paths to Degree Completion From High School Through College*, Adelman (2006) followed the same cohort of students and examined specific factors that supported student successful bachelor degree completion noting first year student persistence indicators. This study found that students who earned less than 20 degree credits during their first year had a low probability of degree completion which supported the general conclusions of the original *Toolbox* (Adelman, 1999). Often students with low credit accumulation during the first year were enrolled in remediation non-degree credit courses. The original *Toolbox* found that these students were less likely to be retained, and the subsequent study presented evidence that supported this finding.

While Tinto (1975) and Adelman (1999) offered keen insight into student retention, both researchers acknowledged the limitations of their respective studies. Both researchers focused their research on student level variables with limited review of institution level variables. Given this unilateral approach to examining student retention, a more comprehensive examination of all variables is necessary to present a complete understanding of student experiences and reasons for leaving college. Several researchers have used these theorists' works to enhance their ideas and advance the study of student retention.

In a study conducted to test Tinto's (1975) theory of student departure, Terenzini and Pascarella (1977) examined the relative impact of student-faculty informal interactions on freshman attrition. Using longitudinal data and drawing from a sample of 1,008 incoming freshman at Syracuse University, the researchers used surveys and descriptive statistics to investigate this phenomenon. The findings of this study suggested that student-faculty informal interactions played an integral role in student departure. More specifically, Terenzini and Pascarella suggested that faculty interactions that involved intellectual, coursework, and career related discussions had the most significant influence on student decisions to persist or not. Other theories highlight academic, financial, and social support as important elements for student success and retention (Griffith, 2010; Kokkelenberg, 2010; Leppel, 2001; Pascarella, 1986; Seymour & Hewitt, 1997).

In a study of student persistence in STEM fields, Maltese and Tai (2011) found that students often chose a major in high school based upon their experiences with a course or instructor. In this instance, the choice of a STEM major had nothing to do with aptitude or grades. These researchers suggested that student major selection was based upon personal wants and desires that have led to a major change after the first year of enrollment. Using data from the National Science Foundation (NSF), Maltese and Tai (2011) stated that "those students who indicated an early interest in science and persisted to earn a degree in STEM accounted for one in five of the STEM majors" (p. 878). It's not surprising that this study found that students who completed their STEM coursework with high grades were more likely to remain in the major; however, the study also noted the potential influence of classroom practices on STEM retention. Since the study was unable to identify specific classroom practices that influenced retention and warned that there may be other factors influencing student decisions, the researchers suggested that future studies examine classroom practices as well as student and teacher interactions to gain a more in depth understanding of freshman attrition.

According to Titus (2004), student persistence could be attributed to multiple variables (e.g. background characteristics, college and high school experiences, and attitudes). Using data from the 1996 – 98 Beginning Postsecondary Student (BPS: 96/98) survey administered by the NCES excluding schools with less than 2% racial/ethnic and female populations, Titus examined 5,151 first-time full-time students enrolled at 384 four-year institutions. Examining the 1995 Fall Enrollment survey from the Integrated Postsecondary Education Data System (IPEDS) to obtain demographic data for students, the study focused on persistence within institutions, excluding transfer students. Seventy-nine percent of the students in Titus' study indicated that they expected to earn a bachelor's degree from the initial institution of enrollment.

Using multilevel regression techniques to explore student persistence, Titus (2004) found that "a one standard deviation increase in a student's ability is associated with a 2% point increase in the student's chance of persistence" (p. 688). For this study, ability was measured using a composition of high school GPA and SAT scores. Thus, as the student's high school GPA and SAT score increased so did the student's rate of persistence. Additionally, Titus (2004) found that "a one standard deviation increase in educational goal increased the chance of student persistence by 1 [percentage point]" (p. 688). Educational goal was measured using a categorical notation of the level of education students expected to complete – ranging from one (no degree or less than a four-year degree) to five (doctoral or professional degree). Based upon this definition, Titus found that as students aspired to achieve higher educational levels persistence rates increased.

Although Titus' (2004) study examined multiple influences on persistence, it did not include narrative regarding student experiences and aspirations. This study also suggested that students with high educational goals persisted. However, it failed to discuss specific factors that determined those educational goals. Additionally, Titus proposed that "the chance of persistence is higher by 16% points for students who are committed to earning at least a bachelor's degree…" (p. 688). While an increased likelihood of earning a bachelor's degree of 16 points may be significant, Titus warned that the effect may be exaggerated because 79% of the students in the study had high expectations of earning a degree. Using longitudinal data to assess persistence rates, Titus highlighted several factors that supported student persistence.

In support of Titus' (2004) argument, Georg (2009) found low commitment to subject matter had a significant impact on student retention. Dr. Werner Georg is a professor in the Department of History and Sociology at University of Konstanz in Konstanz, Germany. Georg (2009) conducted a study to examine both individual and institutional factors involved in student attrition from higher education. Collecting data from various German universities, Georg (2009) used surveys to gather information about teacher quality, access to computer and networking resources, financial aid, on and off campus interaction, challenges and expectations. The results of this study suggested that teacher quality and certainty about major were important determinants of persistence. This study also showed that students who felt "anonymous" on campus attended class less frequently and were not likely to persist. While this study offered confirmation of other research, it too was limited in its generalizability. The data used for this study focused on German schools only and the models used provided an estimate that did not include an exhaustive list of measures. Nonetheless, Georg provided another view of student persistence which encouraged continued investigation of student attrition.

While Tinto (1975), Terenzini and Pascarella (1977), Adelman (1999, 2006), Titus (2004), Georg (2009), Maltese and Tai (2011) offered valuable insight to student persistence, the researcher still failed to provide in depth analysis of the many reasons why students do not persist. Since the problem of student persistence is multifaceted, research examining persistence must include more complex methodological designs that integrate multiple variables impacting persistence. Sole use of longitudinal data sets limits access to narrative to explain the numbers presented through quantitative analysis.

High School Academic Experiences

Research studies show that early educational experiences in science courses influence student academic preparation and persistence. According to Adelman (2006), teacher expectations, rigorous coursework, and student-centered instructional approaches influenced student retention rates. Arguing that “there is a … curriculum story that illustrates how students cross the bridge onto and through the postsecondary landscape successfully,” Adelman (2006) posited that a student’s “academic history” played a crucial role in successful completion of gateway courses, which ultimately affected degree attainment (p. xix). In response to Adelman’s *Toolbox Revisited,* Maltese and Tai (2011) examined the influence of high school experiences on student major choice and degree completion. Using data from the National Education

Longitudinal Study of 1988 (NELS: 88)[4], Maltese and Tai found that the number of completed high school science courses positively correlated with student persistence in STEM majors. This study also found that student perceptions of their science aptitude influenced their major choices and plans to remain in STEM majors.

Russell and Atwater (2005) conducted a study to examine African American student persistence in the sciences at a predominately White institution. Eleven undergraduate senior African American students enrolled in college preparatory advance placement (AP) or accelerated classes while in high school were selected to participate in this study – eight female students and three male students. The researchers were particularly interested in identifying high school experiences that impacted student decisions to pursue a biology degree. Additionally, the researchers examined how those experiences influenced student persistence in the science major. Using questionnaire and interview data, Russell and Atwater found that parental relationships, teacher interactions, high school experiences in science coursework, and experiences in the college introductory science courses influenced student attrition. Data analysis indicated that high parental expectations positively correlated with selection of a science major and persistence towards a science degree. Students reported that while in high school, parent and grandparent implicit and explicit commentary regarding college enrollment influenced their major choice and persistence decisions. Additionally, students felt enrollment in magnet schools and advanced science courses were indications of parental expectations and thus compelled them not to disappoint the family by dropping out.

Examining the role of teacher interactions, this study found that teacher confidence in student ability also had a strong influence on persistence. One participant in the study stated that

[4] The NELS:88 provides information regarding student experiences and attitudes towards mathematics and science.

the caring nature of teachers was an influence. She writes, “Well, they were caring. They not only cared that you did well in the class, they cared that you loved the class and enjoyed it” (Russell & Atwater, 2005, p. 701). Using memories as far back as elementary school, students shared comments regarding teacher interactions and how those encounters impacted their decision to pursue and persist towards a science degree. One student said this of her high school science courses, “Taking classes like biology, chemistry, and physical science and stuff like that in high school, I always liked it. I liked all the applications and how they applied to my life. So those were like the real big issues I guess that influenced my decisions to pursue science” (Russell & Atwater, 2005, p. 703).

This study provided insight from the student perspective and greatly added to the body of literature on student persistence in the sciences. While focusing on students who had completed advanced science coursework and restricting data collection to questionnaires and interviews limited the generalizability of the research findings, it provided an intimate look at student experiences from the student perspective. An examination of persistence through this lens assisted with offering a rich description of student persistence in the sciences which could be used to support other research data.

Underrepresented Groups in STEM Fields

Most research studies of persistence, targeting underrepresented groups in STEM majors, focused on comparing Asian and White students to African American, Hispanic, and Native American students. From 1984 to 2004, the number of underrepresented[5] students enrolled in higher education increased overall, but the number of freshman students pursuing engineering majors declined (Trenor et al., 2008). A growing body of literature examining STEM persistence

[5] Asian students are not classified as underrepresented.

of African American, Hispanic, and women students permeates education policy discussions at conferences and forums. While collegiate enrollment for these groups had increased over the years, their enrollment in and graduation from STEM related fields had not kept pace with that of their White counterparts (Atwater, 2000). This phenomenon is the topic of many discussions amongst policymakers, education leaders, and researchers.

Ethnic and racial minorities. Griffith (2010) suggested that ethnic and racial minorities have lower persistence rates in STEM than non-minorities with each group reporting different factors that influenced student decisions. Griffith (2010) examined student persistence from the institutional and student perspective using two national data sources. The first data source included information from the 1999 National Longitudinal Survey of Freshman (NLSF). This data set followed the academic career of first-time freshman students enrolled at 28 selective colleges and universities, particularly looking at non-White enrollment. The second data source considered data in the National Education Longitudinal Study of 1988 (NELS: 88) which was a follow up survey of 1988 eighth graders during their 10^{th} and 12^{th} grades to assess education outcomes and processes. In this study, Griffith found that while minority students initially select STEM fields upon entry to college, “only 47% of minority students remain in a STEM major by sophomore spring [semester], as compared to 58% of non-minority students” (p. 8). Griffith (2010) also noted that “of the students originally planning to major in a STEM field, 32% of minority students, and 48% of non-minority students remained in a STEM major by senior year” (p. 8).

Examining factors that influenced student persistence, Griffith (2010) suggested that prior preparation was crucial to STEM persistence for minority students. Students who took more AP coursework in STEM disciplines appeared to persist in STEM majors at a higher rate

(Griffith, 2010). She also found that course grades, GPA, and faculty/student involvement predicted student STEM persistence. Another key aspect of student persistence was an institutional focus on STEM education. Griffith argued that high school curriculum focused on STEM education supported student persistence, but the findings suggested that a college's institutional focus on STEM also may have influenced student success. Price (2010) noted that given racial differences, White students were more likely to persist than Black students, which was not surprising. However, he also found that after controlling for ACT/SAT scores and grades, the persistence gap between White and Black students decreased which suggested that high school academic preparation was important.

In a pilot study of academically gifted Black students, Bonner, Alfred, Nave, Lewis, and Frizell (2013) examined the challenges faced by gifted Black students who intended to pursue STEM majors at one of 12 four-year Historically Black College and Universities (HBCUs). In this study, the researchers sought to examine how giftedness played a role in student decisions to persist in STEM majors at HBCUs. Student participants were selected based on their cumulative grade point averages and faculty recommendations. Focus groups yielded data from which Bonner et al. found that notwithstanding their giftedness the students had personal attributes that hindered success. Giftedness did not guarantee persistence. Both faculty and students in the study suggested that social interactions with peers, family and faculty were a crucial determinant.

In their study of African American student persistence, Russell and Atwater (2005) found that student enrollment, success, and experiences in high school science and mathematics courses had an impact on their persistence in a science major. This was not surprising as much research suggested that student high school preparation was a crucial factor in science persistence (Adelman, 1999; Griffith, 2010; Price, 2004; Russell & Atwater, 2005; Tinto, 1997). Taking high school science courses could create a familiarity with course content which could assist with success and influence a student's decision to change majors. While this study also noted that family support and teacher interactions played an important role in student persistence, the researchers noted that student persistence was more consistent for those with positive experiences in previous science coursework.

Women. Increasing numbers of women entering the workforce have guided researchers to examine female persistence in STEM majors (Griffith, 2010; Maltese &Tai, 2011). According to NCES (2011), in 2008-09, fifty-seven percent of all bachelor's degrees awarded in the United States were given to women. Although women outnumber men on college campuses, they were less likely to enroll in and complete STEM majors (NCES, 2011). The National Science Foundation (2014) indicated that while women earned half of the science and engineering bachelor's degrees in 1990, the number of degree awarded between 2000 and 2011 remained the same. In a study of the impact of race and gender on STEM persistence, Price (2010) found that female students chose a STEM major as their initial choice at a lower rate than they chose non-STEM majors, 34.4% and 59.3% respectively. In her study of women and minority persistence in STEM majors, Griffith (2010) corroborated this indicating that "women make up a larger percentage of planned non-STEM majors than they do of planned STEM majors, and they are less than 50% of STEM majors in the NELS:88 data set" (Griffith, 2010, p. 6). Both researchers noted that as women leave high school many were not choosing to pursue STEM majors. In 2008-09, only 16% of engineering and engineering technology degrees were awarded to women (NCES, 2011). This phenomenon has caught the attention of several researchers.

In a study to examine the resistance of talented female students towards science majors, Enman and Lupart (2000) explored two characteristics – student interest and commitment to earning a science degree. Drawing from a sample of 151 undergraduate students in the Canadian postsecondary school system, the researchers administered two questionnaires the *Eccles' College Questionnaire* and the *Schommer's Epistemology Questionnaire*. The College Questionnaire was used to examine students' academic expectations and the Epistemology Questionnaire explored their individual knowledge beliefs. The findings of this study were not surprising. Students who indicated that science was their favorite course and declared a science major denoted a high expectation of success than those who did not, and persisted at a higher rate. An interesting finding was that students who indicated science as their favorite subject and declared a science major were an average of two years older than other students suggesting that time and age played a crucial role in persistence for women. The researchers offered no specific reasons for the age disparity in persistence, which advocated the need for additional research. This study illustrated the importance of student interest and commitment to science in female student persistence. Enman and Lupart (2000) stated that "once a student commits to a major in Science, s/he may begin to place less emphasis on the ability to learn and more emphasis on acquiring knowledge …" (p. 172). Once students had made this commitment, they were more likely to persist.

Studies showed that low persistence was not surprising for this population, given that STEM careers were non-traditional fields for women (Trenor et al., 2008). Trenor et al. studied the potential impact of social supports, perceived barriers to achieving goals, experiences, and perceptions of engineering on female student persistence. Three hundred and fifty female engineering students were invited to take the survey and 160 students were invited for interviews. One finding of this study was that a higher percentage of African American and Hispanic students reported having academic difficulty. Students in this study also indicated that support programs were instrumental in their persistence and success. Findings were consistent with other claims that academic preparation, faculty interactions, and institutional learning environments all influenced student major selection and persistence (Tinto, 1997; Adelman, 2006; Griffith, 2010; Maltese & Tai, 2011).

Imposter phenomenon. In 1978, Clance and Imes studied 150 high achieving women at Yale University. In this study, the researchers identified individual behaviors and experiences that were barriers to student success and categorized them using the ‘imposter phenomenon’ label. In their study the authors found that although the women had earned Ph.D.’s or were high achieving undergraduate students, they felt like imposters, “unintelligent” and “overevaluated,” doubting their abilities and accomplishments. The women believed they did not belong at Yale or any other university. They also believed themselves to be intellectually inferior and “self-declared” themselves as intellectual imposters. These negative beliefs served to diminish the women’s self-confidence compelling them to set unrealistically high expectations for achievement. Believing that meeting higher academic standards would somehow legitimize their success, the imposter phenomenon became self-fulfilling when the women experienced performance anxiety and were unable to meet the self-imposed high standards. For the undergraduate students, the anxiety associated with imposter phenomenon challenged their successful completion of coursework. Kolligian and Sternberg (1991) also examined the imposter phenomenon in young adults. In this study, the researchers found that individuals perceived their successes to be fraudulent which impacted their success in the classroom. Also in called the imposter syndrome, imposter phenomenon is typical for women and underrepresented groups, particularly in science courses as STEM fields are typically dominated by White or Asian men.

Stereotype threat. In addition to the imposter syndrome, women in STEM majors are impacted by what Spencer, Steele, and Quinn (1999) have labeled ‘stereotype threat’. Stereotype threat occurs when expectations of behavior and intellect are based upon a stereotype related to race, ethnicity, gender, or some other distinguishing characteristic. Traditionally, STEM fields have been dominated by men and seen as challenging or difficulty for women. Society has engendered a culture that perpetuates this and other negative stereotypes, for women and minorities. Women who hear these negative perceptions can exhibit feelings of inadequacy and unintelligence which is a characteristic of imposter syndrome (Clance & Imes, 1978; Kolligian & Sternberg, 1991). The negative stereotype that women are not good in STEM coursework challenges the female students’ self-confidence which can lead to underperformance on tests, threatening success and persistence.

In their study, Spencer et al. (1999) examined women students’ performance on mathematics tests. The authors argued that “when a stereotype about one’s group indicts an important ability, one’s performance in situations where that ability can be judged comes under an extra pressure – that of possibly being judged by or self-fulfilling the stereotype – and this extra pressure may interfere with performance” (p. 6). The findings of their study suggested that women majoring in the sciences are impacted by stereotype threat. Spencer et al. (1999) posits that for instruction to promote women’s success on mathematics tests, coursework and classroom environments must manipulate or eliminate stereotype threat as much as possible. By doing so, women’s performance on math tests will be enhanced which would influence STEM success and persistence. Deemer, Smith, Carroll, and Carpenter (2014) found similar results in their study of stereotype threat and academic procrastination in STEM. Looking at stereotype threat and achievement goals, Deemer et al. (2014) found that women will “adopt an avoidance goal to avoid confirming the stereotyped belief that they cannot perform in science” (p. 152).

In another study examining student performance on verbal tests, Steele and Aronson (1995) discussed the influence of stereotype threat on African American student success. Through this study, the authors confirmed that African American students, when compared to White students, underperformed on assessments used to evaluate individual learning. They argued that the self-doubt created by stereotype threat compromised student performance on tests; and, students who perceived themselves as unintelligent based upon a stereotype threat underperformed on learning assessments. Steele and Aronson (1995) stated that “the group stereotype becomes relevant as an explanation and may undermine performance.” The authors surmised that stereotype threat negatively impacts African American student performance on verbal tests. While focused on verbal tests, the findings of Steele and Aronson (1995) offer insight to assist in examining the performance of African American students in STEM fields.

Research on Educational Practices in STEM

Student persistence literature focused on various educational practices offered another view of STEM student retention. The last several years have guided researchers to examine classroom practices, group work, interactive learning, institutional practices, and faculty instructional practices (Eagan & Jaeger, 2008; Gay, 2010; Harper, Etkina, and Lin, 2003; Jett, 2013; Ladson-Billings, 1995; Pascarella, 1986; Rychly & Graves, 2012; Seymour & Hewitt, 1997; Springer et al., 1999).

Classroom practices. Maltese and Tai (2011) suggested that implementation of curriculum and instruction related to the students’ lives positively influenced student persistence in STEM majors. Recommending that “the presentation of material to make school mathematics and science more related to the daily lived of students," Maltese and Tai (2011) encouraged STEM faculty to support educational practices that "make the science personal, local, and relevant" (p. 900). In a study on STEM retention using a scientific thoughts and methods course, Koenig, Schen, Edwards, and Bao (2012) stated that "it is possible that the use of cooperative learning in a small class setting under the guidance of a caring instructor is just as important in helping student transition from high school to college" (p. 29). The research suggested that successful practices included, but were not limited to, small-group learning modules, interactive learning, institutional practices, and faculty pedagogical practices (Eagan & Jaeger 2008; Harper, Etkina, & Lin, 2003; Maltese & Tai, 2011; Seymour & Hewitt, 1997; Springer et al., 1999).

In a research study to examine the predictive factors of critical thinking skills, Facione (1990) found college GPA to be one of several factors statistically correlated to critical thinking ability. In a study of undergraduate nursing student disposition towards critical thinking, Ip, Lee, Lee, Chau, Wootton, and Chang (2000) found that critical thinking skills, such as open-mindedness, inquisitiveness, and analytical ability correlated with higher term GPAs for nursing students. Recognizing that some students arrive on campus lacking abstract reasoning and analytical skills, Solid GEMS instructional practices present course content in a way that supports student ability to apply critical reasoning to chemistry related problems.

Small-group learning modules. Springer et al. (1999) conducted a study to examine the effects of small-group learning on STEM student persistence. The researchers found that "some small-group work is more effective than purely lecture-based instruction in the gateway courses taken by major who strive toward SMET professions" (Springer et al., 1999, p. 40). Focused on what and how students learn, their study discovered that small group integrated learning experiences were best at promoting student persistence. Suggesting that student-centered small group learning environments had a positive influence on student persistence, Springer et al. encouraged use of small group work in secondary and postsecondary classroom instruction.

Interactive learning. Progressive educators, like John Dewey (1916), considered the use of integrative learning models that incorporated student everyday experiences into educational practices as effective teaching practices that enhanced student learning. Instructional practices focused on students' experiences offered inquiry-based projects encouraging hands-on and real-world experiential learning and cultivated student interest in the subject matter. Student reflection in student-centered learning environments was expected to increase student knowledge and skills promoting student persistence, particularly for EOF students (Springer et al., 1999).

Institutional practices. Eagan and Jaeger (2008) studied the influence of using part-time faculty in introductory science courses on student persistence. Their study found that students were negatively affected by having part-time faculty teaching science courses. These findings were not surprising as some part-time faculty typically used instruction-centered practices to deliver instruction. Instruction-centered instruction focuses on content delivery, failing to consider the needs of the learner. Student learning becomes secondary to the number of topics covered during the term. In addition to instruction-centered pedagogy, part-time faculty were less likely to have campus offices, which gave students limited access to the faculty outside of the class and decreased opportunity for faculty-student interactions. Eagan and Jaeger's findings built upon Tinto's (1975) retention theory, proposing that institutional practices that assigned part-time faculty to teach introductory science coursework potentially affected student persistence.

In addition to the concerns regarding faculty-teaching assignments, historically institutions enroll a large number of students in first-year science courses. The class size for a typical college introductory science class is 200 students. Large classroom lectures may be detrimental to student success and persistence. While Pascarella and Terenzini (1991) considered the class size effect insignificant, some studies suggested that it did have an impact and others suggest that it did not. For example, a study conducted by Zietz and Cochran found that classes with more than 30 students had a negative impact on achievement, while Lopus and Maxwell's study found that there was a positive correlation between class size and achievement (as cited in Johnson, 2010, p. 702). As the research on class size is inconclusive, it warrants further examination.

Faculty pedagogical practices. Seymour and Hewitt (1997) suggested that pedagogical practices in first-year coursework typically supported lecture formats where students were viewed as receptacles for knowledge. Instruction-focused lectures limited student engagement and constrained student capacity for intellectual growth especially in large lecture settings that were typical of introductory science courses. Maltese and Tai's (2011) study suggested that increasing student interest in STEM majors supported retention. Their findings recommended that faculty lectures should include discussion of science careers and increased collaboration with industry and organizations within the science field.

In their study of science education, Harper, Etkina, and Lin (2003) examined the role of student questions on student performance in large physics courses. This mixed-methods study examined 200 students enrolled in a first-year introductory engineering course. All students were in the large lecture with approximately 28 students in each recitation and lab section. Each week study participants would submit a written report, complete with narrative explanations and inquiry. Faculty would use student questions to plan future instruction so as to address course content that may seem unclear. Faculty would analyze the content of the questions to assess student knowledge of course concepts as well as classroom instructional techniques. Questions were coded to identify and distinguish between student difficulty with instructional techniques, individual cognitive challenges, and administrative concerns. Using a compilation of student questions and test score data, Harper et al. found that students experienced conceptual challenges as noted in the literature, specifically prior preparation.

Culturally responsive pedagogy. The literature shows that students arrive to classrooms with prior knowledge and experiences that influence their learning, success, and persistence (Adelman, 2006; Astin & Astin, 1992; Griffith, 2010). To support student success and persistence, institutions must create classroom environments that meet the varying needs of diverse student populations. Examination of classroom teaching is crucial to enhancing student success. There is a growing body of literature supporting the adoption of culturally responsive or culturally relevant pedagogical practices to enhance student academic success, particularly for underrepresented minorities (Gay, 2002; Ladson-Billings, 1995; Rychly & Graves, 2012; Jett, 2013).

Gay (2002) defined culturally responsive teaching as “using the cultural characteristics, experiences, and perspective of ethnically diverse students as conduits for teaching them more effectively” (p. 106). In her discussion of culturally relevant pedagogy, Ladson-Billings (1995) argued that instruction should seek to develop each student’s academic potential, through understanding of diverse cultures and incorporating that understanding into the curriculum. Rychly and Graves (2012) shared similar thoughts. In their study examining the characteristics for teaching culturally responsive curriculums, Rychly and Graves (2012) argued that given the increasing number of minority students arriving on college campuses, “a ‘new’ approach, one that teaches students according to the ways they best learn, will have to make its way into our classrooms" (p. 44). These researchers have created an open dialogue which prompts research into pedagogical practices and curriculum redesign to promote student success in the classroom. These are a limited number of studies focused on specific classroom practices, suggesting the need for more research in this area.

Limitations of Existing Research

Although there are voluminous studies on student persistence and retention, the literature is somewhat limited in its examination of pedagogical influence. Early studies offered socioeconomic, gender, race, academic and psychological perspectives on student persistence (Adelman, 1999, 2006; Astin & Astin, 1992; Dweck, 1986; Griffith, 2010; Kokkelenberg & Sinha, 2010; Maltese & Tai, 2011; Sedlacek, 1993; Seymour & Hewitt, 1997; St. John, Hu, Simmons, Carter & Weber, 2004;Tinto, 1993, 1997; Tracey & Sedlacek, 1985; Trenor et al., 2008). The findings of these studies focused on student level variables such as student academic background, educational goals, and SES. Acknowledging the interplay of non-student specific factors related to persistence, Maltese and Tai (2011) "recommend that future researchers collect multiple streams of data" (p. 901). Concentrating a lens on student-specific attributes disregarded the potential impact of institutional practices on persistence. While St. John et al. found that a student's academic performance was important to persistence; their study suggested that institutional practices deserved further study.

Some studies had identified classroom practices, institutional commitment, and faculty and peer interactions as influential in student persistence (Griffith, 2010; Henderson, Beach, & Finkelstein, 2011; Maltese & Tai, 2011; Springer et al., 1999). These studies examined persistence using longitudinal data from the U.S. Department of Education's National Center for Education Statistics (NCES), National Education Longitudinal Study (NELS) and various State

Department of Higher Education data sets. While these data sets offered reliable education statistics, they were limited in their capacity to offer a comprehensive examination of student persistence. Maltese and Tai suggested that "longitudinal data with concrete outcomes… ignore (or did not have available) the rich data providing information on students' educational experiences and interests" (p. 885). Examining persistence through the analysis of longitudinal (typically administrative) data without information on student's actual experiences limited the thorough exploration of student persistence and failed to consider pedagogical and other aspects of the academic experience. Research findings based upon longitudinal data also typically excluded direct conversations with students which restricted in-depth analysis and alternative explanations of persistence from a student perspective.

Arguing that student persistence was predicated on satisfaction with the institutional climate and campus interactions, Tinto (1975) established the foundation for current studies of student persistence. Adelman's *Toolbox* and *Toolbox Revisited* (1999, 2006), the seminal national studies of student persistence, argued that academic preparation and course experiences were important to persistence. Both Tinto (1975, 1993, 1997) and Adelman (1999, 2006) argued that student persistence was predicated on multiple personal, institutional, and academic factors. Although each argument presented a candid view of student retention they failed to sufficiently explored student persistence using narratives of student experiences. More specifically, neither researcher adequately incorporated student commentary nor examined persistence in STEM majors. This study proposes to use both theoretical perspectives, incorporating student narrative, observations and interviews, to examine student success in chemistry and subsequent graduation in a STEM field.

Most current research examines student persistence and retention using longitudinal statistics, which presents an incomplete view of this phenomenon. In a study focused on the relationship of non-cognitive variables to academic success, Tracey and Sedlacek (1985) found that non-cognitive variables are better predictors of student success. More specifically, they found that when measuring success, in terms of retention or graduation rates, use of non-cognitive variables offer greater predictive value. This study offers an alternative view to student success; however, its use of a single data collection method, the Non-Cognitive Questionnaire, eliminates the student's active voice. Incorporating student narrative, observations, and interviews presents a more comprehensive and nuanced view of student persistence that assisted with the generation of hypotheses and interpretations of findings from statistical studies (Creswell & Plano Clark, 2011). Considering Carol Dweck's research on motivation and learned helplessness, research focused on non-cognitive student success measures is warranted. In a study on student motivation and learning, Dweck (1986) discussed adaptive and maladaptive motivational patterns and their influence on student learning. In this study, she found that student goals will shape their motivation to learn, thus their success. Student narratives are crucial to exploring student motivation and thus important to understanding factors that contribute to success and persistence. Studies focused on quantitative longitudinal data analysis concentrated on predetermined hypotheses, restricts the researcher's lens, and may overlook unexpected outcomes.

This study enhances existing student persistence literature by using mixed methods to examine aspects of Solid GEMS Chemistry pedagogy to present a comprehensive view of its potential to influence student success in the introductory chemistry course. More specifically, the study integrates the use of narrative and statistical data to examine student persistence focused on students in STEM majors. Additionally, this study presents a lens through which postsecondary administrators can enhance science pedagogy to support student commitment to remain in a STEM major. Identification of the educational experiences that support first-year student success may encourage the development of innovative instructional practices for other science courses at Rutgers and other institution.

Chapter III

Methods

Students who attend the university and are not intending to enroll in a science major will register for the Impact of Chemistry course to fulfill the university physical science general education requirement. Impact of Chemistry is specifically designed for non-science majors and does not require a lab. Any student switching to a science major and has not taken General Chemistry 161 and 162 must take the courses as a prerequisite for upper-division science coursework. Since General Chemistry 161 and 162 is the required course sequence for students intending to study the sciences, this study assumes that all students enrolled in the General Chemistry 161 and 162 course sequence are potential science majors. The study builds upon information learned in a qualitative pilot study conducted in 2012 that examined student feelings about General Chemistry course instruction. The sections below contain a brief summary of the 2012 pilot study, as well as detailed explanations of this study's research design including the site selection, sample, data collection, and data analysis procedures.

A Pilot Study – Spring 2012

In the spring of 2012, the researcher conducted a small pilot study to explore student feelings about General Chemistry course instruction, particularly Solid GEMS Chemistry instruction. In that study, two SEBS EOF students and one faculty member were interviewed to examine student perceptions of how Solid GEMS Chemistry instructional pedagogy influenced their performance in the first year introductory chemistry course sequence at Rutgers University in New Brunswick. The results of this qualitative study suggest that both faculty and students believe that first-year SEBS EOF student success is influenced by (a) student expectations of the chemistry course, (b) student perceptions of faculty engagement, and (c) faculty expectations of students. In this study, the students noted that their high school experiences with chemistry and other science courses influenced their perceptions of college chemistry. The student whose high school experiences matched her college expectations had a positive attitude and expected to successfully complete the course, while the student whose high school experiences and college expectations were unmatched had a less positive attitudes and did not expect to earn higher than a "C" in the course. Additionally, students indicated that faculty "caring" or engagement influenced their attitudes about chemistry. Teresa, a first year SEBS EOF student, stated that "As long as the [professor] cares it makes it so easy to learn. 'Cause you don't feel like you are aggravating them. Some teachers when they don't really care they make you feel like you are annoying them because when you keep asking them questions…" When asked how she knows the professor cares, she states, "Because he talks to you about your grade. He lets you know, he keeps mentioning that he is here. That's the proof…"

These statements suggest that faculty expectations and commitment were important in her success. While the results of the pilot study suggest that faculty and student expectations may influence student success in General Chemistry 161 and 162 and subsequent registration in Organic Chemistry 307, additional research is necessary for a greater understanding of student success in General Chemistry and how that success supports student persistence in and influences student attitudes towards the sciences.

Research Design

This study uses a mixed methods design to examine the influence of Solid GEMS Chemistry pedagogical practices on first-year SEBS EOF student success in the introductory general chemistry courses sequence at Rutgers University in New Brunswick. Mixed methods designs use both qualitative and quantitative research methods to explore a particular phenomenon. Using this design supported an in-depth examination of student success, persistence in, and attitudes towards, the sciences. Additionally, using a mixed methods design assisted with triangulation of data, promoted greater understanding of the phenomenon, and assisted in identifying contradictions in the data, all of which addresses potential challenges to research findings (Sandelowski, 2000; Creswell & Plano Clark, 2011). A mixed methods research design worked best for this study, as it enhanced the validation process beyond what would have been accomplished using only one research method.

The following narrative presents details of the research design used in this study and includes: (a) a discussion of the site selection process, (b) details of the sample populations, (c) a summary of data collection and analysis procedures, (d) challenges to the research design, (e) ethical consideration; and (f) the role of the researchers.

Site Selection

Rutgers University is a four-year public research institution with three campuses located in northern, central, and southern New Jersey, Newark, New Brunswick, and Camden respectively. The flagship university within the state of New Jersey, Rutgers offers bachelors, masters, and doctoral degrees, as well as certificate programs up to the master's level.

According to the Integrated Postsecondary Education Data System (IPEDS) fall 2012 enrollment report, total enrollment at Rutgers University in New Brunswick was 40,434 with an undergraduate population of 31,593. Of those numbers, SEBS enrolled 3,672 students - 3,468 full-time and 204 part-time enrollees. Full-time students are registered for 12 or more credits, while part-time students are registered for less than 12 credits. Of the total fall 2012 enrollment numbers, EOF enrollment numbers were approximately 152 SEBS and 1,210 SAS students. With respect to faculty, three Rutgers New Brunswick Department of Chemistry and Chemical

Biology faculty provide instruction for General Chemistry 161 and 162. Although all three campuses confer science degrees that require General Chemistry for graduation, in 1986 the Solid GEMS Chemistry instructional model was adopted on the New Brunswick campus and remains exclusive to that campus.

Since New Brunswick is the only campus offering the Solid GEMS Chemistry course, it served as the primary site for this study. Only the School of Arts and Sciences (SAS), School of Environmental and Biological Sciences (SEBS), and Ernest J. Mario School of Pharmacy accept the General Chemistry 161 and 162 as a graduation requirement for science majors. The Ernest J. Mario School of Pharmacy has significantly higher admission requirements than SAS and SEBS, as their students are enrolling in a six-year Doctor of Pharmacy program. For this reason, the School of Pharmacy students are excluded from this study. SAS and SEBS students were selected as participants for this study because the school's admissions standards (SAT/ACT scores, high school GPA, and academic requirements) are most comparable. While the restricted site selection limits generalizability, the selection is appropriate for this study because the phenomenon is unique to the Rutgers University New Brunswick campus and the target audience is SEBS and EOF administration. Sampling and participant selection criteria are presented below.

Sample Selection

Given the 28 year history of Solid GEMS Chemistry at Rutgers, there are many students who have experienced the course pedagogy. To investigate the research questions, the researcher solicited participation and data from current undergraduate students, classroom lectures, as well as Department of Chemistry and Chemical Biology faculty. Qualitative student sampling was done purposefully to obtain SAS and SEBS EOF first-year students who enrolled in Solid GEMS and non-Solid GEMS General Chemistry 161; and, to solicit faculty who taught Solid GEMS and non-Solid GEMS General Chemistry (Patton, 1990). The quantitative sample consisted of alumni students. The narrative below explains the qualitative and quantitative sample selection process.

Qualitative sample. The qualitative sample included first-year and upper-class students. The first-year student sample was identified using enrollment lists for SEBS EOF and SAS EOF students enrolled at the university in fall 2012 and fall 2013 (N = 613). These lists were retrieved from EOF administrators and provided data for first-year EOF students enrolled in General Chemistry 161 during the fall 2012 and fall 2013 semesters. Of the total fall 2012 first-year SAS and SEBS EOF student enrollment (N = 269), 41 students were enrolled at SEBS and 228 students were enrolled at SAS. In the fall of 2013 (N = 344), 36 first-year students were enrolled at SEBS and 308 were enrolled at SAS. The upper-class student sample was identified using fall 2011 SEBS EOF and SAS EOF first-year student enrollment lists coupled with counselor recommendations. SEBS EOF and SAS EOF counselors provided a list of 7 fall 2011 first-year students who were currently enrolled at the University and had taken General Chemistry 161 during their first semester of enrollment. Fall 2011 was chosen for this population to support accurate recall of student experiences, since the student had taken the course less than two years ago. Student participants were selected based upon the following criteria: (a) enrollment in the SEBS or SAS EOF program, (b) declaration of or intention to declare a STEM major at time of initial enrollment, and (c) enrollment in General Chemistry 161 and 162 (Solid GEMS or non-Solid GEMS) during first semester of college.

Table 1

EOF Student General Chemistry Course Enrollment by School Affiliation

	GEMS	Non-GEMS	*N*
	51 (49%)	53 (51%)	104 (100%)
SAS			
Fall 2011	2 (3.9%)	1 (1.9%)	3 (3.0%)
Fall 2012	9 (17.6%)	21 (39.6%)	30 (28.8%)
Fall 2013	3 (5.9%)	27 (50.9%)	30 (28.8%)
Total SAS			63 (60.6%)
SEBS			
Fall 2011	3 (5.9%)	1 (1.9%)	4 (4.0%)
Fall 2012	21 (41.2%)	0 (0.0%)	21 (20.1%)
Fall 2013	13 (25.5%)	3 (5.7%)	16 (15.3%)
Total SEBS			41 (39.4%)

Once the sample criteria were applied, 104 potential participants were identified. Forty-nine percent of the students were enrolled in Solid GEMS General Chemistry 161 and the remaining students were enrolled in non-Solid GEMS General Chemistry (see Table 1). Forty-one (39.4%) students were affiliated with the SEBS EOF program, and the remaining 63 (60.6%) students were enrolled in the SAS EOF program. Further examination of the sample showed that58.8% and 31.4% of the potential first-year sample was enrolled in the GEMS course during fall 2012 and fall 2013, respectively. For the upper-class sample, 9.8% of GEMS students were enrolled during the fall of 2011. Involvement from all first-year and upper-class students was solicited to maximize participation. Detailed information for the actual sample is presented in Table 2.

Of the 104 potential participants, 97 first-year and two upper-class students participated in the study. All participants were EOF and enrolled in General Chemistry 161 during their initial semester of enrollment. Continued review of participant data revealed that 65.2% of the students were enrolled during the fall of 2012, 75% were SEBS EOF students, 37.5% were males, and African American and Hispanic students, 29.2% and 27.1%, made up more than 50% of the enrollment. An examination of the non-GEMS enrollment numbers revealed that, 39.2% of the students were enrolled during the fall of 2012, only 5.9% of the students were SEBS EOF students, 62.8% were male, and Asian students make up 45.1% of the course enrollment Of the students interviewed, 80% were SEBS EOF students. Forty percent of the students interviewed were enrolled in the GEMS chemistry course during the 2012 fall semester; and, 20% of the GEMS enrollees were male.

The sample population also provided an opportunity to solicit focus group participants. Of the 99 potential participants, eleven first-year students agreed to participate in the focus group but only eight showed up to the scheduled session. All students who participated in the focus group were from SEBS EOF and enrolled in the GEMS chemistry course during the 2012 fall semester. Although the researcher attempted to maximize the sample variation to include SAS students, the SAS student population was not as responsive as the student SEBS population. Table 2 presents more detailed characteristics of the student sample.

While there are three faculty members who teach General Chemistry at the university, there are two who are intimately familiar with Solid GEMS course. The researcher chose to interview one faculty member who taught non-Solid GEMS Chemistry and one faculty member who taught both non-Solid GEMS Chemistry and Solid GEMS Chemistry. The non-Solid GEMS Chemistry instructor has been teaching at the university for seven years and is familiar with the Solid GEMS teaching pedagogy, as he works with the Solid GEMS instructor to develop General Chemistry course materials used in both courses. Additionally, the Solid GEMS Chemistry instructor was instrumental in the initial design of Solid GEMS course pedagogy and has taught the course for over 25 years.

Table 2

Percentage Enrollment of Qualitative Sample by Chemistry Course Section

	Population		Sample		
			Interviewed		Focus Group
	GEMS	Non-GEMS	GEMS	Non-GEMS	GEMS
N/n =	48	51	5	3	8
Fall 2012 %	65.2%	39.2%	40%	0.0%	100.0%
Upper-Class%	4.2%	0.0%	40%	0.0%	0.0.%
SEBS %	75.0%	5.9%	80.0%	100.0%	100.0%
Male %	37.5%	62.8%	20.0%	33.3%	37.5%
Ethnicity					
African Am.	29.2%	19.6%%	40.0%	66.7%	25.0%
Hispanic	27.1%	19.6%	0.0%	0.0%	50.0%
White	18.7%	13.7%	20.0%	0.0%	12.5%
Asian	14.6%	45.1%	40.0%	33.3%	0.0%
No Response	2.1%	2%	0.0%	0.0%	12.5%
Other	8.3%	0.0%	0.0%	0.0%	0.0%

The Solid GEMS instructor taught both fall 2012 and fall 2103 semesters, which are the semesters from which the qualitative sample was drawn. His perspective provided unique historical narrative regarding the goals and objectives of the Solid GEMS pedagogical model as well as unique understanding of Solid GEMS course evolution. Since the non-Solid GEMS instructor works with the Solid GEMS instructor, assisting with the preparation of instructional materials, his perspective was helpful in securing an unbiased examination of the differences and similarities between the two courses. Given that both faculty members provide instructional support for Solid GEMS and non-Solid GEMS sections, this selection supported a comparative dialogue regarding student achievement and success in the General Chemistry course sequence.

It also encouraged a rich discussion of the unique characteristics of each course and the instructor's perception on how the course may influence student success.

Quantitative sample. The quantitative sample included SEBS and SAS EOF and non-EOF students enrolled from 1997 - 2006. An examination of student course enrollment assured that all participants were first-year students enrolled in General Chemistry 161 during their initial semester of enrollment. All students were first-time full-time freshmen enrolling during the fall semester. It should be noted that prior to 2006, SAS was comprised of several separate schools that included Rutgers College, Douglass College, Mason Gross School of the Arts, University College, and Livingston College. After restructuring its undergraduate programs in 2006, the university consolidated these schools into one school – the School of Arts and Sciences. To support review of student data focused on science majors only, students in the Mason Gross School of the Arts were excluded from the sample because those students were enrolled as dance, music, or theater majors. Also, students enrolled in University College were excluded because the college's enrollment consists of part-time, transfer, and non-traditional students who are not included in the target population. As a result of these adjustments, the sample population included 2,928 students enrolled in five schools – Rutgers College, Livingston College, Douglass College, SAS, and SEBS. For purposes of this study, Rutgers, Livingston, and Douglass are grouped under the School of Arts and Sciences (SAS) effectively limited the focus to SAS and SEBS.

Figure 1 shows the distribution of the 2,928 students in sample, all of which were initially enrolled in General Chemistry 161. Of the total sample, 90.2% were enrolled in non-GEMS section of General Chemistry 161. As noted in Figure 1, of the 2,928 students initially enrolled in the study, 2,587 earned a "C" or better in General Chemistry 161 and were eligible to enroll in

General Chemistry 162, thus continuing in the study. Of this population, 90.4% were enrolled in non-GEMS sections of General Chemistry 161. Figure 1 also shows that of the 2,587 students who continued in the study, enrolling in General Chemistry 162, 2118 participants earned a “C” or better, were eligible to enroll in Organic Chemistry 307, and continued in the study. Of the 2118 remaining participants, 1,588 enrolled and persisted to Organic Chemistry 307. Ninety-one percent of students who persisted to Organic Chemistry 307 were enrolled in non-GEMS sections of General Chemistry 161.

Figure 2 shows specific characteristics of the quantitative sample. Of the total population, 9.8% of the sample was enrolled in the GEMS sections of General Chemistry 161. When examining the school of registration and EOF status, Figure 1 shows that 49.7% of the students registered for GEMS were enrolled in SEBS and 15.7% of were EOF students. Examining SAS student enrollment in GEMS, it was noted that 50.3% of the population were registered for the GEMS course sections. For the non-GEMS sections, the data shows that 33.4% were enrolled in SEBS and 2.3% were EOF students. Additionally, 66.6% of the SAS students were enrolled in the non-GEMS course sections. Looking at the ethnicity of students enrolled in the GEMS course shows that 47.2% were White, 27.7% were Asian, 16.8% were African American, 9.8% Hispanic, and the remaining 4.5% were of another or unknown ethnicity. The non-GEMS course population consisted of 49.9% White students, 36.4% Asian students, 4.3% African American students, 4.7% Hispanic students, and the remaining 4.7% students were of another or unknown ethnicity.

Summary

The actual qualitative sample consisted of 16 first-year and upper-class students, and two faculty. While small in size, the number was sufficient to gather data and understand the Solid

GEMS Chemistry course pedagogy phenomenon. This small sample size allowed the researcher to become intimately involved with the data and expose potential themes and patterns. Recognizing that small samples challenge transferability of the findings in this study, the need for rich descriptive data supports use of smaller samples. While small samples may potentially limit access to data regarding the phenomenon, the smaller sample can enhance the richness of understanding student experiences in and attitudes towards Solid GEMS pedagogy and the sciences. Creswell (2007) admonishes that qualitative designs support smaller samples, as the focus is quality, not quantity. Limiting the number of interviews supports in-depth discussions and meticulous analysis of narrative to investigate how Solid GEMS influences student attitudes towards science majors. The quantitative sample consisted of 2,928 alumni students. This sample size allowed for examination of empirical data to support the qualitative findings. The next section provides an overview of the qualitative and quantitative data collection methods used for this study.

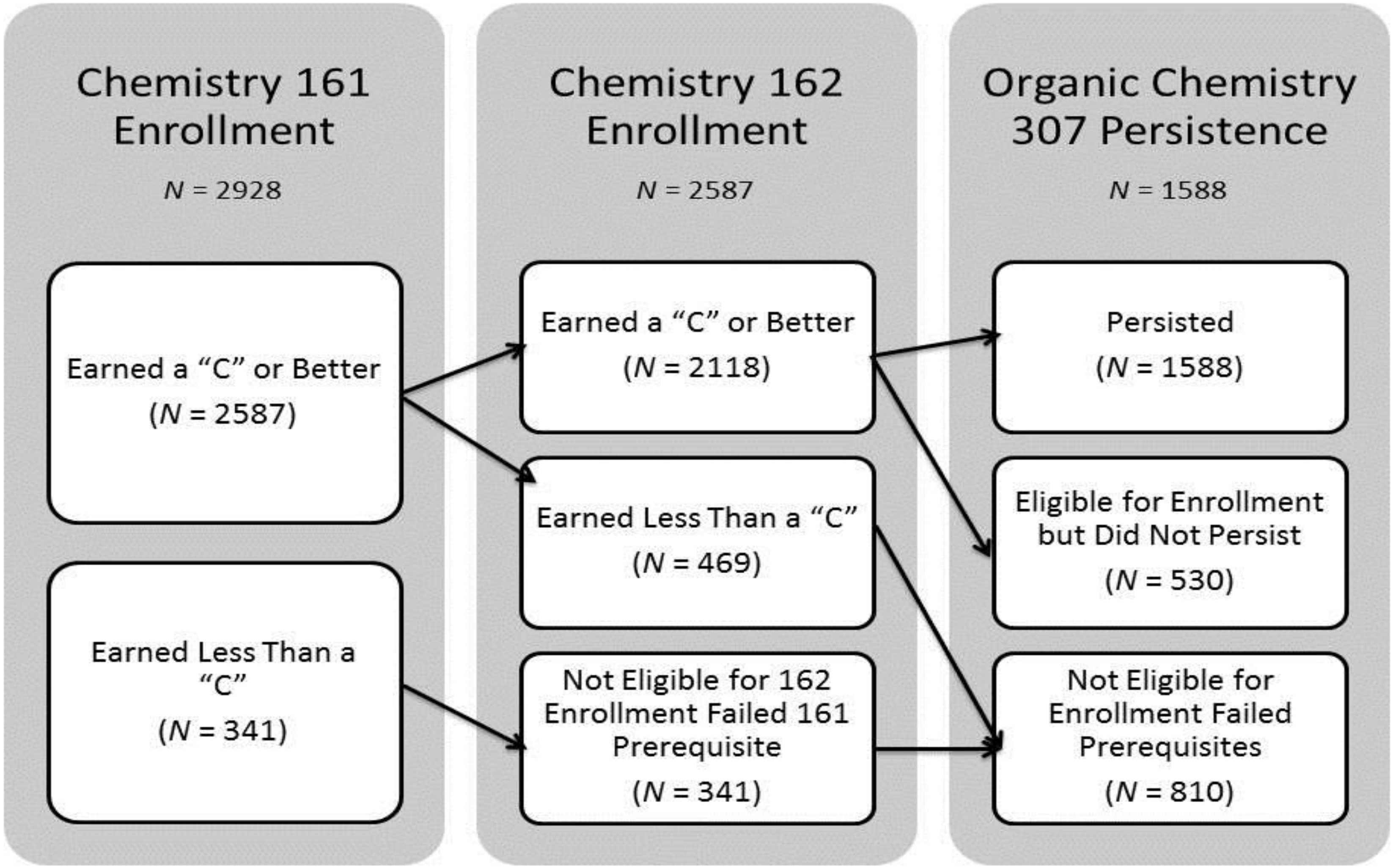

Figure 3. Diagram of the Quantitative Sample Population

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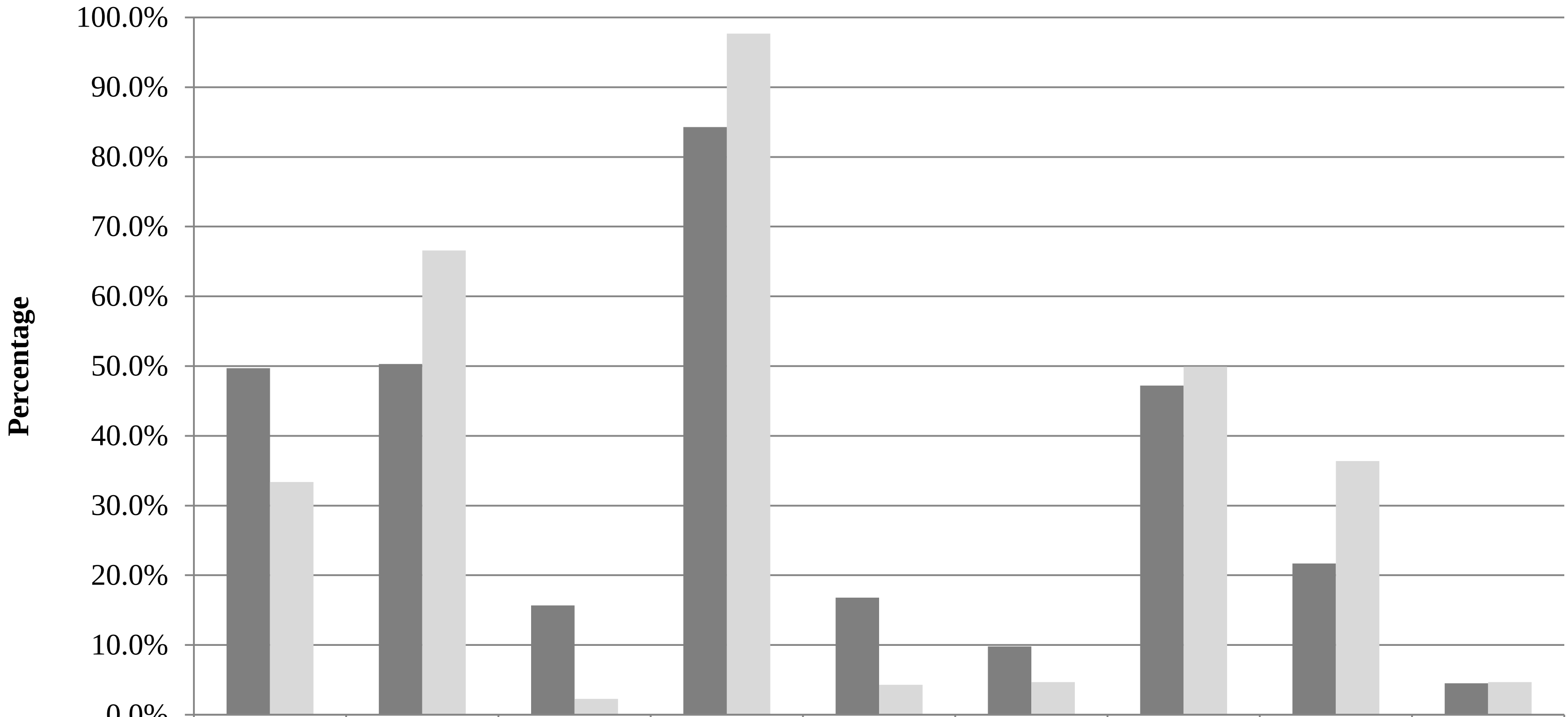

	%SEBS	%SAS	%EOF	%Non-EOF	%African American	%Hispanic	%White	%Asian	%Other
GEMS	49.7%	50.3%	15.7%	84.3%	16.8%	9.8%	47.2%	21.7%	4.5%
Non-GEMS	33.4%	66.6%	2.3%	97.7%	4.3%	4.7%	49.9%	36.4%	4.7%

Footnote: *N*= 2,928 Enrollment in GEMS = 286 and enrollment in non-GEMS = 2462.

Figure 4. Characteristics of the Quantitative Sample Population.

Data Collection

This study employs five data collection methods: focus groups, interviews, classroom observations, and student course registration. Understanding that narratives are important to this study, the researcher conducted a focus group as an initial data collection method. The focus group was selected to initiate discussion, assist with developing interview protocols, and encourage communication from students that might not occur during the one-on-one interview sessions. Focus group discussion techniques use student interactions to uncover obscure thoughts, patterns, and themes that the researcher might overlook. Student and faculty interviews encouraged rich description of student experiences and supported understanding of Solid GEMS pedagogical practices. The classroom observations provided the researcher with an insider perspective of the Solid GEMS phenomenon. In addition to the qualitative data collection methods mentioned above, this study examined quantitative data to address questions related the potential influence (as opposed to perceptions) of Solid GEMS pedagogy on student success and persistence. Student demographic and course registration data assisted in providing a more general understanding of the Solid GEMS phenomenon to complement qualitative research findings.

The researcher ensured that all participants completed an informed consent form designed specifically for this study. Using IRB approved protocols, the researcher read the consent form to each participant informing them of their rights and ability to withdraw from the study at any time. Each student participant signed an informed consent form and received a copy for future reference, if needed. All interview and focus group participants completed consent forms and received a full disclosure statement prior to engaging in research activities. The researcher retained the original copy of the consent form and used standard data collection methods to support minimal risk to all participants.

Since a goal of this study is to investigate how students experience Solid GEMS Chemistry pedagogy and how those experiences may influence their success and persistence in the sciences, a two-phase exploratory data collection methods approach was used. During the first phase, qualitative data was collected to explore student experiences and attitudes. The qualitative data collection process commenced in the fall of 2012 and ended in the fall of 2013. Data was collected from first-year students enrolled during each fall semester. Using both fall 2012 and fall 2013 enhanced the number of potential participants to help maximize data collection.

The next phase involved gathering quantitative data to complement and enhance research validity. Quantitative data were obtained from existing Rutgers records compiled by the University Registrar (SRDB) and Office of Institutional Research and Academic Planning (OIRAP). All data collection was conducted to support and maintain individual confidentiality. Files were delivered using email, and to maintain confidentiality files were password protected with passwords delivered via telephone conversations. File passwords were maintained throughout the data collection process. Due to the voluminous data contain in the files, the quantitative data sources were delivered using multiple files. The data included confidential records in which individual student Rutgers Identification Number's (RUID) were used to match data from various files and sources.

Table 3 describes the relationship between the data collection procedures and the research questions. As illustrated in Table 3, interview data served as the primary qualitative data set. Next is a detailed description of procedures followed for collecting data for use in this study.

Table 3

Relationship Between Research Questions, Sample, and Data Collection Methods

		Qualitative Methods			Quantitative Methods
No.	Research Question	Interview	Demographic Data	Focus Groups	Demographic Data
1.	How do SEBS EOF students perceive Solid GEMS Chemistry pedagogical practices to influence their grades in General Chemistry 161 and 162?	S		S	
2.	Do Solid GEMS Chemistry pedagogical practices influence student attitudes towards the sciences?	FS	S	S	
3.	What is the impact of Solid GEMS Chemistry on student enrollment in Organic Chemistry 307?	FS	S	S	S
3a.	Does Solid GEMS Chemistry influence SEBS EOF student subsequent enrollment in Organic Chemistry?	S	S	S	S
3b.	What factors differentiate those who enroll (persisters) and those who do not enroll (non-persisters) in Organic Chemistry?	FS	S	S	S

Note. “F” = data was retrieved from the faculty interactions, and “S” = data was retrieved from the student interaction or records.

Qualitative Data Collection

This study was conducted in a naturalistic setting, using observation, interview, and focus group techniques. These data collection methods provided the researcher with rich descriptions of student experiences and reactions to faculty instructional practices that influenced their perceptions and attitudes toward science. The pages that follow provide specific details of data collection procedures for focus groups, interviews, and classroom observation.

Student focus groups. To identify potential themes, patterns, and questions for interviews, a focus group was conducted during the fall 2012 semester. Fifty-one SEBS EOF and SAS EOF first-year students were registered for Solid GEMS Chemistry during fall 2012 and were invited to attend the focus group session. The researcher contacted students using email, text messaging, telephone, and counselor reminders to encourage maximum participation. Time and location were selected using Doodle, an online meeting scheduler. To enhance probability of student attendance and accommodate access, the focus group was held on a Friday on the Rutgers University New Brunswick Cook/Douglass campus in Hickman Hall room 131. The session commenced at 4:00pm and lasted approximately one hour. The time and location was selected because the Solid GEMS Chemistry course is held in the Hickman Lecture Hall on Friday afternoon. Hosting the session immediately after the class lecture and in the same building limited student travel and other distractions that might prevent student attendance. Pizza and soda were provided to accommodate commuters and those who might miss the dining hall service.

On the day of the focus group, eight students showed up and participated. The focus group consisted of 5 women and 3 men. All students were between the ages of 17 and 18. To support anonymity in presenting the focus group demographics, student names are replaced with

FGS1 – FGS8, where FGS1 = focus group student 1, FGS2 = focus group student 2, etc. FGS1 was an 18 year old Hispanic female Biology major. FGS2 was an 18 year old African American female Biochemistry major. FGS3 was a 17 year old White male Biology major. FGS4 was an 18 year old Hispanic female Animal Science major. FGS5 was an 18 year old African American Biology major. FGS6 was an 18 year old Hispanic male Animal Science major. FGS7 was a 17 year old Hispanic male Animal Science major. And, FGS8 was an 18 year old female Biology major who chose not to respond to the ethnicity question. Table 4 presents this information.

Table 4

Characteristics of Focus Group Participants

Student ID	Age	Gender	Status	Ethnicity	Major
FGS1	18	F	1st Year	Hispanic	Biological Sciences
FGS2	17	F	1st Year	African American	Biochemistry
FGS3	18	M	1st Year	White	Biological Sciences
FGS4	18	F	1st Year	Hispanic	Animal Science
FGS5	18	F	1st Year	African American	Biological Sciences
FGS6	18	M	1st Year	Hispanic	Animal Science
FGS7	17	M	1st Year	Hispanic	Animal Science
FGS8	18	F	1st Year	No Response	Biological Sciences

Note. FGS = Focus group student ID code used to protect student identity

Using a pre-determined focus group protocol, participants were presented an overview outlining the purpose of the study along with participant expectations during and after completion of the focus group session. All participants received full disclosure and were given the opportunity to decline participation. Informed consent forms were read to the group and each participant was asked to sign as a symbol of agreement to participate in the session. Each participant received a copy of the informed consent form for future reference. During the focus group session, digital audio and video recording devices were used to capture student narrative and accommodate identification of speakers. Participants were informed of the use of these devices and given the opportunity to decline participation. To assist with ensuring a collegial discussion, participants were asked to be respectful of one another and state their name prior to speaking to capture beginning and ending points for individual comments.

The focus group session was instrumental in the gathering of shared and individual experiences. According to Krueger and Casey (2000), “The focus group presents a more natural environment than that of an individual interview because participants are influencing and influenced by others – just as they are in life” (p. 11). Placing students in this semi-structured environment encouraged a fluid conversation which yielded detailed accounts of individual experiences. The video and audio recordings aided the researcher in recalling verbal and non-verbal communication. The session was transcribed using Microsoft Word and Dragon Speech Recognition (DSR) software. DSR was a valuable tool in transcribing the data; however one limitation of the software is that it is unable to recognize multiple voices. The software was trained to recognize the researcher’s voice only, thus the session was transcribed using the researcher’s voice then edited using Microsoft Word.

Student interviews. Student interviews were a primary qualitative data collection method for this study. These were face to face interviews conducted by the researcher. Having the researcher conduct each interview ensured questioning to support rich detail regarding students’ perceived experiences of General Chemistry and beliefs about how those experiences influenced their attitudes, perception, and course success.

The researcher used email, cellular phone messaging, and EOF counselor reminders as the primary method of contact. This information was retrieved from the Rutgers Online Directory as well as the SAS and SEBS EOF administrator lists. All students were sent an email identifying the researcher and purpose for the communication. Students in the fall 2012 cohort were contacted in January 2013, while students in the fall 2013 cohort were contacted in January 2014. All registered first-year SEBS and SAS EOF students were invited to participate in one-on-one interviews. Selection of interviewees was based upon EOF status, course registration, student responses, and student availability. Of the 97 potential first-year sample, nine (9.3%) students agreed to participate in one on one interviews. While nine first-year students agreed to be interviewed only six (6.2%) were interviewed. Scheduling and personal conflicts prevented the researcher from interviewing three first-year students, despite repeated attempts to reschedule. Of the 7 potential upper-class student participants, 2 students were interviewed. Both were SEBS EOF third-year female students who enrolled in the Solid GEMS Chemistry 161 course during the fall of 2011. All upper-class students were invited to participate in the study; however student participation was limited due to student availability at the time of solicitation. These students were preparing for standardized test reviews and searching for internship opportunities which when coupled with their rigorous academic load, restricted their availability.

Table 5 provides detailed information about the interview participants. To maintain anonymity, student names are replaced with IS1 – IS8, where IS1 is interviewed student 1, IS2 is interviewed student 2, etc. Of the six first-year students, two were African American, three were Asian, and one was Hispanic. There were four female students and two male students. While all students intended to pursue science majors, two were undeclared science majors. Both upper-class students were female Biology majors. Table 2 provides detailed information regarding the percentage of students enrolled in the GEMS verses the non-GEMS sections.

Table 5

Characteristics of First-Year and Upper-Class Interview Participants

Student ID	Age	Gender	Ethnicity	Major
First-Year Students				
IS1	17	F	African American	Undeclared Science
IS2	17	F	African American	Undeclared Science
IS3	18	M	Asian	Biological Sciences
IS4	18	M	Asian	Food Science
IS5	17	F	Asian	Biological Sciences
IS6	17	F	Hispanic	Animal Science
Upper-Class Students				
IS7	19	F	African American	Biological Sciences
IS8	19	F	African American	Biological Sciences

Note. IS – Interviewed student ID coded used to protect student identity

All interviews were conducted using audio recording devices, transcribed into a Microsoft Word document using DSR, and then uploaded to Dedoose for coding and analysis. Each interview used a pre-determined protocol and lasted approximately 45 minutes to one hour. Although a pre-determined protocol was used, the emergent nature of this study required adaptation to address relevant patterns and themes that arose during data collection. Samples of the protocols used for this study are presented in Appendix B. While limited in number, the participants were reflective of the diverse background of EOF students on the New Brunswick campus.

Faculty interviews. To obtain faculty participants, the researcher reviewed the university course schedule and faculty directory. This process allowed the identification and retrieval of contact information for General Chemistry 161 course instructors. Potential faculty participants were contacted using email as the primary form of communication. As with the student sample, Chemistry faculty were purposefully selected to ensure their course load included at least one section of Solid GEMS General Chemistry 161 or 162. Selection for participant in this study also required faculty to have taught General Chemistry at the university for at least five years and understand the Solid GEMS Chemistry model. Ideally, the faculty members would have taught both Solid GEMS and non-Solid GEMS sections. Designating a five-year chemistry teaching requirement supported the selection of faculty who were sufficiently knowledgeable of the General Chemistry course curriculum. Selecting faculty who taught both courses offered insightful comparative dialogue regarding the Solid GEMS and non-Solid GEMS course pedagogy to enhance understanding of phenomenon under study. This selection process identified two faculty members as potential participants.

Faculty interviews were used to identify Solid GEMS and non-Solid GEMS pedagogical practices and investigate faculty perceptions of instructional influence on student successful completion of the introductory General Chemistry 161 and 162 course sequence. The interviews assisted with the identification of instructional practices specific to the Solid GEMS Chemistry course. Two faculty members were interviewed twice during the course of the semester. Each faculty member provided instructional support for both Solid GEMS and non-Solid GEMS sections of General Chemistry at the university. Their familiarity of Solid GEMS and non-Solid GEMS instructional models allowed the researcher to gather comparative information. Faculty member X, the Solid GEMS instructor, was interviewed during the fall of 2012, and faculty member Y, the non-Solid GEMS was interviewed during the spring of 2013. To accommodate faculty schedules, each interview took place before or after the class lecture. The first interview was conducted before the first examination, and the second before the final examination. This process was chosen in consideration of the potential influence of student familiarity and test performance on faculty responses.

Instructors were asked to share their beliefs on the fundamental differences between the Solid GEMS and non-Solid GEMS course instruction, and how they believe those differences may impact student success and persistence in the sciences. Through these discussions, the researcher gathered data useful in understanding the differences and similarities between both courses. Interviewing the Solid GEMS and non-Solid GEMS faculty members supported the compilation of instructional techniques and learning artifacts for each course. Comparison of interview transcripts and classroom observations allowed the researcher to identify potential bias and contradictions in faculty responses. Faculty also provided a historical perspective of course evolution and student performance to confirm or disconfirm data results. These discussions assisted in answering the research questions and identifying instructional practices that distinguishes Solid GEMS Chemistry pedagogy from non-Solid GEMS pedagogy.

Classroom observations. Four classroom observations were conducted during the 2012–13 academic year. Two observations were conducted during the fall of 2012, between September 2012 and December 2012, and two during the spring of 2013, between January 2013 and May 2013.

On October 10th and November 14th, the researcher observed the Solid GEMS and non-Solid GEMS course fall lectures, respectively. And on February 12th and April 12th, the researcher conducted classroom observations of the Solid GEMS and non-Solid GEMS course spring lectures, respectively. These dates were strategically chosen to avoid exam and review sessions. Faculty members were notified of the observation date ahead of time. During these observations, the researcher observed the entire Solid GEMS (80 minute lecture) and non-Solid GEMS (55 minute lecture).

To support an uninterrupted class lecture, the researcher sat among the students while observing the classroom and gathering information. In addition to notes taken using a laptop, observations were recorded using audio/video devices. Review of both GEMS and non-Solid GEMS lectures provided comparative data related to faculty instructional pedagogy and student experiences. The classroom observations assisted with corroborating student statements, as well as supporting adaptation of interview protocols to enhance understanding of student experiences (Patton, 1990). Additionally, classroom observations allowed the researcher to "experience" the Solid GEMS phenomenon which supported researcher familiarity with the classroom setting to help interpret and understand the student descriptions of their experiences.

Protocols are important to soliciting data to address specific research questions. Instruments used in this study were drafted using standard of protocol development outlined by Creswell (2007) and Patton (1990). A detailed description of protocol development is presented below and samples are provided in Appendix B.

Protocols

Interviews encourage in-depth exploration of the phenomenon being studied. Creswell (2007) stated that "the important point is to describe the meaning of the phenomenon for a small number of individuals who have experienced it" (131). As Creswell suggests, a small number of participants can tell a lot about what is being studied. Skillfully crafted protocols support the use of a small sample size and can provide rich data to explain a phenomenon.

The interview protocols for this study were designed using the initial protocol developed for the 2012 pilot study. Using the findings of the pilot study, focus group, and classroom observation data, the researcher developed interview questions to facilitate participant responses with minimal need for clarification. Interviews with faculty and students were conducted using

Patton's (1990) recommendations for semi-structured interviewing. Using this approach enhanced the experience for participants creating a relaxing environment that supported in-depth exploration of the phenomenon under investigation. The student and faculty interview protocols included closed and open-ended questions. These questions served as core inquiries which were used to encourage free discussion. Follow-up questions were used to encourage dialogue and assist in ensuring that the data collected would assist with answering the research questions.

The focus group protocol was developed to encourage student conversation regarding their experiences in the General Chemistry. The protocol provided a timeline, an introduction, discussion guideline, date, time, and location. Protocol questions focused on student high school science experiences, chemistry knowledge prior to college enrollment, student attitudes towards science, and classroom behaviors and participation. The researcher encouraged free discussion while ensuring that the session would conclude within the allotted time period. At least ten minutes before the end of the session, participants were asked to share any information that they believed would help the researcher understand their experiences. This session was video-taped to support identification of participants and accurate accounting for individual statements. As previously mentioned, all participants were given prior notice of video-taping and agreed to participate.

Classroom observations supported identification of Solid GEMS Chemistry pedagogical practices. The observation protocol included information about the site, time, date, and location. A detailed description of the course section number, reason for the observation, observer information, targeted group, data collection methods, and notes section was recorded on each protocol. Using these protocols, the research recorded essential information regarding Solid

GEMS Chemistry pedagogical practices. Detailed versions of the instruments used for this study are included in Appendix B.

Trustworthiness

Researchers are duty bound to ensure that research activities are conducted using rigorous standards to authenticate findings. To address questions of rigor, Lincoln and Guba (1986) created criteria, parallel to traditional designs, for establishing trustworthiness for qualitative research. Looking at quantitative measures of trustworthiness– internal validity, external validity, reliability, and objectivity – Lincoln and Guba (1986) devised the following parallel qualitative measures – credibility, transferability, dependability, and confirmability.

According to Lincoln and Guba (1986), credibility or internal validity supports confidence that the data offers a true reflection of the phenomenon under investigation. To meet this criteria the research ensured that interview data was transcribed verbatim and participants were given the opportunity to review and correct transcripts. Focus group participants were able to review the tape and transcripts to confirm statements. Classroom observations also served to support research findings. Williams and Morrow (2009) stated that "the use of triangulation of the data with other sources of data can help provide evidence of data quality" (p. 578). Use of multiple data collection streams, along with member checks and journaling enhanced the credibility of this study. Transferability is another measure of validity for qualitative research and ensures that applicability of research findings to other contexts. To support transferability of findings, the researcher endeavored to provide detailed explanation of research methods which included meticulous description of the site and sample. Detailed notes from observations and memos served to offer rich description of data as well as insight to potential researcher bias. Dependability and confirmability support external validity challenges. Prior to data collection, Institutional Review Board (IRB) approval was granted. The researcher completed the Human Subject Certification and followed IRB protocol. In addition to IRB audit of procedures, the researcher was guided by qualitative design and content experts who examined each component for consistency.

Quantitative Data Collection

While focus groups, interviews, and classroom observations provided insight to individual feelings regarding Solid GEMS Chemistry, these methods are limited in their ability to support researcher inferences regarding the potential influence of Solid GEMS on student success and persistence. This study uses quantitative data collection to support statistical analysis of a larger data set to investigate the potential influence of Solid GEMS Chemistry pedagogy on student commitment to science studies, which is crucial to answering the research questions: “What is the impact of Solid GEMS Chemistry on student enrollment in Organic Chemistry 307?” and “Does Solid GEMS Chemistry influence SEBS EOF student subsequent enrollment in Organic Chemistry?”, and “What factors differentiate those who enroll (persisters) and those who do not enroll (non-persisters) in Organic Chemistry?”

Whereas Rutgers offers various majors, and not all are science specific, the researcher generated a targeted list of majors for this study. The primary factor used to select the majors focused on enrollment in General Chemistry 161 and 162, since most science majors require the general chemistry two-course sequence. The researcher used the university course catalog to identify SAS and SEBS majors requiring General Chemistry 161 and 162 to generate a target list of majors. Appendix C displays a list of majors targeted for this study.

Using the University Registrar’s Student Records Database (SRDB) and Office of Institutional Research and Academic Planning (OIRAP) data, information for SEBS and SAS students who enrolled in Solid GEMS and non-Solid GEMS General Chemistry sections from 1997 to 2006 was collected. From these sources, 2,928 student records were analyzed for this study. Information collected included gender, ethnicity, school (SEBS or SAS), EOF status, Mathematics and Verbal SAT scores, course grades, GEMS enrollment, major, initial mathematics course placement, and other demographic data.

Once received, the data were uploaded into SPSS to be merged, sorted, and recoded for analysis. Use of SPSS required that some data variables be recoded using binary distinctions, as the data received from university database systems did not use binary codes. For example, the university codes for gender included Male = M and Female = F. These variables were recoded using Male = 0 and Female = 1. Additionally, the university coded ethnicity coded using the numerical range 1 through 8; however, for purposes in this study each ethnicity was recoded creating dummy variables to support use in final analysis. While the university codes African American = 3, the researcher recoded African American using No = 0 and Yes = 1. Although the university distinguishes between Hispanic (Puerto Rican) and Hispanic (non-Puerto Rican), the researcher combined these groups into the variable name “Hispanic”. The university also has categories for American Indian/Alaskan Native, Native Hawaiian/Pacific Islander, Other Racial/Ethnic Group, More than One Race, No Response, and Unknown. For these distinctions, the researcher used the variable name “Other”. For purposes of this study, Hispanic, Asian, and Other were coded using No = 0 and Yes = 1. Other binary variables included EOF status and Solid GEMS enrollment. The data also included continuous variables such as SAT scores and student grades. Table 6 provides the details for all variables used in this study.

These variables were selected to assist in examining patterns of student performance and identify possible relationships between enrollment in Solid GEMS Chemistry and student success in the General Chemistry 161 and 162 courses. These data also provide a basis for exploring relationships between student success in General Chemistry, persistence in the sciences, and specific student characteristics such as their SAT scores, gender, etc. Quantitative data collection techniques explored student success, persistence patterns, and themes to complement qualitative results. Given that multiple factors can explain student success and persistence in the sciences, the use of multiple data streams provided detailed and complete data on each student's background, in addition to information on course enrollment, grades, and progress, which was essential for the validation of research findings. An explanation of the data analysis process is presented in the subsequent pages.

Table 6

Quantitative Data Variables, Definitions, Codes, and Descriptive Statistics

Variable	Definition	Code	%/$\bar{x}$	*SD*	Min	Max	*N*
Gender	Female	No = 0, Yes = 1	57.9%		0	1	2,928
Ethnicity							
	White	No = 0, Yes = 1	49.7%		0	1	2,928
	African American	No = 0, Yes = 1	5.5%		0	1	2,928
	Hispanic, Any Race	No = 0, Yes = 1	5.3%		0	1	2,928
	Asian	No = 0, Yes = 1	34.9%		0	1	2,928
	Other	No = 0, Yes = 1	4.6%		0	1	2,928
Verbal SAT	Verbal SAT Score		587.9	7.74	25	80	2,928
Math SAT	Math SAT Score		632.8	7.11	36	80	2,928
School	SEBS Affiliation	No = 0,Yes = 1	35%		0	1	2,928
EOF Status	EOF Affiliation	No = 0, Yes = 1	3.7%		0	1	2,928
GEMS161	GEMS 161 Enrollment	No = 0, Yes = 1	9.8%		0	1	2,928
GEMS162	GEMS 162 Enrollment	No = 0, Yes = 1	9.7%		0	1	2,587
CHEM 162	Chemistry 162 Enrollment	No = 0, Yes = 1	88.4%		0	1	2,928

Table 6

Quantitative Data Variables, Definitions, Codes, and Descriptive Statistics

Variable	Definition	Code	%/$\bar{x}$	*SD*	Min	Max	*N*
Initial Math Course	Fall Semester Math Course						
	Calculus	No = 0, Yes = 1	5.4%		0	1	2,928
	PreCalculus 115	No = 0, Yes = 1	18.2%		0	1	2,928
	PreCalculus 111	No = 0, Yes = 1	5.5%		0	1	2,928
	Other Math	No = 0, Yes = 1	70.9%		0	1	2,928
RegOrgo	Organic Chem 307 Registration	No = 0, Yes = 1	54.2%		0	1	1,588
CHEM 161 Grade	Chemistry 161 Grade		2.4	0.95	0.0	4.0	2,928
	A	4.0			0.0	4.0	2,928
	B+	3.5			0.0	4.0	2,928
	B	3.0			0.0	4.0	2,928
	C+	2.5			0.0	4.0	2,928
	C	2.0			0.0	4.0	2,928
	D	1.0			0.0	4.0	2,928
	F & W	0.0			0.0	4.0	2,928
CHEM 162 Grade	Chemistry 162 Grade		2.2	1.09	0.0	4.0	2,587
	A	4.0			0.0	4.0	2,587
	B+	3.5			0.0	4.0	2,587
	B	3.0			0.0	4.0	2,587
	C+	2.5			0.0	4.0	2,587
	C	2.0			0.0	4.0	2,587
	D	1.0			0.0	4.0	2,587
	F & W	0.0			0.0	4.0	2,587
CHEM 161 Success	Chem161 Grade of “C” or better	No = 0, Yes = 1	88.4%		0	1	2,928
CHEM 162 Success	Chem162 Grade of “C” or better	No = 0, Yes = 1	72.3%		0	1	2,587

Data Analysis

To begin data analysis, qualitative data were transcribed, coded, and stored using Dedoose, a qualitative data storage, organization, and retrieval software. This software was chosen to assist with storage, centralization, and easy access to the research data. Examination of the descriptive data began with using student RUID numbers and term information to merge Excel data files received from the SRDB and OIRAP. This process supported matching data records to identify duplicates. These data file were coded to support use in SPSS, a computer-based statistical analysis software. The information was sorted by school of enrollment and student enrollment type to exclude student records not pertaining to SEBS, SAS, or full-time enrollment. Duplicate student records were removed using RUID's and term data. As previously noted, prior to 2006 the School of Arts and Sciences consisted of several independent colleges and the consolidation of those schools created SAS. Since the data collection timeline included records before consolidation and the university systems were unable to prepare a data set for SAS using current parameters, the data received included records from all schools and had to be manually sorted to remove records that were not associated with the target schools.

This study engaged independent analysis of qualitative and quantitative data to explore the research questions. Below is a detailed description of the procedures used to analyze both qualitative and quantitative data in this study.

Qualitative Analysis

Exploring student perceptions and experiences required examination of and responsiveness to data that might uncover unexpected views of Solid GEMS pedagogy. It also necessitated follow-up discussions and observations to clarify statements and observed behaviors. Given the volume and time sensitivity of data, classroom observations, field notes, interviews, and focus group discussions were transcribed within 48 hours of the initial event when possible. Immediate transcription enhanced data recall and provided the opportunity for immediate clarification of ambiguous statements to support reliability (Patton, 1990). Dragon Speech Recognition (DSR) software facilitated timely transcription of interview and focus group data and ease of transferring information to Microsoft Word for coding in Dedoose. Participants received copies of their transcripts and were given the opportunity to confirm or disconfirm the researcher's summary of their statements. Participant review of interview and focus group transcripts encouraged additional comment and correction to support accurate representative of participant perspectives and avoid misrepresentation, (Patton, 1990).

The transcribed data were uploaded and organized in Dedoose. Using Dedoose systematized the data collection process assisting with data management and storage. This was especially useful, given the volume of data collected during the interviews and focus group session (Creswell, 2007). The software package was also helpful in generating code frequency tables and matrices to assist with immediate identification of expected and unexpected themes. Some researchers challenge use of qualitative data analysis software packages, suggesting that researchers become detached from data. However, the volume of interview data and time constraints support the use of computer-assisted analysis for this study (Creswell, 2007; Denzin & Lincoln, 2000; Patton, 1990). The software centralized the coded data making it easy to identify patterns and themes. This systematic method of organization and review supported dependability of interpretations to enhanced reliability of results.

The transcribed data were reviewed and inductively coded to support understanding of each participant's experience. Each interview, focus group, and classroom observation was transcribed by the researcher to support familiarity with participant statements and encourage analytic memos to help with developing a coding structure. Immediate review of transcripts ensued to begin coding and annotating the data. Open coding was used to illustrate general categories and statements about Solid GEMS pedagogical practices. Researcher memos assisted with refining the codes to identify specific patterns and themes. This method of coding yielded a tri-level coding system.

Eighteen codes were created during the open coding phase. After applying these first level codes to each document, the accuracy of code assignment was confirmed by reviewing all documents line by line. This review allowed for notation of differences and similarities between participant experiences, as well as commonly reoccurring statements. Upon reexamination of data, the researcher decided that additional coding was needed to clarify and further categorize student responses. A coding tree was established which created second and third level codes. An example of one three-tiered code would be first level = “High School Factors,” second level = “Teachers,” and third level = “Science.” In this segment, a participant would indicate that their high school experience influenced their attitudes towards the sciences, and a teacher was particularly influential, and that teacher was a science teacher. This coding practice was repeated throughout all documents.

Table 7

Qualitative Independent Variable

Variable Name	Category
Student Attitudes	Negative = 0, Positive = 1
Student Perceptions	Negative = 0, Positive = 1
Academic Preparation	No = 0, Yes = 1

Using this descriptive coding scheme clarified information in the text to highlight student experiences. These codes were useful in identifying patterns to assist the researcher’s understanding and interpretation of student narratives. The independent variables used to examine student success were student attitudes, perceptions, and academic preparation. Students were asked about their high school preparation and whether they believe that high school prepared them for the college experience. Student academic preparation was coded in Dedoose using key words to indicate feelings of unpreparedness or preparedness. Key words or responses such as "No," "didn't," and "not really" denoted a negative response, while phrases or words such as "Yes," "I liked," and "helped me" denoted positive responses. These variables were categorized and given numerical codes to enhance the researcher's ability to infer relationships in the data. Student attitudes and perceptions were classified as positive = 1 or negative = 0. Student academic preparation was classified Yes = 1 (students feel that their prior experiences prepared them for college chemistry) or No = 0 (students feel that their prior experiences did not prepare them for college chemistry). Table 7 shows the coding scheme for the qualitative independent variables.

To address concerns regarding researcher bias, analysis of transcribed interviews, focus groups, and classroom observation notes included researcher analytic memos highlighting researcher perceptions and feelings. To enhance the trustworthiness of research findings, an analysis of research journals supported bracketing of researcher bias and was noted in the final analysis (Creswell, 2007; Patton, 1990; Wolcott, 2009).

Quantitative Analysis

To answer the research questions, Excel data files were requested and received from the university SRDB and OIRAP. These files included information for first-year students registered in General Chemistry 161 from 1997 - 2006. The data were sorted to identify a representative sample population for this study. Non-matriculated, part-time, transfer, and students not enrolled in SAS or SEBS was excluded from the data set. Once cleaned, the data were uploaded to SPSS and analysis began with a review of variable frequencies to explore the sample population demographics. Next, crosstab analysis was conducted to examine data by chemistry course enrollment (GEMS or non-GEMS), school, EOF status, gender, ethnicity, grade, and SAT scores. Last, binary logistic regression analysis was performed to examine the potential effect of Solid GEMS Chemistry on student success and persistence to Organic Chemistry.

The data set included information for 2,928 SAS and SEBS first-year students enrolled in General Chemistry from 1997 to 2006, EOF and Non-EOF. Non-EOF students were included to understand and highlight possible differences or similarities between the student populations and assist in answering the research question “What factors differentiate those who enroll (persisters) and those who do not enroll (non-persisters) in Organic Chemistry?” Student names were removed to assure participant anonymity. The researcher used student RUID numbers to facilitate matching of student records from multiple data sources. Once all of the matching was completed identifying information including the RUID was removed.

The dependent variables for this study are success in chemistry course (earning a grade of “C” or better) and persistence (subsequent registration for Organic Chemistry). The variable names used to identify success in chemistry was ‘CHEM161 Success’ or ‘CHEM162 Success’; and, the variable name used to identify persistence was ‘RegOrgo’. The binary codes No = 0 and Yes = 1 were used for each dependent variable. Each student who successfully completed chemistry or registered for Organic Chemistry was coded using 1 and each unsuccessful chemistry course grade or unregistered student was assigned a 0. Chemistry grades are continuous values and were coded using a universal grade translation scale of A = 4.0, B+ = 3.5, B=3.0, etc. Student withdrawals (“W”), incompletes (“I”), and failures (“F”) were all coded using the value 0.0. Using a scale of 0.0 to 4.0, the researcher noted that successful students earned a grade between 2.0 and 4.0, and were coded using a 1 for successful, while grades between 0 and 1.9 were coded using a 0 for unsuccessful. Dummy variables were created for grades to allow for inclusion in regression analysis. The mean grades for General Chemistry 161 and 162 are displayed in Table 6.

The independent variables for this study included EOF status, Verbal and Math SAT scores, gender, ethnicity, school, and initial mathematics course placement. All independent variables were coded using binary codes, no = 0 and yes = 1, except for SAT scores. Verbal and Math SAT scores were continuous variables with a minimum and maximum value of 200 and 800, respectively. The researcher performed frequency distribution and statistical analysis on all data variables, with additional mean, minimum, maximum, and standard deviation calculation on the SAT data. The descriptive statistics for SAT are shown in Table 6**.**

As previously noted, success is noted when students complete both General Chemistry 161 and 162 with a “C” or better; hence, students who earn a less than a “C” in either course are considered unsuccessful. This categorization is in line with STEM curriculum standards, as all Rutgers majors require completion of General Chemistry 161 and 162 with a “C” or better for major declaration or graduation.

Table 8

Descriptive Statistics for the Population

Variable	Mean	SD	N
Chem 161 Grade	2.4	.95	2,928
Chem162 Grade	2.2	1.09	2,587
Verbal SAT	587.9	7.74	2,928
Math SAT	632.8	7.11	2,928

Table 8 shows descriptive statistics for student grades in General Chemistry 161 and 162, as well as SAT scores. According to Table 8, the average course grade for General Chemistry 161 was noted as 2.4, very close to a C+ (2.5) as noted on a universal grading scale. This calculation was based on the total sample, while the average grade for General Chemistry 162 was noted as 2.2, closer to a C (2.0), which is based upon a sample of 2,587 indicative of the 341 students who were ineligible for enrollment because of their failure to complete General Chemistry 161 with a "C" or better. Other noteworthy data is the average math and verbal SAT's, 632.8 and 587.9 respectively. In addition to descriptive statistics, bivariate analysis offered correlation data for the population.

Bivariate analysis of the data revealed a negative correlation between school of enrollment and student success in Chemistry 161. Since school was coded SAS = 0 and SEBS = 1, the analysis indicated that SAS students were more likely than SEBS students to successfully complete the General Chemistry course sequence and enroll in Organic Chemistry. Additionally, the bivariate analysis showed a negative correlation between GEMS enrollment and success in Chemistry 161. With GEMS enrollment coded using GEMS = 1 and non-GEMS=0, the negative correlation suggests that GEMS students are less likely to successfully complete the General Chemistry course sequence and enroll in Organic Chemistry. And, looking at Initial Math Course Enrollment, the bivariate analysis showed that enrollment in Calculus is associated with student success and registration for Organic Chemistry. Of course, because these bivariate correlations do not control for other associations they cannot be interpreted as indicating causality.

Persistence was examined using subsequent enrollment in Organic Chemistry 307. Using student registration for Organic Chemistry 307, during the third semester of enrollment, to denote persistence, students were categorized as “persisters” and “non-persisters” Table 9 provides descriptive statistics for GEMS and non-GEMS enrollment. Using frequency and crosstab analysis techniques facilitated identification of “persisters” and “non-persisters.” These techniques were useful in highlighting specific characteristics for student persistence in the sciences.

Next, logistic regression techniques were used to explore the likelihood that student participation in the Solid GEMS Chemistry course impacted their success in the General Chemistry course sequence and persistence to enrollment in Organic Chemistry. Using the logistic regression model is most appropriate for this study for two reasons. First, logistic regression is ideal for predicting the probability of binary outcomes. The dependent variables in this study are focused on the probability of a yes = 1 or no = 0 outcome, particularly whether students are successful or persist in the sciences. Given that these are categorical outcomes with a dichotomous probability, logistic regression techniques are best suited to answer questions related to whether student enrollment in Solid GEMS supports success and persistence in the sciences. Second, logistic regression modeling uses odds ratios which allows for hypothesis testing to examine the likelihood that Solid GEMS and non-Solid GEMS participation impacts student enrollment in Organic Chemistry 307. Use of logistic regression techniques also supported examination of factors most impactful on student success and persistence. This method of analysis permitted exploration of the relationship between each independent variable to student persistence and success.

Simple linear regression techniques were used to assess the relationship between student enrollment in GEMS sections and student grades. Table 11 provides a list of the variables used in the logistic regression models. All data were coded as noted in Table 6 and examined to facilitate answering the research questions. Analysis was guided by Adelman (1999, 2006) and Tinto's (1993, 1997, 2003) conceptual frameworks.

Table 9

Characteristics of the Quantitative Sample by Chemistry Course Registration

	GEMS 161					Non-GEMS 161				
	%/$\bar{x}$	*SD*	Min	Max	*n*	%/$\bar{x}$	*SD*	Min	Max	*n*
%SEBS	49.7%	N/A	0	1	286	33.4%	N/A	0	1	2642
%EOF	15.7%	N/A	0	1	286	2.3%	N/A	0	1	2642
%Female	62.6%	N/A	0	1	286	57.3%	N/A	0	1	2642
Ethnicity										
%African Am	16.8%	N/A	0	1	286	4.3%	N/A	0	1	2642
%Hispanic	9.8%	N/A	0	1	286	4.8%	N/A	0	1	2642
%White	47.2%	N/A	0	1	286	49.9%	N/A	0	1	2642
%Asian	21.7%	N/A	0	1	286	36.4%	N/A	0	1	2642
%Other	1.0%	N/A	0	1	286	0.9%	N/A	0	1	2642
%No Response	3.5%	N/A	0	1	286	3.7%	N/A	0	1	2642
Verbal SAT	54.6	7.3	25	79	286	59.2	7.7	34	80	2642
Math SAT	57.9	7.1	36	80	286	63.9	6.9	40	80	2642
Initial Math Course										
%PreCalc111	23.4%	N/A	0	1	286	3.6%	N/A	0	1	2642
%PreCalc115	27.3%	N/A	0	1	286	17.3%	N/A	0	1	2642
%Calculus	39.5%	N/A	0	1	286	74.3%	N/A	0	1	2642
%Math Other	9.8%	N/A	0	1	286	4.9%	N/A	0	1	2642
%Chem161 Success	87.1%	N/A	0	1	286	88.5%	N/A	0	1	2642
%RegChem162	87.1%	N/A	0	1	286	88.5%	N/A	0	1	2642
%Chem162 Success	74.3%	N/A	0	1	185	82.7%	N/A	0	1	1933
%RegOrgo	50.0%	N/A	0	1	286	54.7%	N/A	0	1	2642

Table 10

List Logistic Regression Variables

Variable Name
Chemistry161 (GEMS/Non-GEMS)
Chemistry162 (GEMS/Non-GEMS)
School
EOF Status
Initial Math Course
Gender
Ethnicity
Math SAT
Verbal SAT
Chem161 Grade
Chem162 Grade

Challenges to Mixed Methods Designs

Choosing a mixed methods design supports the collection of a breadth and range of data to examine the phenomenon under study. While there are benefits to mixing quantitative and qualitative methods, there are also challenges. One challenge to mixed methods designs highlights the use of different sample sizes for quantitative and qualitative data collection and analysis (Sandelowski, 2000; Creswell & Plano Clark, 2011). Despite challenges to differing sample sizes, qualitative methods supported in-depth examination of the data and quantitative methods enhanced generalization of findings to other science coursework (Creswell & Plano Clark, 2011).

Since this study examines a phenomenon that is unique to Rutgers, the smaller qualitative sample allowed an intimate look at student experiences in a natural environment to answer the research questions. Using the larger quantitative data sample complimented qualitative methods and offered additional insight to support conclusions (Maxwell, 2013). This study employed each method independently. Once data was organized for analysis, it provided a better understanding of Solid GEMS Chemistry pedagogical influence on student attitudes and perceptions of their ability to complete a science major. Using only one method limits the researcher's perspective of the phenomenon. Integration of both methods supported review of the data in a sequential manner and allowed identification of missed information and emerging themes. Qualitative data themes and patterns were coded using comparative quantitative codes which addressed concerns regarding inconsistent data comparisons. This method supported the use of separate analysis and interpretation to draw conclusions and inferences that would not be possible using only one method.

Another challenge to mixed methods designs focuses the amount of time it takes to collect and analyze the data (Creswell & Plano Clark, 2011; Morgan, 1998). While the time it takes to collect and analyze the data is cumbersome, much of the quantitative data for this study was stored in the Rutgers database and accessible through the university's SRDB or Office of Institutional Research. Use of existing database information and statistical software significantly reduces quantitative data collection and analysis time. Notwithstanding the time required for interviewing and transcribing, the time taken to collect and analyze the qualitative data was limited by purposeful sampling and limiting the number of interviews, focus groups, and field observations to support timely completion of all tasks. These and other challenges have become less important with the introduction of computer software packages that record, store, and organize data. Use of SPSS for the quantitative data, Dedoose, and audio-video devices for the qualitative data lessened the collection and analysis time. Ongoing review of qualitative and quantitative data encouraged the identification of divergent findings to offer alternative explanations for the phenomenon.

To examine the qualitative data, the researcher used both structural and descriptive coding techniques. These techniques supported preparation of a general coding scheme to identify broad topics which were later used to focus analysis on specific research questions. These codes were then used to create comparable codes for use in matching quantitative data to better corroboration of findings (Saldana, 2009; Creswell & Plano Clark, 2011). The researcher transcribed interview and classroom observation data into numerical data for inclusion in quantitative analysis. This method addresses specific challenges to concurrent collection of data from different data streams, allowing the researcher to focus on each data stream independently for more detailed analysis and broader understanding of the research questions.

Ethical Considerations

Mixed methods designs present various ethical considerations. Site selection ensured that normal activities were not disrupted and would affect observations and data collection. Research activities were IRB reviewed and approved prior to data collection to ensure that activities were conducted to safeguard participants and make sure that no one was unduly harmed before, during or after completion of research activities. The researcher conducted classroom observations in such a manner to support uninterrupted operation of instruction. Interviews and focus groups were scheduled according to participant availability, and all participants were encouraged to review of interview transcripts to confirm or disconfirm statements. Study participants were provided full disclosure regarding the study to ensure that participants understood the purpose and use of data collected. Researcher bias in reporting findings was checked regularly throughout data collection using researcher memos, participant review, and analytic notation.

Role of the Researcher

The primary researcher for this study serves as an administrator within the Rutgers University SEBS EOF Office. This study is designed to assist the researcher, Department of Chemistry, EOF, and university administrators with information that will support student success in introductory science coursework. Noting that high schools may not have prepared all students equally, the Solid GEMS Chemistry course gives all students the opportunity to enhance their academic skills and analytical thought process to be successful in college science coursework. The researcher is an Ed.D. student in the Rutgers Graduate School of Education. She is also the current Assistant Dean/Director of the EOF and Solid GEMS Chemistry program, as well as a former EOF student which makes her sensitive to the academic concerns of EOF students.

The researcher's administrative role at SEBS places her in direct contact with EOF and Non-EOF students, as well as the Solid GEMS Chemistry faculty. Through her daily work, the researcher is confronted with the task of helping EOF and Non-EOF students successfully negotiate the SEBS academic curriculum. SEBS offers a variety of majors, most of which focus on science and technology. Whether students select a science major or one of the non-science majors, they are required to complete General Chemistry to graduate from the college. This study seeks to inform discourse regarding a problem influences EOF, SEBS and university science retention rates. As the study focused on SEBS first-year EOF students and the researcher is a SEBS EOF administrator, she was careful to ensure that participants were free from coercion and voluntarily participated in data collection activities. Participants receive full disclosure of the purpose and scope of the study using oral presentations and written consent. Each potential participant was given the opportunity to decline or ignore invitations to participate without consequence.

Mixed methods studies require review of empirical data both quantitative and qualitative. The quantitative data was collected using minimal contact with study participants; however, the qualitative data required greater intimacy with participants. A central role of the researcher is the interpretation of student experiences using observation, interviews, and narratives. Given the subjective nature of qualitative methods, the researcher remained sensitive to the ethical concerns related to participants' physical space and emotional well-being. While the researcher has completed survey design, inquiry, and qualitative research methods coursework, the researcher consults with Graduate School of Education faculty to assist maintaining neutrality in conducting this study. The researcher's curriculum vita is provided in Appendix D.

Summary

Qualitative methods encourage exploration of student success in naturalistic settings and offers value to this study (Coffey & Atkinson, 1996; Creswell, 2007; Gall, Gall, & Borg, 2007; Patton, 1990). Quantitative methods present a broad examination of the phenomenon but limits interaction with participants in their environment (Creswell, 2007; Patton, 2008). Use of qualitative methods for this study provided close interaction with participants and data which encouraged unconstrained investigation of research questions. The quantitative methods offered examination of historical data and presented a timeline for trend analysis and data corroboration. Since this study assumes that the pedagogical practices of Solid GEMS Chemistry have a positive effect on student success and hypothesis testing is large part of quantitative methods, use of quantitative methods confirmed or disconfirmed this notion. However, given its fixed nature, sole use of quantitative data would have limited exploration of themes that might emerge during the study. Qualitative methods supported consideration of participant voices and emergent factors that might influence findings. While qualitative designs are not generalizable and the subjective nature of data interpretation challenges its findings, the data offer opportunities to examine student attitudes and experiences using participant voices (Creswell, 2006; Creswell and Plano Clark, 2011; Patton, 1990; Wolcott, 2009).

This study assumes that students who earn a “C” or better in General Chemistry had positive experiences in science coursework and those experiences will lead to a positive attitude towards a science degree. Additionally, this study assumes that students who earn a “C” or better in General Chemistry are more likely to enroll in Organic Chemistry 307 immediately following completion of General Chemistry, and thus will persist towards graduation within the sciences. One limitation of this study is that it focuses on students who complete General Chemistry during their first year of enrollment and subsequently enrolls in Organic Chemistry the following semester. Students who fail to complete the General Chemistry 161 and 162 sequence during that first year or students who complete the sequence but wait to enroll in Organic Chemistry 307 or take the course at another institution may be considered “non-persisters” even though they may eventually complete the sequence.

The findings of this study have proven insightful and will benefit institutions looking for innovative practices that support student success in STEM fields. Institutions with similar student populations should use components of this study to enhance science pedagogy to improve overall retention rates. The use of select quantitative methods supports generalizability of research findings at Rutgers and similar institutions. The findings can be used by colleges and universities to enhance instructional practices to support first-year student success in introductory science coursework. Next is an explanation of research findings and recommendations for future research.

Chapter IV

Research Findings

An analysis of the data is offered in this chapter. While continuously looking through a constructivist lens, the researcher focused on using the data to explain student success and persistence. Within the context of Vincent Tinto's retention theory and constructivism, the researcher examined the data to explore the potential influence of Solid GEMS Chemistry pedagogy on two factors – success in introductory chemistry coursework and persistence to enrollment in Organic Chemistry. The discussion to follow is important for higher education administrators, particularly those at institutions conferring science degrees, as it assists with understanding how classroom instruction influences the beliefs, attitudes, and decisions of first-year students who intend to pursue science degrees. This research assists with exploration of ways to enhance science classroom instruction to support student in-class needs to increase student success in introductory coursework which can encourage persistence in the sciences (Bean, 2005). While successful course completion is important to student retention, it is particularly important to EOF students and EOF administrators. One prevailing challenge for the EOF population is that students enrolling as science majors must register for and successfully complete introductory science courses during their first year of enrollment if they are to remain on track to graduate within four years of enrollment. For EOF students, and students overall, their experiences in the initial science course and interactions with faculty can support or hinder success and retention. This makes review of classroom practices important. Of particular importance for the SEBS EOF administration is that student experiences are both educative and positive. Interactions with faculty and course material should encourage student inquiry through positive interactions and course success. The number one challenge is retaining students who intend to earn science degrees.

The subsequent pages will analyze data collected from SEBS and SAS. This data was examined using qualitative and quantitative methods to address the following research questions.

1. How do SEBS EOF students perceive Solid GEMS Chemistry pedagogical practices to influence their grades in General Chemistry 161 and 162?
2. Do Solid GEMS Chemistry pedagogical practices influence student attitudes towards the sciences?
3. What is the impact of Solid GEMS Chemistry on student enrollment in Organic Chemistry 307?
    a. Does Solid GEMS Chemistry influence SEBS EOF student subsequent enrollment in Organic Chemistry?
    b. What factors differentiate those who enroll (persisters) and those who do not enroll (non-persisters) in Organic Chemistry?

Review of qualitative data presented a clear picture of how classroom pedagogy influenced the success of SEBS first-year EOF students in General Chemistry 161 and 162. It also offered insight into how student participation in the Solid GEMS sections of General Chemistry influenced student attitudes and perceptions of science majors. In addition to looking at current student data, this study used quantitative analysis to examine historical data from 1997 to 2007 which provided insight to how enrollment in Solid GEMS Chemistry may have enhanced student successful completion of the General Chemistry course sequence and promoted subsequent persistence to Organic Chemistry.

To begin the discussion, the researcher addressed the first research question: “What are the pedagogical practices of Solid GEMS Chemistry?” An outline and explanation of Solid

GEMS Chemistry pedagogical goals and objectives is presented and followed by a discussion of student perception of how the pedagogy influences their grades in the introductory chemistry course sequence. Next, data explaining how student experiences in the course shape their attitudes towards the sciences is presented.

Solid GEMS Chemistry Pedagogical Practices

This study relied on classroom observations, faculty interviews, and printed materials to identify Solid GEMS Chemistry pedagogical practices. Printed materials included course syllabi, textbook, drills, and class notes were collected and proved useful in corroborating observed and transcribed data. While printed materials were valuable resources for this study, classroom observations and interviews with Solid GEMS Chemistry students and faculty provided a more candid lens for isolating specific Solid GEMS Chemistry pedagogical practices and highlighting their potential influence on student success and persistence. Below is an outline and explanation of Solid GEMS Chemistry pedagogical goals and objectives. The discussion also offers an interpretation of classroom observation and interview data to describe how students experienced Solid GEMS pedagogy. Included in the analysis is a discussion of student expectations of chemistry and how Solid GEMS pedagogical practices are perceived to influence student success and persistence to enrollment in Organic Chemistry 307.

General Chemistry 161 and 162 are the initial physical science courses offered for all students intending to major in the sciences. Solid GEMS is an instructional model used to teach General Chemistry and is equivalent to the General Chemistry 161 and 162 except for its pedagogical style. Witnessing high attrition rates for minority students in the sciences, the SEBS EOF Director convened a group of educators to address the problem. From this group, the Solid GEMS pedagogical model emerged to enhance minority participation in STEM fields through the modification of existing instructional practices to support greater frequency of content delivery, enhance content mastery, and promote student learning. Although the initial design targeted the EOF student population, the university recognized the benefits of the Solid GEMS model and the course was subsequently opened to all students with specific mathematics course placements.

Students enrolled in the Solid GEMS Chemistry receive the same instructional content as those enrolled in the Non-Solid GEMS sections. The difference between the Solid GEMS and Non-Solid-GEMS sections is rooted within the pedagogical design used by instructors. The literature suggests that some students arrive on college campuses lacking the abstract and critical reasoning skills necessary for scientific inquiry (Lederman, 1992; Ogan-Bekiroglu & Eskin, 2012; Osborne, 2010). With this in mind, Solid GEMS administrators designed the course to enhance student critical thinking skills using instructional techniques to engage students in learning and enhance their cognitive development. Focused on providing students with a positive instructional experience, the Solid GEMS faculty believe that science teachers should engage students at the most fundamental levels to promote interest, curiosity, and a passion for learning. Many four-year public research institutions, like Rutgers, systematically employ adjunct, part-time or temporary faculty to teach the introductory courses, and assign their tenured faculty to upper division courses instruction. This literature shows that this practice limits student engagement with senior faculty who possess more content knowledge and can promote interest in the subject which supports student learning (Eagan & Jaeger, 2009; Jacoby, 2006)

Upper division students are more aware of the skills needed to be a successful student, have acquired specific content knowledge, and are better self-directed learners, thus need limited direction from tenured faculty. Contrary to upper division students, first year students are still transitioning to college life and need help negotiating content knowledge, needing more attention and direction. Leaving the introductory courses to be taught by adjunct or part-time faculty, with limited instructional freedom to support organic curriculum restricts instruction to content delivery and stifles student interest, curiosity, and passion (Eagan, M. K. & Jaeger, A. J., 2008). The Solid GEMS faculty noted that science coursework requires a focus on instructional environments that integrate student experiences, makes the subject interesting, and support positive self-perception to encourage content mastery and learning. The Solid GEMS faculty indicated that Solid GEMS instructional pedagogy offers a “living” curriculum that promotes analytical and critical reasoning skills necessary for science learning.

Solid GEMS Chemistry instruction combines Piagetian and Vygotskyan concepts of cognitive development to enhance the in-class experience to promote abstract and critical reasoning development. The GEMS methodology merges Piagetian and Vygotskyan thoughts of how students construct knowledge to make meaning of the information presented to them. Instruction seeks to incorporate the individual and social/human interaction roles. From a Piagetian perspective, Solid GEMS instruction encourages students to ‘interact’ with chemistry using models and various artifacts to construct knowledge. Using Vygotskyan theory, Solid GEMS instruction facilitates student understanding and connection of chemistry with their familiar environment to assist with learning. To encourage the development of abstract and critical reasoning skills, Solid GEMS Chemistry offers participants an opportunity to “experience” chemistry in ways that challenges and engages their minds to promote discussion and formulate ideas about course topics. The specific pedagogical practices of the Solid GEMS model are: a) smaller class size, b) more and extended classes, c) more testing opportunities, d) problem solving, e) instructional artifacts (lecture notes, supplemental drills, chemistry and mathematics worksheets etc.), and f) faculty engagement. These activities represent the distinctive features of Solid GEMS Chemistry. Below is a discussion of how each feature supports student success in the General Chemistry course sequence.

Smaller Class Size

Typically Non-Solid GEMS Chemistry lectures at Rutgers New Brunswick enroll over 300 students while the Solid GEMS lecture enrolls no more than 150. Although the difference in lecture enrollment numbers may not seem impactful, the lecture is sectioned into recitation sessions where students engage in hands-on experimentation, problem solving and receive more individualized attention. The Solid GEMS sections enroll no more than 20 students in each recitation section, while the Non-GEMS recitation sections will enroll 35 – 40 students. The smaller lecture generates smaller recitations. The recitation sections are taught by teaching assistants who have been trained by the departments to employ supplemental instruction methods to support student learning. Teaching assistants are trained to present lecture notes, course drills, and other course material to stimulate student inquiry. Lecture topics are discussed, using detailed explanations and colorful illustrations, to actively engage student critical reasoning skills. Students are quizzed eight times each semester to provide feedback, assess learning, and notify the professor of individual student progress. Exam and quiz reviews are scheduled to encourage information recall. The recitation sessions offer the opportunity for students to have their individual questions answered by the teaching assistants and allow for peer discussion of topics. While in smaller lecture and recitation sessions, students, faculty, and teaching assistants have greater opportunity for more intimate face-to-face encounters which supports student academic engagement, knowledge acquisition, and confidence. Studies have shown that these instructional practices are important to student retention. (Adelman, 1999, 2006; Brahmia &

Etkina, 2001; Covington, 1984; Duschl & Gitomer, 1997; Marzano, Pickering, & Pollock, 2001; Sedlacek, 1976; Tinto, 1975, 1993).

Extended Class Time

Solid GEMS Chemistry students will attend three 80 minute lectures and two 55 minute recitations, compared to the Non-Solid-GEMS students who are attending three 55 minute lectures and one 55 minute recitation. Since both courses teach the same academic content over the 16 week semester, students in the Solid GEMS course will have more time in class providing extended exposure to course material in a structured learning environment. Solid GEMS faculty and administrators believe that the increased and frequent exposure to course material supports student understanding, cognitive development, enhanced abstract reasoning skills, and overall knowledge retention. One faculty member explained how with GEMS the instructor is can provide more “in depth instruction” and gets to go “step by step” through the material (referring to the extended time in class). Arum and Roksa (2011) stated that “ninety-nine percent of college faculty say that developing students’ ability to think critically is a very important or essential goal of higher education” (p. 35). Given that a primary goal of the Solid GEMS Chemistry pedagogy is to support abstract reasoning skills development, extending student exposure to course material can support enhanced learning and student course success (Chickering & Gamson, 1987; Li, Klahr, & Siler, 2006; Tinto, 1999). In a study focused on good practices in undergraduate education, Chickering and Gamson (1987) discussed seven principles that support good teaching and student learning – faculty student contact, mutual learning objectives, active learning techniques, prompt feedback, time on task, high expectations, and respect for learning styles and differences. Li, Klahr, and Siler (2006) conducted a study examining the challenges of aligning science instruction to standardized test scores. In this study, comparing affluent schools with urban schools, the researchers found that students in affluent district mastered course content in two days, while the urban district student to 2 to 3 weeks. The urban students took more time to master the course content. By adding 25 minutes to each lecture and one additional recitation, Solid GEMS increases student exposure to instructional staff and chemistry concepts which supports two of the seven principles – placing an emphasis on ‘time on task’ and encouraging contact between students and faculty. While extending faculty contact and time on task do not exclusively ensure student success, researchers argue that these and similar practices have a positive impact on student experiences and thus may support their overall success (Adelman, 1999; Chickering & Gamson, 1987; Seymour & Hewitt, 1997; Tinto, 1997, 1999, 2012).

Additional Tests/Assessment

Studies have shown that formative assessment supports the ability to address concerns with program implementation to support positive learning outcomes (Andrade & Cizek, 2010; Bakula, 2010; Black & Wiliam, 2009; Bennett, 2011; Nicol & Macfarlan-Dick, 2006). The Solid GEMS model uses this philosophy by providing more testing opportunities. Additional testing opportunities, promotes timely feedback on academic progress and allows both student and faculty to assess current knowledge. Test results help students to formulate questions and identify topics for discussion in recitation sections. Test scores also provide valuable information to faculty which assists with redirecting lecture topics to review and clarify material requiring additional review. . While the Non-Solid-GEMS students are given three tests and a final exam, Solid GEMS students have four tests and a final exam. Students in the Non-Solid-GEMS Chemistry course take 55 minute tests that cover 25% of the course material, while the Solid GEMS students take 80 minute tests that cover 20% of the course material. Solid GEMS administrators believe that students perform better when given the opportunity to demonstrate learned topics in more frequent intervals. Solid GEMS will have taken two quizzes and a test before Non-GEMS students have taken their first test. The feedback provided through these testing opportunities proves valuable to student and faculty assessment of learning. This pedagogical practice allows students to assess their knowledge of chemistry more often which stimulates critical analysis of their own learning. It also allows the faculty and teaching assistants to assess student learning more frequently to promote possible adjustments in teaching. A statistical assessment of test questions highlights student correct and incorrect responses. Using data from this assessment, the instructional staff will identify topics for review in lecture and recitation to enhance student knowledge in preparation for subsequent examinations.

Problem Solving

During recitation sessions, students engage in group problem solving activities. The recitation instructor is specially trained to facilitate group discussions that use course materials to encourage students to ask probing questions about lecture topics. While in the classroom, the Solid GEMS instructor challenged students to find “the chemistry” in all things around them. He asked students to bring “discoveries”, every day encounters with chemistry, to lecture and recitation sessions to generate dialogue and expose chemistry in a real world setting. The professor attempts to “draw” students into chemistry by making it of interest to them. He speaks of trying to create ‘passion’ for chemistry to assist with learning. When students did not offer their personal “discoveries” during lectures, the instructor provided real world examples related to the current lecture topic.

For example, during one lecture a student asked a question regarding the validity of an action that combines electrons. Specifically, the student asked, “can you take electrons from nitrogen and give them to oxygen?" In response to this question, the professor began sketching the process of electron transfer, then using a fiscal analogy he explained that "rich atoms can share their atoms with poor atoms, but the poor atoms have very little to share with the rich atoms." To offer additional clarification, he noted that "Bill Gates can give $1 million to me, but I do not have $1 million to give to him." This reflective and problem-based learning model of instruction enhances the educational experience to make chemistry topics "real" which supports student persistence by the integration of student current knowledge with chemistry concepts (Knowlton, 2003; Seymour, 2001).

The discussion provides the student with concrete examples that are connected to everyday experiences which heightens the student's awareness of chemistry. Through this heightened sense of awareness the student can engage in critical thought about chemistry – in this case electrons. The instructor is conscientious of making these analogies throughout the classroom discussion as a way of bringing chemistry to the student. Reflective learning takes place as the student uses the analogy to make meaning of electron transfer by connecting chemistry to everyday thoughts. Studies show that using problem-based learning pedagogical practices enhances the relevance of course content which promotes student interest and may influence overall success and persistence (Boyd & Fales, 1983; Frymier & Shulman, 1995; Knowlton, 2003; Wilson & Jan, 1993). Problem-based learning requires several steps – problem identification, exploration, invention/ideas, and application of ideas.

The in-class discussions engage the student in a process of examining the process for electron transfer. During the class, the professor follows the tenet of problem-based learning by using notes, handouts, and transparencies to illustrate the transfer process. Starting with the rules for bonding, the professor draws on the transparency various atoms, and through interactive dialogue, guides the student (and class) through the discovery of electron transfer. Here the student is guided through the learning process.

Instructional Artifacts

Solid GEMS faculty used various instructional artifacts during the lecture. Preprinted lecture notes, mathematics worksheets, chemistry drills, and other artifacts enhance student ability to understand and master chemistry concepts. Using SAKAI, one of the university's electronic course delivery modes, students have 24-hour access to faculty lecture notes, old exams with answers, formulas, homework sheets (drills) with answers, and mathematics worksheets. The lecture notes eliminate having to write copious notes while trying to listen and see the professor's detailed illustrations. Drills provide ongoing reinforcement of lecture and recitation discussions to keep chemistry concepts fresh. And, the math worksheets reinforce math skills for some who have limited 'practice' hand calculations.

Since sufficient problem solving and quantitative reasoning skills are necessary to succeed in General Chemistry, the mathematical problem solving drills are an important component of Solid GEMS pedagogy. To ensure that course materials are in line with the Non-Solid-GEMS coursework, all artifacts are created in conjunction with the Non-Solid-GEMS Chemistry faculty. Each artifact is carefully reviewed and modified at the end of each term to ensure that it meets the department requirements for General Chemistry coursework completion. The Solid GEMS faculty argue that the organic nature of these items contributes to student academic success, learning, and knowledge transfer.

Faculty Engagement

Currently there is only one faculty member teaching the Solid GEMS Chemistry course lecture. This instructor has been involved with the initial development of Solid GEMS, has taught the course for more than 25 years, and is actively involved with maintaining and enhancing the course structure. Observation notes that during the first class he explains course requirements and encourages students to seek assistance from him, teaching assistants, classmates, and college learning centers when needed. Expressing a desire to make the course an "enjoyable learning experience," the instructor warned students that they must attend all class sessions, read the textbook, complete the drills, and ask questions to be successful in the course. While the course is scheduled in a large lecture hall with a stage, the instructor limits his use of the stage, instead opting to position himself on the "floor" with the students, which allows him easy access to walk the aisles to engage with the students. During the lectures, he walks through the room making contact with students, looking at their notes, and asking questions. He often uses humor and current world events to introduce chemistry concepts and illustrate a point. During one lecture discussion regarding ionization, the professor encouraged students not to memorize but to learn the chemical bases so that they "know" the information and it is available for immediate recall. He stated, "If you know this (referring to the chemical base of sodium hydroxide), you know all of them. Do not memorize anything. You should always have an educated guess and do not be intimidated. Start with the basics."

The pedagogical practices of Solid GEMS Chemistry are not unique. Many teachers and faculty use similar techniques in their classrooms. What is important and exceptional about Solid GEMS Chemistry pedagogy is the consistency in application of practices and faculty commitment to student learning. For more than 25 years, the Solid GEMS model has supported student learning at Rutgers University in New Brunswick, NJ. While the model appears to have enhanced successful student progression through introductory chemistry, there has been limited research on student successful completion of the course, and its potential to support student persistence and improve student attitudes towards the sciences. Currently, assessment of Solid GEMS Chemistry success has been restricted to semester by semester grade analysis. Examination of student perceptions and attitudes has been limited to end of semester course and professor surveys. This study enhances current evaluation data by offering an examination of course grades as well as student attitudes and perceptions, and other data, to investigate how Solid GEMS influences student enrollment in Organic Chemistry 307, the next course in the sequence for science majors.

Some studies argue that student preparation is important to academic success (Adelman, 1999; Allen, 1992; Kim & Conrad, 2006; Seymour & Hewitt, 1997; Warbuton, Bugarin, & Nunez, 2001). Noting that the lack of student preparation creates frustration which hinders student success, Professor Reyes suggested that because there are more interactions with the Solid GEMS students through extended class time, the Solid GEMS course model mitigates the lack of student preparation which enhances the opportunity for student success, if students are committed. He explained that given the extended time, he is able to provide a more in-depth explanation of chemistry concepts. He also indicated that the additional hourly exams and quizzes provide faculty and students added opportunities for knowledge assessment which is important to facilitating the student learning. The additional testing opportunities allow both student and faculty to identify what students are understanding/learning. These assessments help guide faculty instruction and student self-directed learning to facilitate the learning process.

Low mathematics placements place Solid GEMS students at risk of failure. Faculty interactions and in-depth explanations of chemistry concepts offer students a more intimate look at chemistry which makes the material more personal. Faculty and students have noted that the time spent going over the material, in detail, assists with knowledge acquisition which helps with understanding and learning. Discussions with Solid GEMS students suggest that course pedagogical practices do influence their course grades, attitudes, and perceptions towards the sciences. Student interview data indicate that the instructional artifacts, faculty interactions, additional quizzes and exams, and extended class time are valuable to their success and positive attitudes towards the sciences.

After identifying Solid GEMS pedagogical practices, I began examining student perception of how the Solid GEMS instructional practices may have influenced their grades in chemistry and their respective attitudes towards the sciences. The following pages explain student attitudes and perceptions of Solid GEMS pedagogy, how those feelings influence student success in the course, and what impact student experiences had on persistence or student enrollment in Organic Chemistry 307.

Student Attitudes and Perceptions

Review of student interview and focus group data provided in-depth understanding of student perceptions and attitudes. Using Dedoose to store and organize qualitative data, a coding system was created to assist with identifying patterns in student narrative. While coding the data, I identified more than 800 excerpts with over 228 (28.5%) excerpts related to student attitudes and perceptions. Coding focused on key words to highlight patterns related to student feelings, perceptions, and attitudes. Key words such as “I believe,” “I feel,” and “I think” were used to indicate statements relevant to student feeling, perceptions, and attitudes. For example, when speaking about her first day in the Solid GEMS Chemistry class, Andrea, a focus group participant, noted, “Okay. So, the first day…when I got there, I felt as if I was prepared…” Her suggestion that she “felt as if [she were] prepared” provided an indication of her perceived preparedness for the course and was coded for use in analyzing student perception and attitudes toward the sciences. Use of these and similar phrases to denote student perceptions and attitudes enhanced identification of patterns necessary for the evaluation of student experiences. These identifiers also enabled the assessment of how Solid GEMS pedagogical practices influence those experiences, perceptions, and attitudes towards the sciences.

Class Size: Attitudes and Perceptions

Solid GEMS offers students the opportunity to attend lectures with fewer students than the Non-Solid GEMS sections. On average the Solid GEMS sections enroll approximately 150 students while the Non-Solid-GEMS sections will enroll 300 or more. Some studies show that class size does not impact student learning; others argue that class size does matter (Borland, Howsen, & Trawick, 2005; Chapman & Ludlow, 2010; Hoxby, 2000; Kerr, 2001). Review of data collected for this study show that students enrolled in the Solid GEMS sections believe that the smaller class size supports their connection with faculty and promotes interest in the subject. When asked “What ways do your professor’s instructional styles influence your learning?” one student indicated that “it's just easier for the professor to help out the kids that actually need help instead of going on with the lecture…” As first year students are transitioning from high school to college, many face the challenge of acclimating to a new social and academic environment. This adjustment is particularly stressful as they learn to adapt to different living and classroom environments. The classroom structures that promote large lecture halls seem to be most challenging, since many students are most familiar with smaller high school classroom environments. When asked to reflect on changes in instructional practices from high school to college, Terri replies:

> The lecture that I have now is a lot different compared to high school…because the lecture I have right now is pretty much, well, you’re in a classroom with 300 other people. And then the professor doesn't pay attention [to] you specifically. They just kind of talk about the subject and they kind of finish the lecture. But in

high school… you can actually talk to the teacher and [there] is more interaction.

The findings from class size literature are inconclusive. Hanushek (1999) suggested that class size has limited impact on student success while others argue that class size has a large impact on achievement (Glass, Cohen, Smith, & Filby, 1982; Finn & Achilles, 1990, 1999; Molnar, Smith, Zahorik, Palmer, Halbach, & Ehrle, 1999). Notwithstanding challenges to the impact of class size to student achievement, studies have shown that class size has a great impact on students enrolled through the EOF program.

When looking at the EOF student population, class size does matter. Biddle and Berliner (2007) argued that "gains [from class size reduction] were … most notable for students who came from groups traditionally disadvantaged in education." While much of the literature focused on class size and achievement is inconsistent and geared toward secondary schools, it is important to note that parents and students use their secondary school experiences to make college decisions. Based upon educational reform efforts, many high schools have reduced their teacher-student ratios and prospective students are looking at faculty-student ratios when making a college choice. Keeping this in mind, post-secondary institutions must consider class size effect when designing instructional models for incoming students, particularly those from educationally disadvantaged groups interested in the sciences. Students are coming to campuses with high aspirations and given the high cost of education for both students and institutions, it is wise to consider all factors that influence individual enrollment decisions.

Extended Class Time: Attitudes and Perceptions

In addition to class size, Solid GEMS offers students extended classes and an additional recitation session. When discussing the impact of the extended class time on student learning Professor Reyes stated, "I see them twice a week, plus [during] office hours; that is more than enough to build a relationship." When asked about the additional recitation session offered to

Solid GEMS participants, Terri remarks:

> The recitation teacher really polishes my knowledge of the material, because I ha[ve] to hear it a second time for me to get it. She just explains it in a different way [than the faculty member]… And you can bring it together and then it will help you even more. So, I feel like that's [the second recitation] really helpful.

When speaking of the 80 minute Solid GEMS lectures verses the 55 minute Non-Solid GEMS lectures, Sarah goes on to say, “that the lectures are longer is always good.” Some students are challenged to understand the benefits of the extended time and additional session, but will later express appreciation of the course structure, noting how other students appreciate the Solid GEMS course structure. Sarah was asked about her perceptions during and after the first day of class. She stated:

> The first thing [I thought] was, I have Chem[istry] every day! I was like how am I going to do this? I thought you only had Chem[istry] three times a week, then [the professor] told us, “you are in Solid GEMS. We go slower”, and then I [thought] I think I can do it. I [thinking] why am I in Solid GEMS? I think I can do the three-day one [Non-Solid GEMS Chemistry]. But then as [the class] went on, I heard about people in regular [Non-Solid GEMS] Chem[istry] struggling.[Then] I'm pretty happy that I'm in this class [Solid GEMS] it's better for me. [The professor] does go really slow and explains most of the things better. So, even people who are in Non-Solid GEMS… friends come to my lectures. They [tell me] “yeah [the professor] explains it much better my professor.

Shelia acknowledges the significance of the two recitation sessions on her success in the course stating:

> It is the recitation [that] really polishes my knowledge of the material, because I had to hear it a second time for me to get it. [In the recitation, the instructor] explains it in a different way so you get all aspects… So, I feel like that is really helpful. Especially, [having recitation] twice.

Students are in class more often which supports understanding and learning of course material. Students see faculty more often which encourages interactions that foster academic relationships. These actions are important for student retention. As suggested in Sarah’s response, the Solid GEMS course offers a different instructional model that attracts students who need different instruction. While this does not indicate that one model is better than another, it does present a challenge for institutions to address the various instructional needs of diverse student populations.

Faculty Engagement: Attitudes, And Perceptions

Tinto and other researchers have studied the influence of institutional factors on student retention offering evidence that positive faculty interactions support lower student attrition. The Solid GEMS pedagogical model makes the professor accessible inside and outside of the classroom. Using instructional techniques such as molecule sets that offer visual comparisons of compounds and structures and call-response classroom techniques to engage students in active dialogue during lectures, the Solid GEMS model attempts to provide an interactive classroom experience. To promote student and faculty contact, the professor meets with students before and after class, in addition to hosting weekly office hours. Regarding faculty availability, Shelia remarks:

> He's [the professor] really interactive and uses a lot of analogies [which] makes it easy to learn and know the material. He really cares about the students. I forgot what day it was, but it was last week [when] he stayed 20 minutes extra time in order to go through the whole exam. A lot of people left, but it shows that he cares more than the students that are taking his course do.

In the pilot study I conducted in 2012, students indicated that “faculty caring” was important to their success in the science courses. Shelia earned a “B” in the Solid GEMS course which adds support to the notion that positive faculty interactions can influence student success. Her comment illustrates how student perception of faculty caring about their success may influence academic performance and persistence. During the focus group discussions, study participants indicated that the professor’s ability to connect with students is a factor in their understanding and success in the course. Sharing her experience in the Solid GEMS lecture, Mary noted that the professor asks many questions during the course of the lecture and “he will actually wait for you [students] to respond… It keeps you thinking." Simone shared an experience where the professor used humor to assist students with translating and understanding a lecture topic. She stated, "[the professor will say] something and he will make a joke out of it. And I think that helps you memorize [the material]." The literature advocates the importance of faculty interactions to student success and retention. The participants in this study have shared experiences that identify the significance of these interactions on their learning and success in Solid GEMS Chemistry.

While students speak highly of faculty interactions inside the classroom, most students in this study have had limited contact with the professor outside of class. Since the Solid GEMS course meets five days per week, which is different from most classes, the students noted that their academic schedules prevent them from meeting his scheduled office hours. Mark stated that while he appreciated the Solid GEMS concept he "would [have liked to be] in [Non-Solid GEMS] Chemistry just because [it gives] more flexibility in scheduling. [I would] have recitation once a week and lecture three times a week instead of two recitations." Notwithstanding this challenge, Shelia indicated that the professor is available to students after class and for extra review sessions.

Additional Tests/Assessment: Attitudes and Perceptions

Another important component of Solid GEMS methodology involves formative assessment using multiple quiz and test opportunities. Studies show that use of formative assessment techniques support pedagogy that tracks student understanding and allows the instructor to monitor student learning (Bakula, 2010; Black & Wiliam, 1998; Duschl & Gitomer, 1997). The Solid GEMS course provides students with four exams verses the three exams given in Non-Solid GEMS sections. This practice allows students to be tested on fewer topics to reduce the potential for information overload. The Solid GEMS pedagogical model contends that additional testing opportunities allow students to review and absorb concepts in "smaller chucks" which potentially enhances information recall. Faculty noted that offering these multiple testing opportunities was designed to allow students to process less information prior to tests/quizzes because the targeted population is not only learning chemistry, but also enhancing their mathematical skills to learn how to apply those new skills to chemistry. Focusing on 'smaller chunks' of material, is thought, to alleviate test anxiety and promote information recall. When asked about the additional testing opportunities in Solid GEMS, Shelia remarks, "the quizzes are pretty good because you know they can make it [your grade] better or worse. So, it is really helpful." Mark, a student who took Solid GEMS Chemistry 161 and then registered for Non-Solid GEMS Chemistry 162, shared his comparison of the two course methodologies by stating:

> Solid GEMS [is] broken up more. So you cover material in smaller bits of information that's more spread out. While General Chemistry [Non-Solid GEMS] is just like a lot of information that is jumbled in and you are supposed to absorb it.

Review of the pedagogical practices of Solid GEMS yields nothing unconventional about its practices. Studies argue that smaller classes, extended class times, and formative assessment are important to learning and understanding. Engaging these practices and using specially designed instructional artifacts have provided students with maximum exposure to chemistry and situated chemistry concepts within the contextual realm of student lives. Through daily exposure and concrete experimentation, Solid GEMS contextualizes chemistry with student everyday interactions and enhances student learning. But how do these practices influence student grades and attitudes towards science? An examination of student and faculty narratives attempts to explore student perception of how Solid GEMS influences their grades and attitudes towards the sciences.

Pedagogical Influence on Student Success/Grades

When examining student narratives, students indicated that class size was important to their perception of how the Solid GEMS course influenced their success in chemistry. Students in this study explained that their high school environments presented opportunities where the class size was no more than 15 – 25 students in each class. When speaking of their transition from high school to college, most students shared thoughts of how introductory college courses (psychology, mathematics, chemistry, and biology) were scheduled in 200 – 300 seat lecture halls where they felt their ability to get the instructor’s attention was limited by the number of students in the class. Paul, a Non-Solid-GEMS student, stated that because he was highly successful in high school chemistry he had felt “overly confident” in his ability to be successful in the course. However, once he walked into the large lecture hall he began to feel overwhelmed and less confident. He stated that in high school:

> [Chemistry] was really easy. I really didn't have to put much effort into it. It was just something I picked up right away and I did really well in the course… When I took tests, I didn't really need to study. It was more of me paying attention and understanding it really quick.

As a Non-Solid-GEMS student, Paul is experiencing less classroom contact, less formative assessment opportunities, and less faculty interactions. Given this statement regarding his high school science experience, Paul may have benefited from the Solid GEMS model. The Solid GEMS smaller class size, particularly the recitations, may have lessened Paul’s anxiety. Two other students shared similar high school verses college chemistry experiences. Terri, a Non-Solid-GEMS student, stated:

> [College Chemistry is] on a different level… than in high school. The information [is] more in depth and intense. It is not as general as in high school. In high school it goes fast. But in college, it's like every single level goes deeper and deeper and stuff.

Mark, a Solid GEMS student, stated, "I thought it was going to be pretty easy taking General Chemistry. I was totally wrong. Well my high school experience with science was pretty easy. And, I was like college will be the same thing…"

These statements illuminate the challenges faced by higher education curriculum developers, particularly those in the sciences areas. Science departments are challenged to increase interest in their majors and must contend with student perceptions based upon high school experiences. As Solid GEMS methodology is focused on skills development as well as content mastery, its instructional pedagogy supports student need for innovative teaching. Both Solid GEMS and Non-Solid-GEMS courses provide sound chemistry instruction where students are learning and performing well. The Solid GEMS course pedagogy has greatest impact on students who are in need of a different type of instruction. Looking through a constructivist lens, the GEMS pedagogy attempts to meet the student's individual academic need, as much as possible. Based on Piagetian theory, GEMS uses its instructional practices to engage student self-learning allowing them time to absorb, practice, and discussion chemistry concepts in order for them to make meaning out of the information presents. Using Vygotskyan theory, GEMS provides instruction that engages the student's social/human interactions to assist with knowledge acquisition; and, using additional tests it gauges the student 'zone of proximal development' to determine what students know, may need to know, and are ready to learn. The traditional lecture format (non-GEMS) offers less opportunities for this type of engagement.

For example, students in Non-Solid-GEMS Chemistry who have had inadequate high school preparation would probably do better in the Solid GEMS Chemistry course. Conversely, students who have had adequate high school preparation may excel in the Non-Solid GEMS course. An excerpt from my interview with Sarah, a Solid GEMS student, offers one student's opinion of what most students in this study have indicated.

> Sarah: “I don’t understand why they can't just make [Non-Solid GEMS] Chemistry the same way they make Solid GEMS. Because, it feels like the people in Solid GEMS have it [a] lot easier than the people in Non-Solid GEMS.”
>
> Researcher: “And, it is easier because of the time or ..?”
>
> Sarah: “Yeah. I feel like the time and the material [is] a lot less. Even on the quizzes, you don’t need to know as much as you need to know on the [Non-Solid-GEMS quizzes].”

Commenting on how professors can enhance instructional practices to influence student learning, Shelia remarked, “there should be a blend of all types of learning.” She reflects on how Solid GEMS instructional practices support her learning by stating, “[The Solid GEMS instructor] gives you a full lecture of everything that you have to know. And [the lecture] is longer so that [the professor can] talk more about the material. I feel like that is better.”

Review of student narratives show that participants in this study specifically highlight the benefits of the Solid GEMS Chemistry extended class time, additional testing opportunities, smaller lectures, and faculty interactions as contributors to their success and understanding of chemistry. Students in the Solid GEMS sections indicated that there are specific benefits to the Solid GEMS pedagogical model which have influenced their course grades. Additionally, the Non-Solid GEMS students acknowledged the potential benefit of Solid GEMS instructional methods on student success. As noted by Sarah, her classmates attend the Solid GEMS lectures because “he explains it better.” And Paul indicated that he asks Solid GEMS students for copies of their drills to support his understanding.

Both Solid GEMS and Non-Solid-GEMS students have noted the potential influence of Solid GEMS pedagogical practices on their grades, but how do these practices influence their attitudes towards the sciences? To assess student attitudes towards the sciences, I conducted a thorough review of interview, focus group, and observation data. The focus group was most instrumental in providing information about student attitudes. Although the group setting was less intimate than the one-on-one session, students appeared to feel very comfortable sharing both positive and negative feelings regarding Solid GEMS Chemistry instruction. The focus group discussion centered on pedagogy and how it impacted learning. Student dialogue was invigorating and remained engaging throughout the sessions. When I asked students why they chose a science major upon enrolling at the university, the responses were not that divergent. William was the first to open up about his feelings.

William, a SEBS first-year EOF Solid GEMS student, enrolled at SEBS with the intention to pursue an animal science degree and possibly attend veterinarian school, but he also had a strong interest in music. His passion for music was great; however, he noted that he had "better pick a profitable major." When speaking about his major choice William stated:

> Well, what happened [was] the recession. And there are no jobs… Basic jobs, like everyday jobs that are easy to come by. Out of all the fields, the science field has the most opportunities in it. In the end, the mistake that I made was thinking… [that] despite the rigorousness of the potential courses I would have to [pursue] that career [animal science]; because, I would have a career promised for me somewhere. And out of all my courses I took in high school, I liked biology … But, it wasn't something that I liked more than anything else. I like[d] my English class equal to my biology class [and] I liked the music courses… And I liked other things. It's just that, out of all those career options science is the only one that has a vacancy. I guess.

Not unlike William, students in this study selected a science major because they "liked" science in high school, the science teacher made the experience "fun", or there was some connection to the science teacher. Mark indicated that his high school Physics teacher "was really helpful and I got along with him personally, too. And that helped me a lot… and I was one of the top students in the class." He went on to say that:

> Throughout my [high school] science classes I learned that science is always growing and there is never a limit… And I wanted to major in a specific field that's really never ending. Science is like all around you. You discover a lot of neat things that have not been previously discovered before. And, every year it's like they are discovering something new with science. And, I like discovering new things.

These narratives provided a road map for assessing how instructional practices shape student attitudes and perceptions of the sciences. One-on-one interviews and the focus group discussion suggest that student and faculty interactions that create a "fun" and "likeable" atmosphere promote student interest in course material and encourage positive attitudes towards the subject matter. In recognition of the importance of high school teacher interactions, study participants were asked about their interactions with the Solid GEMS Chemistry faculty and how those interactions influenced their success and belief in their ability to be successful in chemistry. John, a participant in the focus group stated:

> "[The professor] is interactive with us. He does more than other teachers do. He actually printed and wrote everything out [for us]. [He] draws different diagrams and stuff… Normally, he writes everything out and I guess he goes over it. [My] other teachers just go over [the material]."

Charkins, O'Toole, and Wetzel (1985) studied the link between teacher instructional styles and student learning styles to assess student attitudes towards an economics course. Looking at course content delivery and how students received the material, Charkins et al. found a positive link between teaching and student learning styles and student attitudes about coursework. Two important findings in this study were that large gaps between a teacher's instructional styles and student learning styles created large gaps in student learning and achievement. When commenting on how the professor's teaching style failed to complement his learning, William stated that:

> I am giving enough attention to try to learn [chemistry] and it's really not coming to me. Where do I go then? I already have the textbook [and] I'm not getting it from [the textbook], the lecture, or the drills.

Charkins et al. (1985) also found that the larger the divergence of the teaching style from student learning styles, the less positive the student's attitude towards the subject. Narrative from students in this study supports this finding in many ways. Study participants indicated that faculty instructional practices that complement student learning styles influenced individual belief in ability to be successful in chemistry. When speaking of an instructional practice that fueled his interest in science, Mark indicated that hands on experiences were important. Mark stated:

> [In a physics class] we made rockets and kept them outside until we could launch them like 300 feet in the air. [In chemistry], we did basic lab experiments involving chemical reactions and chemical change… No one gets interested from just reading a textbook. When you get to do [it], when you learn science hands on its a lot more interesting and you learn a lot more. [You] actually get a bird's eye view of what's going on instead of learning it from a book.

In 1984, Martin Covington described a self-worth theory of achievement noting "a central part of all classroom achievement is the need for students to protect their sense of worth or personal value" (p. 4). If classroom practices are not facilitating individual learning, students will not be successful. If students are not successful their sense of self-worth is compromised which may lead to dropout and attrition. Considering Covington's self-worth theory, it is not surprising that students' positive attitudes can be linked to convergent teacher instructional style and students learning style. The Solid GEMS instructional model presents instruction to engage multiple learning styles. From the lecture notes to in-class demonstrations, Solid GEMS instructional methodology blends teacher and student styles to support positive learning outcomes.

In their book, *Classroom Instruction That Works: Research-Based Strategies for Increasing Student Achievement*, Marzano, Pickering, and Pollock (2001) shared nine useful strategies for supporting student achievement. The nine strategies are:

- Setting objectives and providing feedback
- Reinforcing effort and providing recognition
- Cooperative learning
- Cues, questions, and advance organizers
- Nonlinguistic representations
- Summarizing and note-taking
- Assigning homework and providing practice
- Identifying similarities and differences
- Generating and testing hypotheses

Tinto (2002) shared similar strategies for student achievement by warning that effective teaching pedagogy should engage clear expectations, ongoing assessment, feedback, and engagement. In reviewing these strategies, I noted that the Solid GEMS Chemistry instructional model incorporates many of them. The professor presents and reviews the Solid GEMS syllabus on the first day of class to ensure that all students are aware of course goals and objectives. Through its multiple testing opportunities, Solid GEMS provides ongoing student performance feedback, reinforcing course objectives to promote understanding and learning. The multiple testing opportunities allow for continuous feedback on academic progress to assist both students and faculty to meet learning outcomes and acknowledge content mastery. Lecture notes offer a direct summary of textbook chapters giving students a snapshot of the chapter topics. Supplying the lecture notes encourages students to focus on the lecturer, requiring less emphasis on note taking and more attention on course content. Course drills provide ample homework, encouraging students to practice course material while challenging them to generate hypotheses as they think about chemical compounds and structures. These and other Solid GEMS pedagogical practices assist with delivering course content that effectively supports student achievement.

As is noted, the Solid GEMS instructional model has incorporated many aspects of successful teaching pedagogy. Effective teaching methodology supports student success and assist institutions with retention efforts. Many strategies for reducing student retention focus on student and institutional factors outside of the classroom. Tinto (1997, 1999) cautioned that retention efforts that focus solely on factors outside of the classroom produce marginal results. To effectively impact retention, institutions must revisit classroom instructional practices. Review of Solid GEMS pedagogical practices and student narratives indicate a positive relationship between pedagogy, course grades, and student attitudes towards coursework. Speaking of her perception of how Solid GEMS influenced her course grade Sarah stated:

> I heard about people in [Non-Solid-GEMS] chemistry and they are struggling. I am pretty happy that I am in this class. I feel like it's better for me. [The professor] does go really slow and he explains most of the things better [than the professor in Non-Solid-GEMS sections]. People who are [my] friends come to my lectures. They [say], yeah he explains it much better my professor.

When asked about Solid GEMS instruction and her attitude about science, Sarah went on to say:

> I am understanding everything so much better. I am doing good on the quizzes. I am like oh yeah I know how to do this. And, when I get my quizzes, I am like oh yeah. I feel good. I know this. This is why I get [good] grade[s].

Sarah's experience in the Solid GEMS course appears to give her a positive perception of her ability to succeed. The excitement expressed when she states "I know this" and "this is why I get [good] grades" suggests that Solid GEMS pedagogical practices have influenced her perception and attitude towards science. Stating that her friends attend the Solid GEMS lectures suggests that students not enrolled in the course perceive that its classroom practices are effective in promoting understanding and course success. Studies show students are successful when they feel validated and their confidence is heightened, which creates a positive attitude and feelings of self-worth (Charkins et al., 1985; Covington, 1984). Covington (1984) wrote, “Perceptions of ability are critical to this self-protective process, since for many students the mere possession of high ability signifies worthiness. Moreover, ability is widely perceived as a major cause of success…” (pg. 4).

Interview, focus group, and narrative data highlighted positive student perceptions and attitudes about Solid GEMS pedagogical practices. Sarah noted that her sense of self-worth has been heightened by her experiences in the Solid GEMS course. Solid GEMS Chemistry pedagogical practices appear to have influenced first year SEBS EOF students’ success, perceptions, and attitudes towards the sciences. While student narratives demonstrate that first year Solid GEMS students have experiences that support positive perception of individual ability in and attitudes towards the sciences, it does not provide a clear picture of the characteristics associated with persisters. To explore Solid GEMS impact on student enrollment in Organic Chemistry this study used demographic data. Student grades, course enrollment, and other demographic factors were uploaded to SPSS to determine if participation in Solid GEMS influences subsequent enrollment in Organic Chemistry and what factors distinguish persisters from non-persisters.

Student Success and Persistence to Organic Chemistry 307

The participants in this study have provided rich narrative indicating their perception of how Solid GEMS course pedagogy influenced their success in chemistry and attitudes towards the sciences. While student perceptions are important, it is also equally important to assess actual success and the impact of success on student persistence when examining these phenomena. This study defines success as earning a "C" or better in the General Chemistry course. This definition were chosen based upon the Rutgers University Department of Chemistry's position explaining that students who earn a letter grade of "C" have demonstrated sufficient content mastery to move to the next course in the sequence. Course grades are earned through examinations and quizzes. The grading system is standard across the GEMS and non-GEMS courses; and, because there are 3 tests for GEMS students and only 2 for non-GEMS students. The students do not take the same tests and quizzes, however they all take the same final exam. As this study seeks to determine the immediate impact of Solid GEMS pedagogy on student persistence and more time would be needed to follow students through graduation, persistence is defined as subsequent enrollment in Organic Chemistry 307 after completion of the General Chemistry 161 and 162. This definition is chosen because Organic Chemistry 307 is the next course in the academic course sequence for science majors.

Successful completion of General Chemistry 161 and162 is required for enrollment in Organic Chemistry 307 hence analysis of the data began with examining predictors of success in General Chemistry 161. Next to determine predictors of student success in General Chemistry 162, an analysis of student success in General Chemistry 161 and subsequent enrolled in General Chemistry 162 was initiated. Finally, an analysis of student enrollment in Organic Chemistry 307 was conducted to determine predictors that differentiate "persisters" from "non-persisters". In this study, "persisters" were defined as students who enrolled in Organic Chemistry 307 subsequent to completion of both General Chemistry 161 and 162; and, "non-persisters" were defined as those students who did not enroll in the course. "Non-persisters" also included students who failed to complete 161 and/or 162, as well as those who completed 162 but did not enroll in Organic Chemistry.

In additional to review of the descriptive statistics for student successful completion, both linear and logistic regression techniques were used to estimate the effects of GEMS participation on student grades, success in the course, and Organic Chemistry registration controlling for all other independent variables. The variables used in this analysis included School, EOF status, GEMS 161, GEMS 162, CHEM 161 grade, CHEM 162 grade, Organic Chemistry registration, Initial Math Course, Gender, Ethnicity, Math SAT. Table 11 presents the logistic regression results examining the effects of School, EOF Status, GEMS 161 Status, Gender, Ethnicity, Initial Math Course, and Math SAT on student success in Chemistry 161.

Table 11
Logistic Regression Examining Students Earning "C" or Better in Chemistry 161

Model	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-3.150	.696	20.489	1	.000	.043
SEBS	-.066	.013	26.364	1	.000*	.936
EOF	.149	.301	.244	1	.621	1.160
GEMS161	.660	.212	9.694	1	.002*	1.934
Female	.157	.128	1.520	1	.218	1.170
African American	.071	.274	.067	1	.796	1.073
Hispanic	-.353	.237	2.212	1	.137	.702
Asian	-.418	.146	8.195	1	.004*	.658
Other/Unknown	-.071	.331	.046	1	.831	.932
Other Math	1.335	.222	36.133	1	.000*	3.800
Precalculus111	.372	.263	1.990	1	.158	1.450
Precalculus115	.636	.211	9.107	1	.003*	1.889
Math SAT	.074	.012	41.394	1	.000*	1.077

Note. R^2 = .158, *N* = 2,928

According to Table 11, School, GEMS 161 enrollment, Asian student status, Other Math, PreCalculus 115, and Math SAT are significant predictors of student success, at $p < .05$. While School and Asian student status are negatively associated with student success, the other variables are positively associated with success. The table showed that the odds of success in

Chemistry 161 for students enrolled in SEBS are less than the odds of success for students enrolled in SAS. The data revealed that SEBS students are 6.4% less likely to be successful than students enrolled in SAS. Controlling for all other variables, EOF affiliation was not found to be a significant predictor of success, while enrollment in GEMS 161 was significant at $p < .05$. GEMS 161 enrollment was positively associated with student success in General Chemistry 161. According to Table 11, the odds of success are 93.4% higher for students enrolled in GEMS 161 sections of chemistry than for those in non-GEMS sections.

Using White students as the reference ethnic group, the table showed that being African American, Hispanic, or Other/Unknown race was not significantly associated with success; but, being Asian was significant at $p < .05$. The data showed that Asian students were 34.2% less likely to successfully complete Chemistry 161 than their White counterparts. Looking at the initial mathematics course enrollment and Calculus serving as the reference math group, the data showed that the odds of successful completion of Chemistry 161 for students enrolled in PreCalculus 115 and Other Math courses were higher than the odds of success for students enrolled in Calculus, 88.9% and 280% respectively. The Nagelkerke R Square denotes that 15.8% of the variability in student success in Chemistry 161 is attributed to the variables used in the model.

Figure 3 illustrates that of the 2,928 students enrolled in General Chemistry 161, 2,587 students earned a "C" or better and 341 students did not. Linear regression techniques were used to examine the relationship between student enrollment in GEMS 161 and student grades in the course. Table 12 presents the linear regression results examining GEMS 161 enrollment and student grades.

According to Table 12, EOF status was not significant in predicting student grades in

Chemistry 161; but, School, GEMS 161 enrollment, Math SAT, and initial mathematics course were significant at a $p < .05$. The table shows that students enrolled in SEBS are predicted to earn lower grades than students enrolled in SAS. Also, students enrolled in GEMS 161 sections were predicted to earn higher grades than students enrolled in non-GEMS 161 sections. Math SAT is the strongest predictor of student grades with a moderate effect size of .335. The Adjusted R-Square value denotes that 22.2% of the variation in student Chemistry 161 grades can be explained by the predictor variables.

Table 12

Linear Regression Results for GEMS 161 Enrollment and Chemistry 161 Grades

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-.228	.182		-1.254	.210
SEBS	-.019	.003	-.096	-5.714	.000*
EOF	.146	.086	.029	1.686	.092
Math SAT	.045	.003	.335	16.445	.000*
PreCalculus 111	-.390	.075	-.094	-5.225	.000*
PreCalculus 115	-.346	.045	-.141	-7.768	.000*
Calculus	-.545	.075	-.130	-7.232	.000*
GEMS 161	.341	.056	.107	6.099	.000*

Note. Adjusted R^2 = .222, N = 2,928

Of the 2,587 students who earned a “C” or better in the 161 course, all students enrolled in General Chemistry 162 during the subsequent semester of enrollment. Tables 13 and 14 present logistic regression results that examine student enrollment and success in General Chemistry 162. Table 13 uses logistic regression to examine student enrollment and success in General Chemistry 162, using all predictor variables except GEMS 162. According to Table 13, only three variables were found to be significant predictors of student success in Chemistry 162 and they include Other/Unknown ethnicity, Math Other, and Math SAT. While chemistry department administrators prefer a mathematics placement of PreCalculus 115 or Calculus for enrollment in the introductory General Chemistry course, Table 13 shows that students who enrolled a mathematics course other than Calculus or PreCalculus were 150.9% more likely to be successful in General Chemistry 162. Table 13 also revealed that Math SAT scores are significant predictor variables at $p < .05$. The Nagelkerke R Square shows that 8.2% of the variability in students earning a "C" in General Chemistry 162, excluding the GEMS 162 predictor variable, can be attributed to the predictor variables.

Table 13

Logistic Regression of Students Earning "C" or Better in Chemistry 162 with GEMS 161

	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-1.634	.607	7.236	1	.007	.195
SEBS	-.020	.011	3.191	1	.074	.980
EOF	.342	.291	1.381	1	.240	1.408
Female	.189	.109	2.978	1	.084	1.208
GEMS161	.000	.175	.000	1	.998	1.000
African American	-.173	.222	.610	1	.435	.841
Hispanic	-.034	.239	.020	1	.887	.967
Asian	-.044	.125	.125	1	.723	.957
Other/Unknown	-.586	.246	5.669	1	.017*	.557
Math Other	.920	.243	14.356	1	.000*	2.509
Precalculus111	.202	.292	.479	1	.489	1.223
Precalculus115	.140	.238	.349	1	.555	1.151
Math SAT	.040	.010	16.710	1	.000*	1.041

Note. $R^2 = .082$, $N = 2,587$

Table 14 uses logistic regression to examine General Chemistry 162 enrollment and success including all predictor variables except GEMS 161. Table 14 revealed that five variables were found to be significant predictors of success, and they include School, GEMS 162 enrollment, Other/Unknown race, Math Other, and Math SAT. The data revealed that SEBS students are 2.3% less likely to have earned a "C" or better in General Chemistry 162. The data also showed that students enrolled in a mathematics course other than Calculus or PreCalculus were 164.8% more likely to be successful in Chemistry 162. Additionally, the odds of students earning a "C" or better in the course were 75.8% greater for students enrolled in GEMS 162 sections. The Nagelkerke R Square for this model shows that 8.8% of the variability in students earning a “C” or better in General Chemistry 162, excluding the GEMS 161 predictor variable, can be attributed to the predictor variables used in the model.

When looking at student grades in General Chemistry 162 and GEMS enrollment, linear regression analysis revealed that previous enrollment in GEMS 161 was not significant in predicting student grades in Chemistry 162, but enrollment in GEMS 162 was significant to a $p < .05$. Table 15 presents the linear regression results for student grades in Chemistry 162 with GEMS 162 enrollment and Chemistry 161 grades. Review of Table 15 shows that initial mathematics course placement, Chemistry 161 grade, and GEMS 162 enrollment were significant predictors of Chemistry 162 grades at $p < .05$. It is not surprising that Chemistry 161 grades would have the strongest effect on Chemistry 162 grades, recording an effect size of .646. The Adjusted R-Square shows that 45.5% of the variability in student grades is explained by the variables in the model.

Table 14

Logistic Regression of Students Earning “C” or Better in Chemistry 162 with GEMS 162

	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-1.856	.610	9.263	1	.002	.156
SEBS	-.024	.011	4.255	1	.039*	.977
EOF	.226	.290	.607	1	.436	1.254
Female	.176	.110	2.590	1	.108	1.193
GEMS162	.564	.191	8.757	1	.003*	1.758
African American	-.251	.222	1.279	1	.258	.778
Hispanic	-.032	.240	.018	1	.893	.968
Asian	-.052	.125	.174	1	.677	.949
Other/Unknown	-.586	.247	5.639	1	.018*	.556
Math Other	.974	.244	15.958	1	.000*	2.648
Precalculus111	.120	.292	.168	1	.682	1.127
Precalculus115	.173	.239	.527	1	.468	1.189
Math SAT	.042	.010	18.792	1	.000*	1.043

Note. R^2 = .088, *N* = 2,587

Table 15

Linear Regression Results for Chemistry 162 Grades with GEMS 162 and Chemistry 161 Grades

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-.239	.188		-1.270	.204
SEBS	-.006	.003	-.025	-1.687	.092
EOF	-.076	.091	-.013	-.833	.405
MATH SAT	-.002	.003	-.012	-.657	.511
PreCalculus 111	-.366	.081	-.071	-4.536	.000*
PreCalculus 115	-.191	.047	-.065	-4.040	.000*
Calculus	-.265	.089	-.047	-2.974	.003*
Chemistry 161 Grade	1.001	.025	.646	40.385	.000*
GEMS 162	.225	.057	.061	3.941	.000*

Note. Adjusted R^2 = .455, N = 2,587

According to Figure 3, 2,118 students earned a “C” or better in General Chemistry 162. Descriptive statistics for these students are shown in Figure 5. When examining school affiliation, Figure 5 notes that 68.7% were SAS students and 31.3% were SEBS students; 57.6% were female and 42.4% were male. Additional review of that data show that 90.3% were registered for non-GEMS and 9.7% were enrolled in GEMS. When examining this population for EOF status, it was noted that 2.8% were SAS EOF students and 0.5% were SEBS EOF students. Of the students enrolled in the non-GEMS sections, 2.2% were EOF and 97.8% were non-EOF. For students enrolled in the GEMS sections, 13.7% were EOF and 86.3% were non-EOF. Eighty-five percent of EOF students enrolled in GEMS sections of General Chemistry 162 successfully completed the course; and, 75% of EOF student enrolled in non-GEMS sections successfully completed the course. Additionally, successful completion rates for non-EOF students were 82% for both GEMS and non-GEMS sections. Further examination of the data, looking at student persistence to Organic Chemistry, yielded the following results.

Table 16

Logistic Regression Results for Student Persistence to Organic Chemistry 307- GEMS 161 Only

	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-3.632	.469	59.952	1	.000	.026
SEBS	-.028	.009	10.700	1	.001*	.973
EOF	.682	.223	9.370	1	.002*	1.978
Female	.154	.081	3.593	1	.058	1.166
GEMS161	.303	.143	4.496	1	.034*	1.354
African American	.240	.178	1.805	1	.179	1.271
Hispanic	.003	.183	.000	1	.987	1.003
Asian	.341	.089	14.628	1	.000*	1.406
Other/Unknown	.163	.207	.620	1	.431	1.177
Math Other	.910	.201	20.478	1	.000*	2.485
Precalculus111	.233	.249	.874	1	.350	1.263
Precalculus115	.221	.205	1.158	1	.282	1.247
Math SAT	.047	.007	41.670	1	.000*	1.048

Note. R^2 = .120, *N* = 2,587

Referring to Figure 3, of the 2,928 students in the study, 2,587 (88.4%) enrolled in General Chemistry 162, 2118 (72.3%) earned a “C” or better in General Chemistry 162, and 1,588 (54.2%) persisted to Organic Chemistry 307 registration. Tables 16 and 17 provide the logistic regression results for student persistence to Organic Chemistry. Table 16 presents this information using all predictor variables excluding GEMS 162; and, Table 17 presents the data using all variables excluding GEMS 161.

According to Tables 16, when GEMS 162 is excluded from the variable list , School, EOF Status, GEMS 161 enrollment, Asian student status, Math Other, and Math SAT were significant predictors of student persistence, at $p < .05$. The table shows that SEBS students are 2.7% less likely to persist to Organic Chemistry. Further examination revealed that EOF students are 97.8% more likely to persist. The table also showed that female students and students enrolled in GEMS 161 section had greater odds of persistence, noting 16.6% and 35.4% increased likelihood of persistence respectively. White students were less likely to persist than Asian students; and, the data showed that the odds of persistence were greater for students placed in any mathematics course other than PreCalculus or Calculus. The Nagelkerke R Square for this analysis shows that 12% of the variability in student persistence to Organic Chemistry 307, when excluding participation in GEMS 162, is attributed to the variables in the model. Table 17 examines persistence to Organic Chemistry 307, excluding the GEMS 161 predictor variable.

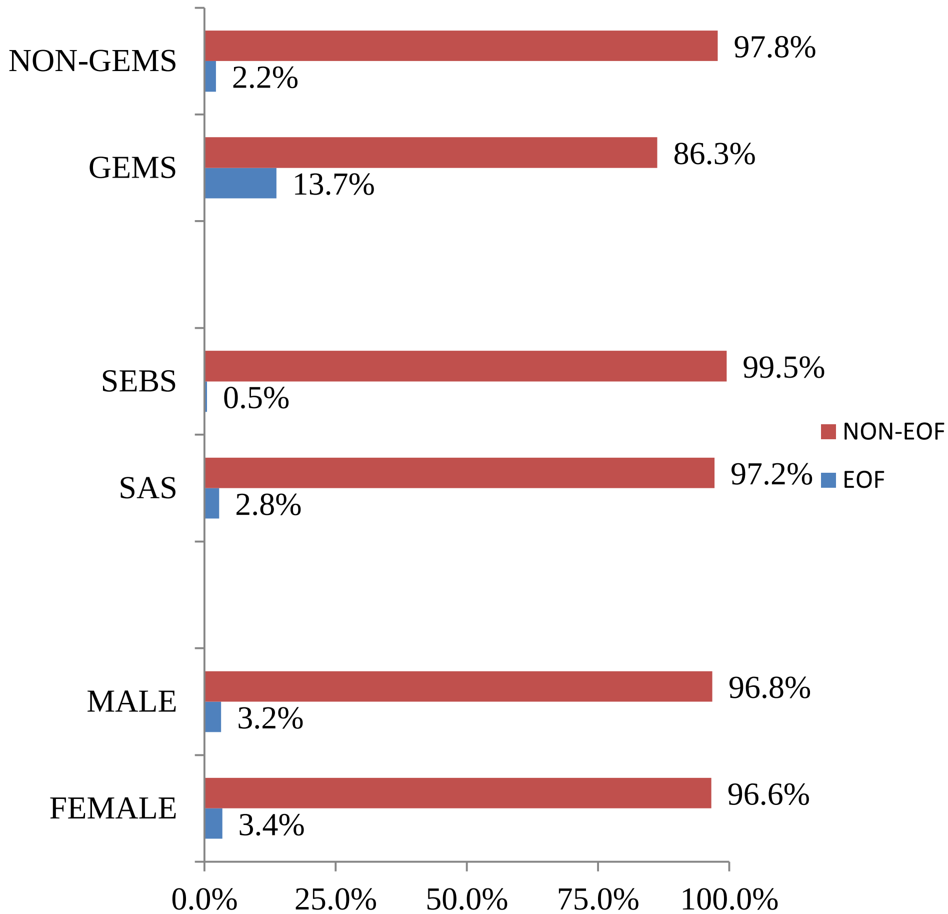

Figure 5. Descriptive Statistics for Students Who Earned a "C" or Better in Chemistry 162

According to Table 17, five variables were significant at $p < .05$ including EOF status, GEMS 162 enrollment, Asian student status, Math Other, and Math SAT. Examination of the table showed that EOF students were 112.1% more likely to persist to Organic Chemistry than non-EOF students. Enrollment in GEMS 162 and Asian students are noted to have greater odds of persistence, 43.7% and 63.9% respectively. Another important note from the table shows that, students whose initial mathematics course not Calculus or PreCalculus 115 were 72.5% more likely to persist. The Nagelkerke R Square reveals that 8.2% of the variation in student persistence to Organic Chemistry 307, when GEMS 161 is excluded, is attributed to the predictor variables used in the model.

Table 17

Logistic Regression Results for Persistence to Organic Chemistry 307- GEMS 162 Only

	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-2.340	.500	21.877	1	.000	.096
SEBS	-.015	.009	2.707	1	.100	.985
EOF	.752	.257	8.553	1	.003*	2.121
Female	.123	.087	2.023	1	.155	1.131
GEMS162	.362	.152	5.677	1	.017*	1.437
African American	.199	.189	1.107	1	.293	1.220
Hispanic	.102	.200	.262	1	.608	1.108
Asian	.494	.097	26.192	1	.000*	1.639
Other/Unknown	.186	.220	.714	1	.398	1.204
Math Other	.545	.227	5.749	1	.016*	1.725
Precalculus111	.032	.278	.013	1	.908	1.033
Precalculus115	-.063	.230	.075	1	.785	.939
Math SAT	.034	.008	19.389	1	.000*	1.035

Note. R^2 = .082, *N* = 2,587

Student Persistence and Non-persistence

This study presumes that students who enrolled in Organic Chemistry 307 immediately following completion of the General Chemistry 161/162 course sequence were considered persisters, and those who did not were considered non-persisters. Additional data review was conducted to determine the characteristics of persisters and non-persisters. Figure 3 showed that 2,118 (72.3%) of the 2,928 who enrolled in General Chemistry 161 during their initial semester of enrollment were eligible to persist into Organic Chemistry during their third semester of enrollment, but only 1,588 (54.2%) actually enrolled in the course. Review of the data in Figure 6 revealed that of the 107 EOF students in this study, 58.9% persisted into Organic Chemistry;

non-EOF persistence was noted as 54.1%. Of the EOF persisters, 55.6% were enrolled in GEMS 161 and 81.8% were enrolled in GEMS 162.

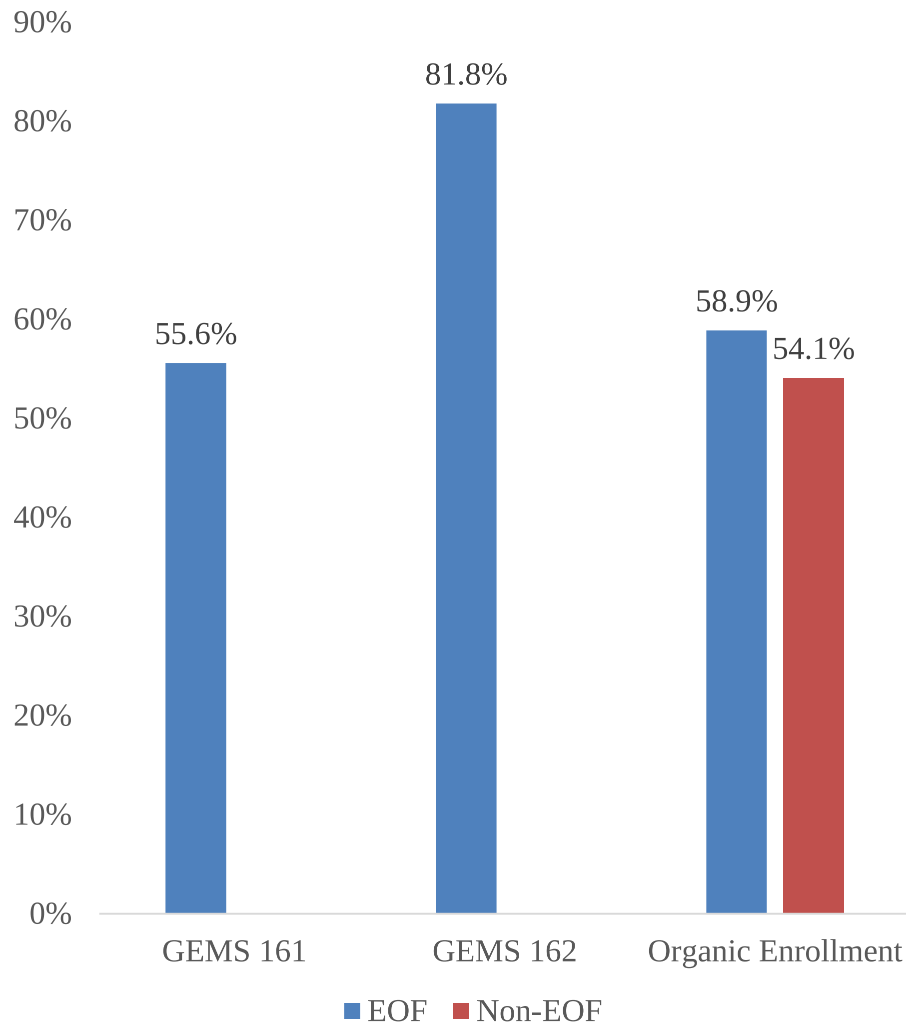

Figure 6. EOF Student Persisters' Data by GEMS and Organic Chemistry Enrollment

Crosstab analysis highlighted specific characteristics of those who enrolled in Organic Chemistry (persisters) and those who did not (non-persisters). Table 18 presents descriptive statistics for persisters and non-persisters. Non-persisters included students who failed one or both of the perquisite courses and were not eligible to enroll in Organic Chemistry, as well as students who completed both prerequisite courses and were eligible but chose not to enroll in the course. Examination of Table 18 revealed the following information regarding persisters and non-persisters.

Table 18

Descriptive Characteristics of Student Persisters and Non-Persisters

	Persisters		Non-Persisters	
	%	*n*	%	*n*
%SEBS	29.6%	1,588	41.3%	1340
%EOF	4.0%	1,588	3.3%	1340
%Female	57.6%	1,588	58.1%	1340
Ethnicity				
%African Am	5.2%	1,588	5.9%	1340
%Hispanic	4.2%	1,588	6.5%	1340
%White	45.0%	1,588	55.2%	1340
%Asian	41.2%	1,588	27.5%	1340
%Other	4.4%	1,588	4.9%	1340

According to Table 18, 29.6% SEBS students persisted and 41.3% did not persist. Four percent of all persisters were EOF students and 3.3% of non-persisters were EOF. On average 57.6% of the female student persisted and 58.1% did not. When examining Ethnicity, the table shows that 45% of persisters and 55.2% of non-persisters were White. Table 19 displays initial mathematics course and GEMS enrollment percentages for persisters and non-persisters. According to Table 19, 80.9% of the persisters and 59.1% of non-persisters were enrolled in Calculus; 16.5% of persisters were enrolled in PreCalculus 111 or 115 and 32.4% of non-persisters were enrolled in PreCalculus 111 or 115; 9% of persisters were enrolled in GEMS 161 and 9.8% were enrolled in GEMS 162; 10.7% of non-persisters were enrolled in GEMS 161 and 9.5% were enrolled in GEMS 162. Table 20 examine Math SAT data for persisters and non-persisters by student GEMS and EOF Status.

Table 19

Mathematics and Chemistry Enrollment Percentages for Persisters and Non-Persisters

	Persisters		Non-Persisters	
	%	*n*	%	*n*
%GEMS				
Chemistry 161	9.0%	1,588	10.7%	1340
Chemistry 162	9.8%	1,588	9.5%	999*
Initial Math Course				
%PreCalc111	3.8%	1,588	7.5%	1340
%PreCalc115	12.7%	1,588	24.9%	1340
%Calculus	80.9%	1,588	59.1%	1340
%Math Other	2.7%	1,588	8.6%	1340

*This number excludes the 341 students who failed to complete Chemistry 161 and could not enroll in Chemistry 162.

Table 20 presents the mean Math SAT scores for persisters and non-persisters by GEMS status. According to Table 20, the mean Math SAT score for persisters was 647.8; and for non-persisters the scores were 615.0. Examining scores for persisters only, the data reported a mean Math SAT score of 591.9 for GEMS students and 653.4 for non-GEMS students. When looking at the Math SAT scores for non-persisters, the data reported a mean of 565.9 for GEMS and 620.9 for non-GEMS students. Examining EOF Status, Table 20 reports that the mean Math SAT scores were 560.2 EOF persisters and 524.1 for EOF non-persisters. With non-EOF student recording Math SAT scores of 651.4 for persisters and 618.1 for non-persisters.

Table 20

Mean Math SAT Scores for Persisters and Non-Persisters by GEMS and EOF Status

	Persisters			Non-Persisters		
	$\bar{x}$	sd	*n*	$\bar{x}$	sd	*n*
Math SAT						
GEMS	591.9	6.661	1588	565.9	7.378	1340
Non-GEMS	653.4	6.419	1588	620.9	6.949	1340
Overall	647.8	6.678	1588	615.5	7.196	1340
EOF	560.2	6.9	63	524.1	6.5	44
Non-EOF	651.4	6.4	1525	618.1	7.0	1296
Overall	647.8	6.678		615.5	7.196	

Chapter V

Discussion

Success in General Chemistry 161 and 162 is important for all Rutgers University science students. Identifying and understanding factors that support success in General Chemistry are necessary to assist the Department of Chemistry, faculty, and school administrators with enhancing enrollment, persistence, and graduation in the sciences. The literature suggests that many factors contribute to student success and persistence. Tinto (1975) argues that the institutional climate has a strong impact on a student's decision to persist. In a later study, Tinto and Goodsell (1994) proposed that social acceptance is crucial to student success and retention. Terenzini and Pascarella's (1977) research suggests that student and faculty interaction place a major role in student attrition rates. Studies propose that high school experiences have an active role in determining student persistence, with some focused on academic preparation and student commitment (Maltese & Tai, 2011; Russell & Atwater, 2005; Tinto, 2004; Titus, 2004). Many researchers have explored the use of specific instructional techniques and how they might enhance student success – small group sessions, interactive learning, questioning techniques, and others (Eagan & Jaeger 2008; Harper, Etkina, & Lin, 2003; Maltese & Tai, 2011; Seymour & Hewitt, 1997; Springer et al., 1999).

Focused on Solid GEMS Chemistry, which is specially designed instructional pedagogy to enhance student learning, retention, and success, the purpose of this study was to examine the Solid GEMS Chemistry pedagogical practices and how those practices might influence success in General Chemistry 161 and 162, which would potentially influence student persistence into Organic Chemistry 307. Success was measured using student final grades in the course and persistence was measured by student registration for Organic Chemistry 307. Of the 2,928 students in this study, 1,340 (45.8%) failed to persist into Organic Chemistry. According to Figure 3, 810 of the 'non-persisters' failed to meet the prerequisite for enrollment in Organic Chemistry 307. Of the 810 students who did not meet the prerequisites for persistence, 341 students did not earn a "C" or better in General Chemistry 161, ant the remaining 469 students failed to earn a "C" or better in General Chemistry 162. These students represent 27.7% of the total population in this student. Figure 3 also shows that 530 students completed the General Chemistry course sequence and were eligible to enroll in Organic Chemistry, but chose not to enroll. These students represent 18.1% of the total population in this study. Finding that 45.8% of first-year students entering SEBS and SAS, from 1997 – 2006, not persisting to enrollment in Organic Chemistry is of great concern for school administration. Students intending to major in the sciences must complete Organic Chemistry to progress towards graduation.

While student enrollment and completion of science curriculum is important to SEBS and SAS administrators, it is also vital to global competitiveness. Institutions of higher learning must seek and encourage ways to enhance programs that support students enrollment and retention in the sciences. A little more than 45% of the students, in this study, did not persist which is alarming. How will SEBS and SAS meet the global demand for scientific and technical workers maintaining slightly more than half of their potential science and technology graduates? Of particular concern for this study is the plight of EOF student success in the science. What are the challenges facing these students and how can college administration and academic departments facilitate student success. This study was designed to assess the influence of Solid GEMS Chemistry pedagogical practices on encouraging successful progression towards a science degree. Some key findings are noted below.

Student Narrative of Experiences and Attitudes

The literature suggests that enhanced academic preparation, student interest, changes in the institutional climate, greater faculty interaction, smaller classroom size, and other interventions will support student retention. Many studies look at these factors in isolation (Eagan & Jaeger, 2008; Griffith, 2010; Harper, Etkina, & Lin, 2003; Maltese & Tai, 2011; Seymour & Hewitt, 1997; Springer et al., 1999; Tinto, 2004). While these are all valid areas of concern, there are limited in their scope by failing to consider classroom instructional practices. Maltese and Tai (2011) suggested that if a student is interested in a particular major they are more likely to be retained, they also admonish that review of classroom practices will present a more in depth understanding of student attrition.

The Solid GEMS Chemistry course was developed through the examination of classroom practices and designed to engage pedagogical practices that attempt to mitigate the factors that attributed to students leaving college. Solid GEMS Chemistry was designed for a population of students who were deemed dropout prone. Using instructional techniques that engage integrate the student's everyday experiences and address the most common reasons for student withdrawal, the course has provided students with instruction that meets their needs and fosters success and retention in the sciences.

Students in this study have indicated that while prior academic preparation influenced their attitudes and success in Chemistry, the instructional methodology assisted with making Chemistry more tangible for them. When speaking about the Solid GEMS Chemistry extended class sessions, Sarah recalled how "the time and the material [is] a lot less. …on the quizzes, you don't need to know as much as you need to know on the [Non-Solid-GEMS quizzes]." John talked about how the professor's interaction with the class made him feel that "he does more than other teachers do." John mentioned that the professor "… actually printed and wrote everything out [for us]. [He] draws different diagrams and stuff… [My] other teachers just go over [the material]." Another student, Mark talks about learning and interest in science by stating "No one gets interested from just reading a textbook. When you get to do [it], when you learn science hands on its a lot more interesting and you learn a lot more. [You] actually get a bird's eye view of what's going on instead of learning it from a book."

The pedagogical practices employed by the Solid GEMS faculty are designed to cultivate student passion for chemistry and learning. Solid GEMS was created to support student success and grow a diverse population of science majors. When speaking with students about their experiences in the Solid GEMS course, the researcher found that while students were not excited about the extended time commitment required by the course, they did find the course instructional practices useful in enhancing their understanding of chemistry. Conversations with students show that students believe Solid GEMS practices have contributed to their learning chemistry, with some feeling more confident in their science ability. Sarah stated "I heard about people in [Non-Solid-GEMS] chemistry and they are struggling. I am pretty happy that I am in this class. I feel like it's better for me."

Potential Influence on Student Success

Student successful completion of science coursework is important for SEBS and SAS administrators. The data in this study reveals that there are many factors that promote student success and persistence. This question is even more important for EOF administrators, as EOF students come to campus with additional academic and financial challenges. Successful progression through the first-year chemistry course sequence is important for students seeking science degrees. Identification of factors that impede student successful completion of chemistry is crucial, as students hoping to become doctors, veterinarians, and science researchers must complete the General Chemistry officially declare and progress to enrollment in a science major.

Demographic data for persisters and non-persisters, in Table 18, revealed that 57.6% of persisters were female and 58.1% of females were non-persisters, which is consistent with the population average of 57.9%. The data revealed that 29.6% of persisters and 41.3% of non-persisters were enrolled in SEBS. These numbers illustrate that SAS students have a much higher rate of persistence than SEBS students. This higher rate of persistence may be attributed to the larger number of SAS students in the study.

One hundred and seven (3.7%) EOF students were included in the initial population sample (*N*=2,928) and 70 students completed both General Chemistry 161 and 162. Table 19 reported that 4% of the EOF student population persisted to enrollment in Organic Chemistry 307. Review of the data revealed that 63 EOF students persisted to Organic Chemistry, which represents 58.9% of the total EOF population. Examination of EOF persisters' enrollment in GEMS sections of chemistry revealed that 25 (39.7%) were enrolled in GEMS 161 during their first semester of enrollment. The results of this study show that 58.9% of EOF first-year students persisted and 39.7% of those students were enrolled in GEMS 161. These numbers suggest that enrollment in GEMS Chemistry may have influenced EOF student success and persistence, as these students are considered at-risk for dropping out of school or failing to complete specific course. This observation notes that EOF student participation in the GEMS sections may assist with student persistence to Organic Chemistry, which is important for EOF and campus administrators.

Table 19 also shows that 9.0% of all persisters were enrolled in GEMS Chemistry 161and 9.8% were enrolled in General Chemistry 162. These numbers show a 0.8% increase in enrollment from General Chemistry 161 to 162. The data noted that twelve persisters who enrolled in non-GEMS 161 Chemistry during the fall semester switched to GEMS 162 Chemistry enrollment in the spring. While this shift in enrollment might not prove cause, it does suggest that students perceive enrollment in the GEMS course sections may influence their success. This study does not interview or examine the actual grades earned by students who changed their enrollment from General Chemistry 161 to 162; however, additional analysis is recommended to determine the reason(s) for the change in enrollment and if the grades earned by these students may have influenced their decision to switch from non-GEMS to GEMS sections.

According to Table 20, the overall mean Math SAT score for non-persisters was 32.3 points lower than persisters' scores, 615.5 and 647.8 respectively. Mean Math SAT scores for non-GEMS persisters exceeded the mean scores for GEMS persisters by 61.5 points. This is expected as students enrolled in the GEMS sections typically have lower mathematics placements. Table 20 also displays Math SAT scores for persisters' and non-persisters' by EOF Status, revealing an interesting phenomenon. While the SAT scores for EOF and non-EOF are expected to differ, the difference noted in the data was substantially larger than expected. For EOF persisters and non-persisters, the difference in the mean Math SAT scores was more than 90 points lower than their non-EOF counterparts. Although, these findings are not unexpected as non-EOF students recorded higher SAT scores and placed in the higher levels of mathematics, what is interesting is that 58.9% of EOF students persisted despite their lower Math SAT scores and lower mathematics course placements.

Review of student initial mathematics placement revealed that placement in Calculus is not a significant determinant of student success. According to the Logistic regression results in Tables 11 and 13, students enrolled in math courses other than PreCalculus and Calculus were more likely to earn a “C” or better in both General Chemistry 161 and 162. While the Department of Chemistry encourages higher mathematics course placements for enrollment in introductory chemistry, the data showed that a higher mathematics placement does not significantly influence student success. Additionally, logistic regression results in Tables 16 and 17 showed that students enrolled in Other Math course are more likely to persistence than those enrolled in PreCalculus or Calculus. These findings suggest that there may be other factors, other than mathematics course placement, that support student persistence.

Table 11 shows that enrollment in GEMS 161 enhanced the odds of students success in General Chemistry 161 by 93.4%. Examining Table 14 logistic regression results for student success in General Chemistry 162 revealed that GEMS 162 enrollment enhanced the odds of student success by 75.8%. Tables 16 and 17 show logistic regression for student persistence to Organic Chemistry, revealing that enrollment the GEMS sections of chemistry enhanced student persistence to Organic Chemistry by 35.4% for GEMS 161 and 43.7% for GEMS 162 students. Additionally, these tables show that EOF status was a significant predictor of student persistence at $p < .05$.

While EOF students arrive on campus with some academic challenges, these academic challenges do not predict their success or hinder their persistence. The data illustrate that, notwithstanding lower SAT scores and lower mathematics placements, EOF student placement in the GEMS course helps support their success in the introductory chemistry course and persistence to Organic Chemistry. Overall, this study suggests that the Solid GEMS Chemistry course helps mitigate lower SAT scores and lower mathematics placements for EOF students, supporting their success in the sciences.

Summary of Findings

As universities seek to maintain diversity and retain STEM students, administrators must examine systemic classroom practices that hinder success and persistence. This study found that Solid GEMS Chemistry pedagogy helps support first-year student success and persistence – especially for EOF students. The data show that:

- Solid GEMS improves student grades in Chemistry and Chemistry 161/162 success rates.
- Solid GEMS supports EOF student subsequent enrollment in Organic Chemistry.
- Students who enroll in Solid GEMS 161 **and** Solid GEMS 162 were more likely to be successful in Chemistry 162 than students who enroll in and complete Solid GEMS 161 only.
- Students who complete Solid GEMS 161 **and** Solid GEMS 162 were more likely to persist to Organic Chemistry.
- An initial mathematics placement in Calculus was not predictive of success in Chemistry or persistence to Organic Chemistry.

Qualitative methods offered addition insights from the perspectives of faculty and students about why Solid GEMS enhances EOF student achievement and persistence in Chemistry.

- Faculty believe Solid GEMS enhances analytical skills necessary for success in the sciences.
- Students believe that Solid GEMS makes course concepts more tangible and less intimidating.

This study suggests that Rutgers and other universities would enhance student success and persistence in STEM majors through the following steps.

- Extending class time and creating smaller classes for EOF students enrolling in chemistry.
- Linking the student's everyday experiences to course content to make chemistry 'tangible' to enhance knowledge of and confidence in the sciences.
- Providing a full year of Solid GEMS type supports rather than summer or one-semester supports.
- Institutionalizing elements of Solid GEMS practices across the science curriculum.

Implications for Policy and Future Research

Student retention in STEM majors, particularly for underrepresented minority students, is a national concern. The National Science Board (2008) reported, "within [science and engineering] fields, undergraduate attrition out of [these fields] is greater than transfers into those fields" (p. 2-22). As a Rutgers administrator, the researcher is focused on the academic success of students interested in STEM majors, particularly underrepresented populations. The number of students who leave STEM majors during and immediately after their initial year of enrollment is a national concern. This research focused on identifying characteristics of persisters and non-persisters. The information provided in this study can assist Rutgers University science departments, SEBS, and other institutions in their quest to address factors influencing student decisions to leave college. Giving valuable insight on how pedagogical practices may influence student success in the sciences, administrators can use this information to promote development of innovative pedagogical models for science instruction that address student dropout factors. Specifically, descriptive analysis of student performance in Solid GEMS Chemistry 161 and 162 helps to inform discourse regarding the influence of innovative instructional pedagogy on student retention at Rutgers SEBS, particularly EOF student retention.

This information is valuable and may assist science department chairs as they develop curriculum to sustain student enrollment. Two years ago, in 2013, the Department of Chemistry and Chemical Biology changed its instructional practices for the Non-Solid GEMS sections of General Chemistry 161 and 162. As a result of high failure rates and declining science enrollment, the department introduced an instructional model that removes students from the classroom recitation session into an online environment. This new mode of teaching incorporates the Solid GEMS philosophical model by meeting students in their everyday environment. These and other innovative practices will reinvigorate student interest and ease student fear of science coursework. The goal of this study is to assist policy makers in developing and implementing programs that will support the retention and graduation of diverse student populations in the sciences. While this study focuses a program unique to Rutgers University – New Brunswick, any college or university could utilize its observations and outcomes to design curriculum and programs to facilitate student successful progression through all science majors.

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Appendices

Appendix A

Solid GEMS Evolutionary Timeline

1986-87	1988-89	1990	1991	1993 - Present
Solid GEMS simulated the Xavier University Project SOAR (Stress on Analytical Reasoning) summer bridge program. Components included : • Summer Session Only • Chemistry 161 Lecture • Chemistry Recitation • Four (4) Vocabulary Development Sessions(GRE Examination Review) • Quiz Bowl (Argument/Debate) • Piagetian-Based Laboratory Experiments	Program redesigned to reflect the institutional environment, moving away from Xavier's Project SOAR model, continuing as a summer program. Components included: • Chemistry 161 Lecture • Chemistry 134 Lecture (for students having difficulty with 161) • Chemistry Recitation • Vocabulary Development (Reduced from four to one session in 1988) • Quiz Bowl (Discontinued in 1989) • Began Using the University	The program began to develop its own identity. Components included: • Chemistry 161 Lecture • Chemistry 134 Lecture (for students having difficulty with 161 coursework) • Chemistry Recitation • Analytical Reasoning Laboratory Added • Mathematical Workshop/Review Connecting Chemistry Concepts • Weekly Quizzes • Three Evening	Summer program model continued with some modifications. Components included: • Chemistry 161 Lecture • Chemistry 134 Lecture (for students having difficulty with 161 coursework) • Chemistry Recitation • Four Laboratories Added to Assist Students With Application of Lecture Concepts • Mathematical Workshop/Review Connecting Chemistry Concepts	Solid GEMS is adapted to include an academic year General Chemistry course sequence. The pedagogical practices of the summer program were modified to accommodate a 16-week instructional format. The summer program is continued for students who are not eligible to take General Chemistry during their first semester of college enrollment.

• Mathematics Workshop/Review • Daily Instruction and Study Group Sessions (9am – 5pm), except Fridays (9am - 3:30pm) • No Evening Recitations	Laboratory Model • Mathematical Workshop/Review Connecting Chemistry Concepts • Weekly Quizzes • Four Evening Recitations Each Week • Science Careers Seminar • Daily Instruction and Study Group Sessions (8:30am - 4:30pm), except Fridays (8:30am – 2:30pm)	Recitations Each Week • Extra Recitations for Students Earning a Grade of "C" or Lower • Exam Review • Daily Instruction and Study Group Sessions (8:30am - 4:30pm), except Fridays (8:30am – 2:30pm)	• Weekly Quizzes • Three Evening Recitations Each Week • Quiz bowl • Three Health Career Seminars	

Appendix B

B1 Student Informed Consent

B2 Faculty Informed Consent

B3 Interview Guide

B4 Focus Group Guide

B5 Classroom Observation Protocol

Appendix B1

Student Informed Consent

STUDENT CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

Solid GEMS Chemistry Pedagogical Practices:
A Study of Student Experiences and Persistence

Researcher: Jenice Sabb, Graduate Student
Rutgers University - Graduate School of Education
Phone: 848-932-3617 Email: Jenice.sabb@gse.rutgers.edu

I am Jenice Sabb, an Ed.D. student at the Rutgers University Graduate School of Education. I am inviting you to participate in a research study to explore the potential influence of Solid GEMS Chemistry instructional practices on SEBS first-year EOF student performance in General Chemistry 161/162.

Participation in this research will assist the SEBS EOF administration and Department of Chemistry with identifying teaching practices that encourage student learning which promotes more student-focused instruction. While there is no guarantee of a direct benefit to you, your participation may help enhance student experiences in General Chemistry 161/162.

This study will commence October 21, 2013 and end June 30, 2014. Your participation will involve participation in one (1) face-to-face interview, focus groups and/or writing a one page narrative of your experiences. The information gathered from these actions will be analyzed to gain greater understanding of your experiences in the Solid GEMS Chemistry course. Additionally, participation in this study requires granting me access to your personal information through the Rutgers student records database. The information retrieved will be limited to your General Chemistry 161/162 course grades and subsequent enrollment in Organic Chemistry 307.

This research is confidential. Confidential means that the research records will include some information about you and this information will be stored in such a manner that some linkage between your identity and the response in the research exists. Some of the information collected about you includes ethnicity, gender, age and narratives of your experiences in science courses. Please note that we will keep this information confidential by limiting individual's access to the research data and keeping it in a secure location. The primary risks of participation in this study are possible embarrassment from answering personal questions, and breach of confidentiality.

The research team and the Institutional Review Board (a committee that reviews research studies in order to protect research participants) at Rutgers University are the only parties (please modify if others will have access to the data) that will be allowed to see the data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. All study data will be kept for three years.

Participation in this study is voluntary. You may refuse to take part in it or stop participating at any time, even after signing this form. Additionally, you may be removed from the study if the researcher is unable to collect the necessary data.

****

Voluntary Consent

I have read and understand the information presented above. The researcher has answered all my current questions and responded to my current concerns. I further understand that if I have any questions about the study or study procedures, I may contact Jenice Sabb at 848-932-3617 or jenice.sabb@gse.rutgers.edu or you can contact my Faculty advisor, Dr. W. Steve Barnett at 848-932-4305 x-23132 or sbarnett@nieer.org. Any questions about my rights as a research participant will be answered by the IRB Administrator at Rutgers University at:

Rutgers University Institutional Review Board for the Protection of Human Subjects
Office of Research and Sponsored Programs
ASB III, 3 Rutgers Plaza
New Brunswick, NJ 08901-8559
Tel: (848) 932-0150
Email: humansubjects@orsp.rutgers.edu

By signing this form, I agree to participate in the Solid GEMS Chemistry research study. A copy of this consent form has been given to me.

Participant's Name (Print): ________________________________

Participant's Signature: ____________________________________ Date: _______________

I give my consent to allow the researcher to access my General Chemistry 161/162 grades, for use in this study (please initial one). ________ Yes ________ No

The Researcher will complete the following section.

Certification of Informed Consent

I certify that I have explained the nature and purpose of this research study to the above-named individual and I have discussed the possible risks and potential benefits of participation in the study. Furthermore, I attest that I have answered all questions presented by the participant and the individual has been informed to contact me should any additional questions regarding this study arise.

_____Jenice Sabb__________________________________ __Principal Investigator___
Name of person obtaining consent (print) Role in research study

____ ________________________
Signature of person obtaining consent Date

Appendix B2

Faculty Informed Consent

FACULTY CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

Solid GEMS Chemistry Pedagogical Practices:
A Study of Student Experiences and Persistence

Researcher: Jenice Sabb, Graduate Student
Rutgers University - Graduate School of Education
Phone: 848-932-3617 Email: Jenice.sabb@gse.rutgers.edu

I am Jenice Sabb, an Ed.D. student at the Rutgers University Graduate School of Education. I am inviting you to participate in a research study to explore the potential influence of Solid GEMS Chemistry instructional practices on SEBS first-year EOF student performance in General Chemistry 161/162.

Participation in this research will assist the SEBS EOF administration and Department of Chemistry with identifying teaching practices that encourage student learning which promotes student-focused instruction. The study will commence on October 21, 2013 and end June 30, 2014. While there is no guarantee of a direct benefit to you, your participation may help enhance understanding of student experiences in General Chemistry 161/162 and how those experiences may promote student success in the course.

Your participation will involve granting me access to your classroom to observe your instructional practices and student response. Additionally, I will request two one-on-one interviews to clarify my understanding of department and classroom procedures.

This research is confidential. Confidential means that the research records will include some information about you and this information will be stored in such a manner that some linkage between your identity and the response in the research exists. Some of the information collected about you includes number of years teaching science in higher education and narratives about your experiences teaching science. Please note that we will keep this information confidential by limiting individual's access to the research data and keeping it in a secure location. The primary risks of participation in this study are possible embarrassment from answering personal questions, and breach of confidentiality.

The research team and the Institutional Review Board (a committee that reviews research studies in order to protect research participants) at Rutgers University are the only parties (please modify if others will have access to the data) that will be allowed to see the data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. All study data will be kept for three years.

Participation in this study is voluntary. You may refuse to take part in it or stop participating at any time, even after signing this form. Additionally, you may be removed from the study if the researcher is unable to collect the necessary data.

****

Voluntary Consent

I have read and understand the information presented above. The researcher has answered all my current questions and responded to my current concerns. I further understand that if I have any questions about the study or study procedures, I may contact Jenice Sabb at 848-932-3617 or jenice.sabb@gse.rutgers.edu or you can contact my Faculty advisor, Dr. W. Steve Barnett at 848-932-4305 x-23132 or sbarnett@nieer.org. Any questions about my rights as a research participant will be answered by the IRB Administrator at Rutgers University at:

Rutgers University Institutional Review Board for the Protection of Human Subjects
Office of Research and Sponsored Programs
ASB III, 3 Rutgers Plaza
New Brunswick, NJ 08901-8559
Tel: (848) 932-0150
Email: humansubjects@orsp.rutgers.edu

By signing this form, I agree to participate in the Solid GEMS Chemistry research study. A copy of this consent form has been given to me.

Faculty Name (Print): ________________________________

Faculty Signature: ____________________________________ Date: _______________

The Researcher will complete the following section.

Certification of Informed Consent

I certify that I have explained the nature and purpose of this research study to the above-named individual and I have discussed the possible risks and potential benefits of participation in the study. Furthermore, I attest that I have answered all questions presented by the participant and the individual has been informed to contact me should any additional questions regarding this study arise.

_____Jenice Sabb_________________________________ __Principal Investigator___
Name of person obtaining consent (print) Role in research study

____ ________________________
Signature of person obtaining consent Date

Appendix B3

Interview Guide

Solid GEMS Chemistry Pedagogical Practices:
A Study of Student Experiences and Persistence

Researcher: Jenice Sabb, Graduate Student
Rutgers University - Graduate School of Education
Phone: 848-932-3617 Email: Jenice.sabb@gse.rutgers.edu

Interviews with Students

- What high school did you attend?
- What was your intended major upon enrolling at Rutgers?
- Which science courses did you complete while in high school?
- Describe your experience in high school science courses.
- What were your greatest struggles with high school science coursework?
- Describe your high school science teacher(s) instructional methodology. How was the material delivered?
- How would you describe the instruction you received in high school science courses?
- Did you enroll in or complete a science during the summer prior to enrolling at Rutgers?
    a. If so, which course? Describe the instructional method. Describe how the summer science course may have influenced your preparation for the Solid GEMS Chemistry course. What grade did you earn?
    b. If not, do you feel that a summer course would have influenced your experiences in Solid GEMS Chemistry?
- Describe how your high school experience influenced your college major choice.
- Describe your feelings during the first day of Solid GEMS Chemistry instruction. What was your attitude about Chemistry?
- Describe your professor's instructional style.
- In what ways does the professor's instructional style influence your learning chemistry in the Solid GEMS Chemistry course?
- Describe the teaching practices you feel are best at enhancing student learning. Which do you feel are not? And why?
- How likely are you to register for the next course in the science sequence? Please explain.
- How has your experience altered your major choice? Why? Why not?

Interviews with Faculty

- How long have you been teaching? How long have you been teaching science courses?
- Have you taught high school science courses?
- How long have you been teaching at Rutgers?

- Which courses to do you teach at Rutgers?
- What do you perceive to be your greatest responsibility as a science instructor?
- What do you perceive to be your greatest challenge teaching General Chemistry 161/162?
- Describe your perception of Solid GEMS Chemistry 161/162 as compared to the Regular Chemistry course.
- Describe the various instructional strategies you use when teaching each course.
- What is your perception of how each course supports student success in the courses sciences?
- What are your perceived differences in the students who register for each course?
- Describe student academic performance in Solid GEMS Chemistry versus non-Solid GEMS Chemistry.
- What is your perception of student attitudes towards the course?
- What is your perception of student attitudes towards the sciences?
- In what ways do you believe the General Chemistry 161/162 course sequence can be improved to support student success for Solid GEMS and non-Solid GEMS?

Appendix B4

Focus Group Guide

Solid GEMS Chemistry Pedagogical Practices:
A Study of Student Experiences and Persistence

Researcher: Jenice Sabb, Graduate Student
Rutgers University – Graduate School of Education
Phone: 848-932-3617 Email: Jenice.sabb@gse.rutgers.edu

Total participant time required:	45 minutes to 1 hour
Total focus group time:	45 minutes to 1 hour
One Break:	10 minutes

Below is a general guide for leading our focus groups. This instrument may be modified as needed as each focus group discussion informs subsequent groups.

Prior to the beginning of each group, participants were welcomed and the purpose of the group discussion was explained. Each individual was asked to participate in the discussion and informed consent be obtained prior to beginning the discussion.

Introduction (10 m)

- Welcome participants and introduce the group moderator (PI).
- Explanation of the purpose for the discussion, how and why the participants were chosen.
- Discuss the purpose and process of focus groups.
- Explain the presence and purpose of recording equipment.
- Outline general ground rules and discussion guidelines such as the importance of everyone speaking up, talking one at a time, and being prepared for the moderator to interrupt to assure that all the topics can be covered.
- Review of the break schedule and where the restrooms are.
- Address the issue of confidentiality.
- Inform the group that information discussed is going to be analyzed as a whole and that participant' names will not be used in any analysis of the discussion.
- Read a protocol summary to the participants.

Hello, my name is Jenice Sabb. I am a student at Rutgers University's Graduate School of Education and I am conducting the focus group to examine how Solid GEMS Chemistry instructional practices may influence student success in General Chemistry 161 and 162 and potentially influence student persistence in the sciences.

The following students have agreed to participant in today's focus group session. (Name all students present). As this session will be videotaped and audio recorded, I am asking your permission to use these devices during today's session. Please recite your name and confirm your consent to videotaping and audio recording of the session. Your responses are confidential and will only be used for purposes of this study. Please be assured that your identity will not be revealed without your expressed permission.

Discussion Guidelines:

This should be an informal discussion, so I encourage you to respond directly to the comments of other people in the group. My participation in this discussion will be limited to facilitating the conversation through guided questions. I ask a question, listen for your responses, make sure that the conversation does not stall, and encourage everyone to share. If you do not understand any question, please let me know.

Please keep each other's identities, participation, and remarks confidential. This encourages everyone to feel free to speak openly and honestly.

As previously discussed, the session will be recorded because I want to ensure that I accurately capture each person's comments. No one outside of this room has access to these tapes and they will be destroyed after our report is written.

Location, Date, and Time:

These will be determined based upon student availability.

Focus Group Questions:

The following is a list of questions for the group discussions. I exercised care to ensure that questions remain focused on the topics listed, redirecting conversations that depart from the intent of the study.

- High school science course experiences
    a. Which science courses did you complete in high school? Describe your experience in those courses.
    b. Which science courses did you find challenging? Describe your greatest struggles in these courses.
    c. Which science courses did you find easiest? Explain what elements of the course(s) made it easy.
    d. Describe your high school science teacher(s).
    e. How would you describe the instruction you received in each high school science course? Explain the classroom practice.
    f. Describe how your high school instruction has prepared or not prepared you for college science coursework.

- Chemistry knowledge and skills
    a. In what year did you take high school chemistry, if you took chemistry in high school? Where was the course taken, at the high school or on a college campus?

b. Tell me how you rate your knowledge of basic chemistry – atomic mass, understanding the arrangement of the periodic table, etc. (Rating of 1 = below average, 3 = average, 5 = above average). Explain your rating.
c. What skills do you possess that assist your understanding and success in chemistry?
d. What skills must you acquire to enhance your opportunity for understanding and success in chemistry?

- Science instruction attitudes
    a. How do you feel about the science instruction you have received throughout your academic career? What are the best practices and what are the worst practices?
    b. How can teachers/professors illustrate points to encourage student learning?

- Solid GEMS Chemistry classroom behaviors and participation
    a. What circumstances led to your enrollment in the Solid GEMS Chemistry course? Describe your feelings about enrollment.
    b. Describe a typical classroom lecture. From the time you enter the classroom until the time you leave, describe your reactions to the professors instructional techniques and your peers’ behaviors.
    c. What are the professor’s classroom rules? Attendance, conversations, asking questions, etc.

- Is there any information you wish to share that we have not discussed?

Appendix B5

Classroom Observation Protocol

Course Title Section Number Semester
Observation Type:
Focus/Question:
Duration:

Observation Information/Details

Observer:	
Date of Visit:	
Class Period:	
Location/Campus/Room:	
Transcription Date:	

About the Participants:	**Data Collection Methods:**	**Additional Notes:**
<u>Targeted Group:</u> <u>Quantity:</u> <u>Other Participants:</u>		

Location/Setting Details:

Field notes write-up (to include time intervals, breaks, etc.)

Appendices (additional information to include classroom artifacts – syllabi, review sheets, and other handouts)

Appendix C

List of Majors Targeted for This Study

Rutgers University
School of Environmental and Biological Sciences
And
School of Arts and Sciences
Science Major Codes/List

001 Undecided ++
004 Engineering (4-Year) ++
005 Engineering (5-Year) ++
007 Unspecified Curriculum +
009 Pre-Science ++
017 Agriculture and Food Systems
067 Animal Science
105 Astrophysics ++
115 Biochemistry *
117 Bioenvironmental Engineering (5-Year) *
119 Biological Sciences *
120 Biological Sciences ++
122 Biomathematics ++
126 Biotechnology
129 Bioresources Engineering (5-Year) *
146 Biology and Neuroscience ++
160 Chemistry *
212 Earth and Atmospheric Sciences +++
375 Environmental Sciences
377 Exercise Science and Sport Studies *
400 Food Science *
447 Genetics *
460 Geological Sciences
628 Marine Sciences
660 Medical Technology ++
670 Meteorology
680 Microbiology *
694 Molecular Biology and Biochemistry ++
704 Ecology, Evolution, and Natural Resource
705 Nursing ++
707 Nutrition ++
709 Nutritional Sciences *
776 Plant Science *
832 Public Health *

+ SEBS major declaration code for all incoming freshmen, as students will not officially declare a major until the spring semester.
++ Rutgers School of Arts and Sciences major only.
* Major offered at Rutgers School of Environmental and Biological Sciences as well as Rutgers School of Arts and Sciences