[Although the author doesn't discuss it, his data show that the Physics First sequence with Modeling Instruction resulted in increased enrollment in advanced science courses. He can be contacted at dkmountz@gmail.com and dmountz2@eastern.edu, as of 2010.]

THE EFFECT OF A SCIENCE CORE SEQUENCE REFORM ON STUDENTS' ATTITUDES TOWARD SCIENCE

A dissertation submitted to the faculty of
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Douglas Kirk Mountz

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Sister Ann Heath, IHM, Ph.D.
DEAN, GRADUATE DIVISION

Sister Carol Anne Couchara, IHM, Ed.D.
CHAIRPERSON, EDUCATION DEPARTMENT

Abstract

This mixed method case study examined the effect that a Science Core Sequence Reform (SCSR) had on the attitudes of high school students toward science. The purpose of the reform was to raise science literacy among high school students in that school district. This reform adopted a science sequence of physics to chemistry to biology for all students beginning in ninth through eleventh grades respectively. An instructional methodology called modeling physics was adapted by physics teachers in preparation for a conceptual physics course that was appropriate for ninth grade students. In this study, (a) the responses to pretest and posttest attitude surveys of over 500 students were analyzed, (b) interviews of fourteen teachers of SCSR students were conducted, and (c) the archival records of past core science course selections were examined. The results of this study suggested that students' attitudes toward science increased in areas of personal interest and relevancy but decreased with respect to student interest in science careers. With the Science Core Sequence Reform required of all students, the relative constancy of student of students' attitudes towards science and the small percentage increase in students selecting science electives could both be viewed as positive outcomes of the reform.

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In his heart a man plans his course, but the Lord determines his steps. Proverbs 16:9

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CHAPTER ONE - INTRODUCTION

Overview

In the years following the successful launch of Sputnik I on October 4, 1957, the initial gains in academic achievement made by students in American education that were spurred by the historic event evaporated (National Commission of Excellence in Education, 1983a). The decline in student achievement continued for 26 years until the National Commission of Excellence in Education (NCEE), in preparing the landmark education status report, *A Nation at Risk: the Imperative for Educational Reform* (NCEE, 1983a), issued a second alarm by leveling an indictment on the existing state of education in the United States. The report came right to the point in its introduction by declaring, "… the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (p. 1).

Indicators that the decline in academic achievement was not merely an occasional anomaly were listed by NCEE (1983a). Among the indicators, the commission noted that average achievement scores on standardized tests by high school students were lower than they were in 1957. In addition, complaints came from the business sector and the military that new employees and recruits required costly training and remediation in basic skills of (a) reading, (b) writing, and (c) computation. Commission recommendations to strengthen high school graduation requirements through four years included: "... (a) 4 years of English; (b) 3 years of mathematics; (c) 3 years of science; (d) 3 years of social studies; and (e) one-half year of computer science" (NCEE, 1983b, p. 1). Although its target was the American educational system, to its credit, *A Nation at Risk* acknowledged, "This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility" (1983a, p. 1).

Support for this position came from the American Association for the Advancement of Science (AAAS) in its report, *Science for All Americans* (1989), which stated, "Although the most powerful argument for improving the science education of all students may be its role in liberating the human intellect, much of the public discussion has centered on more concrete, utilitarian, and immediate justifications" (p. 1). In this report, AAAS pointed to international studies and the most recent study at that time of the National Assessment of Educational Progress which showed that the average performance of seventeen year old students in mathematics and science in 1986 had fallen behind levels achieved in 1969 (1989).

Nobel laureate, Dr. Leon Lederman (2001, October) called for literacy for the general public to extend beyond reading and writing to include science that followed a sequential, physics, chemistry, and biology curriculum. Most recently, President of the United States, George W. Bush, in his State of the Union address, called for the nation, "... to encourage children to take more math and science, and make sure those courses are rigorous enough to compete with other nations" (2006, p. 1). In his address the President also proposed that thousands of additional high school mathematics and science teachers be trained to meet the challenge of enabling the young people to become successful in their lives thereby ensuring that America's future in the world will be successful.

Science Academic Standards

The need for science education reform was echoed by the National Academy of Sciences in the "Call to Action" of its National Science Education Standards (NSES), (1996, p. ix) publication which repeatedly highlighted the importance of scientific literacy as a goal for all students to achieve. Science standards were presented in order to achieve the end goal of science literacy for all students. Those standards that were addressed included: (a) Science Teaching Standards, (b) Standards for Professional Development for Teachers of Science, (c) Assessment in Science Education, (d) Science Content Standards, (e) Science Education Program Standards, and (f) Science Education System Standards.

In the Commonwealth of Pennsylvania, the Academic Standards for Science and Technology described the progress of what students should be able to do and to know in science at grade levels four, seven, ten and twelve (Pennsylvania Department of Education, 2002). The Standards components that provided a framework around which specific standards at each grade level were written included: "(a) nature of science, (b) unifying themes of science, (c) knowledge, (d) inquiry, (e) process skills, (f) problem solving, and (g) scientific thinking" (p. 4). The disciplines of science to which these standards were address included: "(a) Unifying Themes of Science; (b) Inquiry and Design; (c) Biological Sciences; (d) Physical Science, Chemistry, and Physics; (e) Earth Sciences, (f) Technology Education, (g) Technological Devices, and (h) Science, Technology and Human Endeavors" (p. 1).

A Call for Science Literacy

The need for science literacy gave birth to Project ARISE (American Renaissance in Science Education) in 1995 (ARISE, 2003). The goal of this project has been to develop a framework around which high schools can develop a three-year curriculum in the core sciences, following the sequence of (a) Physics, (b) Chemistry, and (c) Biology More than a reversal in the traditional order of sciences from biology to chemistry to physics, Lederman (2006) explained:

> It is, if we do it right, a true revolution in science education. The integrity of the three core disciplines is preserved, but now with the disciplines correctly organized, they can be connected to form a coherent and overarching wholeness which we call science. The disciplines support each other. There are many possible variations to this revision but the essential hierarchy and coherence need to be preserved. (p. 1)

What Lederman meant by science disciplines being correctly organized was that the natural hierarchy of science began with physics which was foundational to the understanding of chemistry. He noted that chemistry in turn provided the foundational understanding for molecular biology and all of its complexities (2001). Prior to entering the high school science curriculum that began with physics, Lederman wrote that it would be practical if middle school age students would be prepared with an understanding of the size of atoms and the role they play in making up our world (2001). He further proposed that the first year of the science core curriculum begin with ninth grade students. At the same time that these students studied the first year of algebra, they would gain a conceptual understanding of physics expressed through language expression and not primarily through mathematical problem solving (2001). Lederman acknowledged that the European and Asian approach to science instruction that cycles through the core disciplines of (a) physics, (b) chemistry, and (c) biology within the span of an academic year was superior to the traditional United States' system of science education (2001). In that system almost all of the student population took biology, falling to 50% of that population that took chemistry, and dropping to only 20% of the original student population that took physics (2001, October). Lederman was insistent when he wrote,

> However, it is my strong conviction that the physics (a full year) must precede chemistry in order to make use of the logical connections – the fact that everything is made of atoms and that the power of physics is the clarification of the structure of atoms, subject to the principles of quantum physics. Obviously, we do not accept the pessimistic view that ninth graders cannot grasp such abstract ideas. (p. 4)

Lederman's call for reform was reinforced by a statement adopted by the Executive Board of the American Association of Physics Teachers (2002). In a statement the board acknowledged that the "Physics First" approach, "has the potential ... to lay the foundation for more advanced high school courses in chemistry, biology or physics" (p. 1). This would open the door to additional and varied science electives, allowing for the implementation of advanced placement science courses such as those called for by President Bush (2006).

Pattanayak (2003) observed that "The physics-first curriculum is more than a cosmetic change to the structure of the curriculum. It represents a different educational mindset" (p. 3). The previous American educational mindset toward physics was expressed by Neuschatz and McFarling (1999). They noted that historically, even though physics had been available in the science curriculum of high schools throughout the nation, it was, "... the manner in which physics was traditionally taught – as an advanced elective for college-bound seniors especially those who were science-oriented – that limited its accessibility for many students" (p. 3). The way of thinking behind putting physics first in ninth grade in the science reform not only provided coherency and connections between the core sciences in the natural hierarchy of science but afforded students in their senior year the opportunity to enroll in advanced science electives such as Advanced Placement Physics or sciences like Earth and Space Science that would be built on the knowledge base built on the framework of the core science disciplines (Lederman, 2001).

Need for the Study

In the rational order of science instruction, physics is foundational for the development of more abstract and invisible concepts of matter and energy within the discipline of chemistry which, in turn, is required for the study of molecular-based biology (Lederman, 2001). To this end, the science department, at the high school where this study took place, completed the transition from a traditional sequence of science instruction to a physics–chemistry–biology (P-C-B) sequence over a period of three years. For the purposes of this study, the particular physics-chemistry-biology sequence as followed by the high school where this study was undertaken was referred to as the Science Core Sequence Reform (SCSR). Physics instruction required the adoption and implementation of an appropriate instructional methodology appropriate for ninth grade students that was more conceptual and limited to Algebra I mathematical concepts. For this reason, it was impossible to isolate the P-C-B sequence from the influence of instructional methodology variables in the study of the effect of the SCSR on the attitudes of students toward science.

The first year of SCSR, beginning in the ninth grade, was referred to as "Freshman Physics". The course promoted student inquiry through a highly constructivist methodology called "modeling" (Wells, Hestenes, & Swackhammer, 1995). This methodology, adapted for ninth grade physics students, placed a greater emphasis on student operational understanding of the physical laws of mechanics and electricity. Conceptual understanding of principles of physics was primarily achieved through active student experimentation and analysis of observations, with less emphasis on mathematical problem solving to gain understanding. This approach gained support from the Gibson (1998) study that showed that middle school students, exposed to inquiry-based approaches to sciences had a higher interest in science than high school students who had been taught using more traditional methods of instruction through note taking and lecturing. Requiring only a basic understanding of Algebra I, Freshman Physics did not presume to be a replacement for Senior Physics. Students entering tenth grade received instruction in chemistry built upon an understanding of the physics concepts of matter and energy learned in their freshman year. With a foundational year of chemistry completed, students were then prepared to complete the final year of SCSR by taking biology which was based upon the chemistry concepts learned in tenth grade.

While physics was widely taught throughout high schools in the United States, Sheppard and Robbins (2003a) noted that the physics instructional methodology needed to be modified to include those students who were not necessarily science-oriented or college-bound. Modification to instructional methodology was a necessary component of science reform, but neglected to consider the preparatory role that physics held among the sciences. Physics laid the foundation for chemistry which in turn provided the foundation for the understanding of biology with its molecular emphasis in explaining cellular events. Bardeen et al. (1998) observed that, "… modern biology requires knowledge and skills drawn from chemistry and physics" (p. 13). Resistance to assign physics anywhere but at the end of a traditional high school science sequence impeded the implementation of the more logical P-C-B sequence. Sheppard and Robbins (2003a) also observed that, "The historical development of high school science education via the B-C-P order coupled with low graduation requirements inevitably lead to low enrollments" (p. 15).

In this study, student attitudes toward science were investigated to determine the effect that the implementation of the P-C-B sequence had on students' disposition toward choosing science in their future educational and career plans. Beginning in 2002, the science department's initiative took aim at instituting two reforms in the high school science curriculum. The first reform was marked by the introduction of a science core sequence beginning with ninth grade physics followed by chemistry in tenth grade and concluding with biology in eleventh grade. The second reform required all students to take these academically rigorous science core course offerings which necessitated a change in teaching methodology, especially for Freshman Physics. This raised the question as to whether it was the teaching methodology, as opposed to the P-C-B reform sequence, which affected changes in students' attitudes toward science. The steps toward implementation of these reforms were neither smooth nor without complications. The challenges of this reform were appropriately expressed by Fullan (1993) who wrote that, "Change is non-linear, loaded with uncertainty, and sometimes perverse" (p. 24).

With the inception of SCSR, the three year physics-chemistry-biology sequence of science courses required for high school graduation, (a) educators, (b) parents, and (c) students may want to know how attitudes of students toward science had been influenced since the implementation of this science core sequence reform (SCSR). Students' attitudes toward science may be related to whether or not students consider science among their future education options or careers. Information gained from the study might aid teachers and administrators in planning for future science course electives.

Studies have linked student attitude to their continuation of science learning after leaving the influence of their teacher (Von Secker, 2004). This investigation into student attitudes about science was conducted to assess the effect that the science core sequence reform has had (a) in affecting student interest in science, (b) in predicting future student science achievement, and (c) in anticipating yearly student science course elective interest and selection. An added benefit of this reform allowed students to broaden and deepen their understanding of science through additional core science and non-core science electives.

More studies investigating student (a) achievement, (b) attitudes, (c) perceptions, and (d) interest are needed to confirm the value of science reform initiatives that seek to restore American science achievement to historical levels of acceptability. As desirable as science reform may be, Fullan (1997) cautioned that a, "... counterproductive problem that appears in the guise of reform is the presence of a multiplicity of change initiatives which actually make matters worse" (p. 290).

Statement of the Problem

The purpose of this study was to examine the extent to which the implementation of the Science Core Sequence Reform influenced the attitudes of those students toward science. The reform consisted of two parts that included the adoption of a science sequence of physics to chemistry to biology for all students beginning in ninth grade and the implementation of new methodologies of science instruction. Concern was raised when the reform was first proposed that physics and chemistry, which could be evaded by students under the traditional science requirements for graduation, were not appropriate for everyone and would serve as major obstacles to graduation from high school. Three years since the inauguration of the SCSR, an examination of its influence on students' attitudes toward science was a timely study that can enable science educators to justify or reexamine the decision to implement the reform.

Definitions of Terms

The following definitions were applied for the purpose of this study.

affect – "... the feelings or emotions people have toward something" (Walker, 2005, p. 1).

attitudes – "... dispositions toward overt action" (Likert, 1932, p. 9).

core science – one of "... the three primary disciplines in high school education - biology, chemistry and physics" (ARISE, 2003, p. 7).

cross-sectional study – "A cross-section is a random sample of a population, and a cross-sectional study examines this sample at one point in time. Successive cross-sectional studies can be used as a substitute for a longitudinal study." (Sharp & Frechtling, 1997, p. 9-3)

Freshman Physics – a specific application of Physics First at the high school which was the subject of this study. The instructional methodology used at this high school was Modeling Physics (Hestenes, Jackson, Halloun, Dukerich, & Swackhamer, 2002).

Likert scale – A scale used in an attitude survey consisting of statements in which the, "... respondent is asked to indicate whether he or she strongly agrees (SA), agrees (A), is undecided or neutral (N), disagrees (D), or strongly disagrees (SD) with the statement; the response is then scored 1, 2, 3, 4, 5 respectively" (Schibeci, p. 566).

longitudinal study – "An investigation or study in which a particular individual or group of individuals is followed over a substantial period of time to discover changes that may be attributable to the influence of the treatment, or to maturation, or the environment" (Sharp & Frechtling, 1997, p. 9-4).

mixed method evaluation – "An evaluation for which the design includes the use of both quantitative and qualitative methods for data collection and data analysis" (Sharp & Frechtling, 1997, p. 9-5).

model – "... (in physics) is a representation of structure in a physical system and/or its properties" (Hestenes, 1996, p. 8).

modeling method – instructional method which engages students, "... in explicit construction and manipulation of externally structured representations" (Hestenes, 1996, p. 5).

non-core science - a science course of study that primarily serves to broaden, rather than deepen, student understanding of the core sciences in those subject areas.

Physics First – "... a three-year core curriculum for high school science [in which] physics becomes the focus of the first year of high school science study, chemistry remains the second, and biology becomes the third" (ARISE, 2003, p. 7).

qualitative evaluation – "The approach to evaluation that is primarily descriptive and interpretative" (Sharp & Frechtling, 1997, p. 9-6).

quantitative evaluation – "The approach to evaluation involving the use of numerical measurement and data analysis based on statistical methods" (Sharp & Frechtling, 1997, p. 9-6).

Science Core Sequence Reform (SCSR) – the term created by the researcher in reference to the three year initiative undertaken at the school where the study was conducted in order to change the sequence of the core sciences. The SCSR extended to all students, grades nine through eleven in a sequence that included freshman physics that implemented a modeling physics methodology, chemistry, and biology.

Socratic dialogue – an instructional questioning technique that engages the student in a dialogue with his or her instructor in order to reveal that student's misconceptions and to evaluate his or her understanding of a concept (Hake, 1992).

Test of Science-Related Attitudes (TOSRA) – a 70 item, Likert-type attitude instrument, developed by Barry J. Fraser, for the purpose of collecting data related to high school students' attitudes toward science (Fraser, 1981a).

TOSRA2 pretest – a 35 item, Likert-type attitude instrument, adapted from the Test of Science-Related Attitudes (TOSRA) by the Australian Council for Educational Research and used by the researcher as the pretest for this study (Fraser, 1981b).

TOSRA2 posttest – a 35 item, Likert-type attitude instrument, adapted from the Test of Science-Related Attitudes (TOSRA) by the Australian Council for Educational Research and used by the researcher as the posttest for this study (Fraser, 1981c).

whiteboarding – "a teacher directed process designed to probe a student's prior understanding, [expressed numerically and pictorially on a white board] and to construct strategies to bring the student to a more complete comprehension" (Yost, 2003, p. 1).

Limitations

The attention of this study was directed at a single school district in southeastern Pennsylvania that implemented the Science Core Sequence Reform initiative in the 2002-2003 school year. At that time, science classes were conducted for 42 minutes each day over the course of the entire 180 day school year. Only students and teachers, primarily science teachers of this school district, were considered as subjects for the study. Research did not extend to other school districts that followed a traditional science sequence for the purpose of serving as a control school. The study focused on student attitudes, not student achievement. While research apart from this study had been conducted to establish correlations between student attitudes and student academic achievement, the researcher did not draw any conclusions regarding the relationship between students' attitudes and achievement in science. Because the researcher was formerly a member of the science faculty at the school where the case study was conducted, researcher bias was a concern since the researcher played an instrumental role in establishing the science reform initiative.

While the impact of the physics – chemistry - biology reform on students' attitudes toward science was the subject of this study, it was not possible to isolate the influence of other factors that could have had an effect on those same attitudes. The most apparent limitation of this study was that the isolation of the P-C-B sequence alone as a single variable was not possible. Inherent in the reform process was the acknowledgment that appropriate instructional methodologies in science at each grade level needed to accompany the change in sequence. This raised the question of whether the changes in the order of the core sciences or the revised instructional methodologies at each grade level were responsible for how data of students' attitudes toward science were affected.

A change which was introduced at the same time that this study was undertaken was a 90 day block schedule made up of 84 minute blocks of instructional time for each subject. Prior to this study and subsequent to the third completed school year since the reform was instituted, instruction in science classes followed a traditional 180 day schedule. As previously mentioned, the three year P-C-B science sequence was required of all students for graduation. This graduation requirement meant that teaching methodologies had to be changed to accommodate all learners. In addition, the repositioning of physics from twelfth grade to ninth grade made it inevitable that an appropriate methodology for teaching physics to ninth graders would have to be developed or adopted.

Another limitation was the turnover in science teaching staff that saw the departure of two science teachers in the third and fourth years of the reform who were instrumental in the curriculum development and instruction of Freshman Physics. This necessitated the hiring of two physics teachers who had to learn and implement the modeling physics methodology that had been developed for Freshman Physics instruction. In a similar manner, the study could not account for variations in teacher enthusiasm and instructional approaches from one science classroom to the next.

The implementation of the Science Core Sequence Reform involved more than a reversal in the order of the subjects in the traditional B-C-P science sequence. Prior to the reform, the three core sciences were not required subjects for graduation. Typically a student would take Earth and Space Science in ninth grade, Biology in tenth grade, and then a science elective in eleventh grade. With the implementation of the reform, student enrollment in core science subjects would no longer be optional. Offerings of non-core science course electives could no longer be substituted for the core sciences in fulfilling graduation requirements. The effect of these and the aforementioned limitations must be considered when analyzing the data generated by science attitude pretest and posttest results, teacher interviews, and archival records which constitute the research instruments of this study.

Statement of Research Questions

The following questions were investigated in this study.

1. Was there a relationship between the attitudes of Science Core Sequence Reform (SCSR) students and their decisions to pursue science related options in their post-high school education and career plans?

2. What changes in students' attitudes toward science had occurred since the implementation of the SCSR?

3. How had science electives been impacted by the SCSR program?

Summary

In response to evidence pointing to a steady decline in student science achievement over the past four decades, one high school science department instituted a science reform initiative that reordered the sequence of the core sciences in the curriculum. This Science Core Sequence Reform (SCSR) placed physics in ninth grade, chemistry in tenth grade and biology in eleventh grade. In addition, the reform required that all students take (a) Physics, (b) Chemistry, and (c) Biology as requisites for graduation. Traditional studies have suggested that there is a link between students' attitudes toward science and their decisions to follow science in various pursuits beyond high school. The purpose of this study was to examine how students' attitudes toward science have been affected since the implementation of the reform. More specifically, this study examined the effect of the reform on students' science attitudes with respect to their future educational and career decisions. In an area of research where data are lacking, the results of this study may serve as a starting point for further research that will investigate more thoroughly the relationship between students’ attitudes and their achievement in science.

CHAPTER TWO – LITERATURE REVIEW

Introduction and Background

Dating back to the second half of the 19thcentury, science education has followed the lead of American public education which has been influenced by, "… industrial-age assumptions about learning." (Senge et al., 2000, p. 35). Senge et al. also noted that the principles along which schools have been organized frequently lie in opposition to what individuals know to be in the best interest of the individual student. The traditional three-year core science sequence of (a) biology, (b) chemistry, and (c) physics (B-C-P) was one such principle or standard that came into existence in American public education during the 1920's (Sheppard & Robbins, 2003b) and has largely remained in place amid challenges to its appropriateness for science instruction. Recognizing this prevailing condition of inertia, Neuschatz and McFarling (1999) stated that American public education, "… is very difficult to change in a coordinated way" (p. 1). Even the compartmentalization of each of the core sciences into one year courses of study was a throwback to the industrial-age, assembly line influences on education. These influences differed sharply from early 20th century European approaches that taught physics over the course of three or four years (Sheppard & Robbins, 2003a).

The present traditional high school science core sequence of instruction, which consists of (a) biology, (b) chemistry, and (c) physics, (B-C-P) was the unforeseen outcome of the work done by the Committee of Ten in 1893, entitled *Report of the Committee on Secondary School Studies* (Sheppard & Robbins, 2003a). Organized by the National Education Association, the Committee of Ten proposed four courses of study for high schools that included (a) Classical, (b) Latin-Scientific, (c) Modern Languages, and (d) English. In each course of study, the science requirements placed physics ahead of chemistry. The controversy that followed the Committee of Ten's recommendations was predictable and immediate. In the ensuing years, (a) numerous committees revised the recommendations of previous committees, (b) college entrance requirements for science were reduced to one year, and (c) general science would serve as either a terminal course or as prerequisite to the introduction of general biology. Sheppard and Robbins (2003b) found that in 1920, the Committee on the Reorganization of Science in Secondary Schools made a formal recommendation to include general biology in the high school science sequence. The committee placed biology at the beginning of the science sequence without specifying the order in which physics and chemistry would follow. A gradual national trend occurred between 1923 and 1930 in which chemistry preceded physics in the high school science sequence. In time, this science sequence became established as science subjects became identified with each grade level. By the time World War II ended, as noted by Sheppard and Robbins (2003b), the B-C-P sequence was firmly in place and had remained so to the present day.

The traditional B-C-P science sequence was instituted at a time when biology was regarded as a descriptive science which focused on topics such as (a) taxonomy, (b) systems, (c) collections, (d) drawings of observations, and (e) other topics that required a minimal amount of mathematics. The abstractions of chemistry and its applications of higher mathematics qualified it as next in the succession of core sciences to follow biology. Since physics was determined to require the greatest preparation in mathematics, it appeared to be the logical science to conclude the sequence (Roeder, 2002). With the advances soon to be made in molecular biology, this sequence became less justifiable but it remained entrenched in the high school science curriculum. Subsequent to the publication of their paper, "A Structure for Dioxyribose Nucleic Acid" by James D. Watson and Francis H. C. Crick (1953), the biology curriculum has included the study of advancements in molecular-based chemistry concepts, making biology instruction increasingly dependent upon a previous student understanding of chemistry.

Support for Science Core Sequence Reform

In 1998, at an international level involving as many as 21 countries, United States students scored significantly below the international average in (a) mathematics literacy, (b) science literacy, (c) advanced mathematics and (d) physics (Third International Mathematics and Science Study (TIMSS), 1998). The results served to lend validity to the perception that science achievement in the United States was in a state of decline and in need of reform. The 2000 science assessment results released by the National Assessment of Educational Progress (NAEP) showed, "… a decline in performance at grade 12 since 1996" (National Center for Education Statistics NCES, 2002, p. 1). The report (2002) further cited that, "Science achievement has been shown to vary depending on the type of science courses students take" (p. 12). Seniors who had taken a first year course in at least one of the three core sciences fared better on the assessment than classmates who had not taken a first year core science.

The Science Core Sequence Reform (SCSR), which was already in place at the high school at the time this study was conducted, was characterized by three factors intended to bring about improvement in student science achievement. First, instructional methodology modifications for appropriate science instruction to all students at all grade levels, especially ninth grade physics, were to be critically evaluated and revised periodically. VanTassel-Baska (1998) pointed to research from the College of William and Mary that one essential element of high ability learners is, "An emphasis on learning the scientific process, using experimental design procedures" (p. 5). Nobel laureate physicist Richard P. Feynman (1969) supported this position by giving his best definition of science as, "... the result of the discovery that it is worthwhile rechecking by new direct experience, and not necessarily trusting the race experience from the past" (p. 319). Secondly, the reform fostered academic intensity with the adoption of the three year P-C-B science core sequence with its emphasis on inquiry and laboratory experience as a graduation requirement for all students. Adelman (1999) identified a high school curriculum with academic intensity as one that has a minimum of at least two core laboratory sciences that are limited to (a) biology, (b) chemistry, and (c) physics. Finally, the logical progression of the physics-chemistry-biology (P-C-B) sequence was the centerpiece of SCSR, but this sequence alone can not ignore the fact that science teachers have a substantial influence, for better or worse, on students' attitudes toward science (Munro and Elsom, 2000).

According to Weiss, “Too few students are taking the kind of courses they need to enter college ready to succeed” (p. 2). In the past, core science subjects, such as chemistry and physics, had been avoided by students who elect less challenging science courses in order to meet graduation requirements. Reid and Skryabina (2002) noted that physics is popular among high school students in Scotland and attributed it to that fact that physics is regarded as a regular school subject among other subjects. The researchers observed that in Scotland it was quite normal for large numbers of students to take physics while in England physics was regarded as a difficult subject, reserved for academically talented students. Weiss (2001) pointed out that since 1950, the number of students finishing a baccalaureate degree today remains about the same while the percentage of students entering college had risen dramatically. The findings of the National Center of Education Statistics (2001, August) showed that students who experienced a rigorous high school curriculum, which included chemistry and physics, were more advantaged to complete a four year program of studies leading to a bachelor’s degree.

In its descriptive brochure, the Southern Regional Education Board (SREB) summarized the purpose of its *High Schools That Work* initiative.

> *High Schools That Work* is the largest and oldest of the Southern Regional Education Board’s school improvement initiatives for high school and middle grades leaders and teachers. More than 1,200 *HSTW* sites in 32 states are using the framework of *HSTW* Goals and Key Practices to raise student achievement. (SREB, 2006, p. 1)

In their study of students taking the *High Schools That Work* - recommended curriculum, Bottoms and Feagin (2003) reported in their key findings, “… that one change in school practices that can have the greatest impact on student achievement is to have every student complete a challenging academic core in either an academic or a career/technical concentration” (p. 1). One component of that recommended curriculum included, “Three credits in lab-based science, with at least two at the college-preparatory level” (p. 3). Lending support to the significant role of academic intensity in student achievement, McLure and McLure (2000) noted a recurring pattern in their study that “The more science courses taken, the higher the ACT Science Reasoning test score” (p. 22).

A Rationale for the Adoption of a Freshman Physics Methodology

With the decline in student science achievement and student interest in science, it was natural that attention had been directed toward what was taught in science and how it was taught. Lederman (ARISE, 2002) advanced the need for reform in the sequence in which high school science subjects are taught. Osborne, Driver, and Simon (1998) recognized the need for variety in science instruction to sustain student interest in science but expressed doubt as to whether there existed a science teaching method that had universal appeal. Woolnough (1994) pointed to the inspirational influence of teachers and the active involvement of students in science as being effective factors that encouraged student interest in science. Stokking (2000) identified a consensus among teachers that to motivate students, a physics education curriculum should have addressed issues in everyday life which engaged the student through active participation. Even with the innovative strategies in place, Wilt (2005) observed that incorrect worldviews about physics concepts that originated in kindergarten through eighth grade persisted among high school and college students.

To a large extent, the purpose of modern education had been to provide students with information about a subject with attention given toward what the student should have learned about the subject. However, Middle Ages expert Dorothy Sayers (1947) lamented, “Is not the great defect of our education today … that although we often succeed in teaching our pupils ‘”subjects”’, we fail lamentably on the whole in teaching them how to think: they learn everything, except the art of learning” (p. 3). The Science Core Sequence Reform would be in jeopardy without careful consideration given to the instructional methodology implemented at each grade level that would cultivate the art of learning. Of the three grade levels affected by SCSR, the methodology developed for freshman physics instruction is the most critical for two reasons. Freshman Physics laid the foundation for the remaining two years of SCSR. Secondly, Physics instructional methodology needed to be redesigned as a required science course that would accommodate (a) the learning preferences, (b) the abilities, and (c) the social dispositions that characterized ninth grade students, not seniors.

Sayers (1947) suggested that the focus of instructional methodology as to how a child could best learn, be drawn in line with the maturing personality development of the child at each of three distinct stages of preparation for learning. As described by Sayers, the first stage, which roughly corresponded to a child’s early elementary school years, was a stage where memorization and recitation are agreeable to the child and reasoning is difficult. In this first stage, for children in their early elementary years, appropriate science instruction is arranged around collections and the identification of things and their properties. While students would not be doing science, their activity would serve as preparation for learning to do science.

In the second stage of learning development, Sayers (1947) observed an argumentative stage in which the child, “... is characterized by contradicting, answering back, liking to ‘catch people out’ (especially one’s elders); and by the propounding of conundrums. Its nuisance-value is extremely high” (p. 6). When students entered into this stage, the learning process should have cultivated reasoning skills among students and sharpened their ability to analyze (a) processes, (b) patterns, and (c) relationships. Ethical issues in science for children to consider would be introduced at this stage. Students should also have been prepared to critically examine information for “… slipshod reasoning, ambiguity, irrelevance, and redundancy” (1947, p. 10).

Sayers noted a third developmental age of self-expression in the personality of a student that she described as:

> ... self-centered; it yearns to express itself; it rather specializes in being misunderstood; it is restless and tries to achieve independence; and, with good luck and good guidance, it would show the beginnings of creativeness; a reaching out towards a synthesis of what it already knows, and a deliberate eagerness to know and do some one thing in preference to all others. (p. 6)

At this stage, students needed to be able to strengthen their understanding of science concepts by communicating these concepts with others. Drayton and Falk (2001) identified appropriate science instruction for this stage in an inquiry-oriented classroom that would allow for students to collaborate with each other as well as, "... test arguments, evaluate methodologies, and compare theories" (p. 29). The age-appropriateness of this stage of learning was evident from the results of a three year study of elementary students that showed that the use of interactive-constructionist strategies did not indicate significant differences in student, "... achievement, attitudes (or) career awareness" (Shymansky, Yore, & Anderson, 2000, p. 11). Reflecting on these results, the researchers asked rhetorically, "Perhaps these strategies would be far more powerful with middle school or even high school students?" (p. 12). This observation pointed out that advanced methods of learning could not be hurried if a child had not matured to a higher developmental age of learning.

If Sayers (1947) was correct, students' attitudes toward learning are closely affected by how they learn at a particular age. Guided by this premise, the search by the high school science department, which is the subject of this study, led to the selection of an instructional methodology in which students could experience physics as opposed to learning about the subject physics. The search ended with the adoption of a methodology called "modeling" for freshman physics.

Modeling Methodology

By the time most students reach the ninth grade, they are old enough to have experienced the three stages of (a) recitation, (b) argumentation, and (c) self-expression (Sayers, 1947) in their lives and are receptive to a physics curriculum that has been tailored to take advantage of these learning stages with an appropriate methodology. In writing about best practices for teaching science students with learning disabilities, Matkins (1999) cited words and phrases originating in science reform research that included, "Inquiry, constructivism, learning cycle, hands-on (also hands-/minds-on), process-based, laboratory, and Socratic Method" (pp. 4-5). For gifted or high ability learners, Van Tassel-Baska (1998) cited elements of instruction that these students hold in common with other students which included (a) mastery of fundamental concepts, (b) higher order thinking, (c) methods of inquiry, (d) use of technology, and (e) experimental design. In order to address these learning styles that would best serve the interests of all students, the instructional methodology selected for ninth grade physics instruction by the high school science department, which was the subject of this study, was called modeling methodology (Wells, Hestenes, & Swackhamer, 1995). Modeling methodology came about though the inspired and dedicated educational research of Malcolm Wells et al. (1995) and was being continued through programs offered at Arizona State University. The rationale for implementing modeling lay in (a) its close correspondence to scientific practice, (b) its superiority to traditional instruction, and (c) its supportive research. While originally intended for senior physics students, modeling physics was adapted successfully for freshman students who had shown gains in their understanding of physics concepts that were higher than those of seniors in traditionally taught high school physics courses (Rice, 2003). Nevertheless, physics for freshmen was not meant to replace senior physics which placed a greater emphasis upon higher level mathematical problem solving.

Student misconceptions about physics concepts were no more typical of freshmen than they were of seniors. In addressing physics instructional concerns faced by high school seniors and college level students, Arons (1997) wrote,

> … research is showing that didactic exposition of abstract ideas and lines of reasoning (however engaging and lucid we might try to make them) to passive listeners yields pathetically thin results in learning and understanding except in the very small percentage of students who are specially gifted in the field. (p. vii)

Arons continued by underscoring, "… the necessity of supplementing lucid exposition with exercises that engage the mind of the learner and extract explanation and interpretation in his or her own words" (p. vii). Regardless of grade level, these misconceptions were linked to traditional instruction that, "… overlooks the crucial influence of students' personal beliefs on what they learn" (Hestenes, 1996, p. 4). Hestenes further stated:

> The modeling view is that students learn best from activities that engage them in actively constructing and using structured representations to make sense of their own experience and communicate with others. To optimize learning, the activities must be carefully planned and managed by the teacher. (p. 18)

Rather than conduct a comprehensive sweep of disconnected facts during the course of a year, teachers employed modeling tools that allowed students to engage in the examination of a physical situation's structure through multiple representations. These representations were constructed by students applying modeling tools that included: (a) verbal expression, (b) diagramming, (c) graphing, (d) mathematical expression, (e) system schema, (f) motion maps, and (g) force diagrams (Hestenes, 1996).

Of the many modeling tools available, two of the most effective tools were also the simplest and most versatile. Following a student's active examination of a physical system, the student prepared a 32" X 24" whiteboard using dry erase markers that provided sufficient information to show that the student understood the concept behind the system. It was through this whiteboarding process that, "… the teacher guides the student toward understanding during the student's explanation" (Yost, 2003, p. 1) before the student's peers. The other modeling tool which could be used by the teacher in the whiteboarding process was Socratic dialogue (Wells et al., 1995). Skillful questioning by the teacher led to deeper student understanding of key concepts through reflection and critical thinking. Student understanding became evident when students explained their understanding of a concept back to the teacher. Attentive students in the class benefited from this process as well.

Factors that May Influence Students' Attitudes toward Science

Studies have shown that, in general, attitudes that students have toward science tend to decline in the middle school grades and follow a similar pattern in high school (George, 2000; Osborne, Driver, & Simon, 1998; Simpson & Oliver, 1990). The results of these studies make a strong case for a better understanding of attitude so that the factors that may influence on students' attitudes toward science might be understood more clearly. Several definitions for attitude have attributed three components to it which can be identified as (a) cognitive, (b) affective, or (c) behavioral (Dwyer, 1993). The cognitive component of attitude is characterized by ideas or beliefs, held by an individual that are related to the value of something. An example of a cognitive attitude component would be the extent to which a student considers science to be relevant to his or her present circumstances or future, as in a career. The affective component, or *affect*, is characterized by a person's emotions or feelings about an issue (Walker, 2005). A student's perceptions about the normalcy of what a future lifework in science would be like would typify an affective attitude. The responsive actions taken by an individual are evidence of the behavior component of attitude (Dwyer). Students who would choose to take advance science electives or apply for summer science internship programs would be examples of the behavior component of attitude.

Although the impact of a new science sequence on students' attitudes was the primary object of this study, it was important for the investigator to be aware of other factors that affected students' attitudes as well. These factors were varied and may be difficult to control while investigating the effect of the one variable that was of primary interest. A number of factors that influenced students' attitudes toward science included: (a) career interest, (b) environmental factors, (c) personal relationships, (d) laboratory instruction, (e) computer use, (f) the passage of time, and (g) the worldview held by each individual student.

Career interest

Munro and Elsom (2000) observed that students were more inclined to take science courses when they learned that science was needed for a particular career that interested them. The researchers cited one teacher as saying, "'… they need a reason for doing science'" (p. 4). Nevertheless, studies showed a relationship between career interests and a culture that fostered gender role attitudes. Research by Taber (1992) suggested that certain areas of work that were closely related to physics were perceived by students to be the kind of work that men, as opposed to women, would do. These student perceptions, which were observed at the time students entered secondary school, may have accounted for the relatively low enrollment of girls in physics courses (Taber). Greenfield (1996) noted that boys in each of four major ethnic groups were less inclined, than were girls, to regard science, "… as an appropriate course of study or career for females" (p. 926). Among college students, a study of the effect of a historical development of chemistry on students' attitudes toward science showed that attitudes improved when students could identify with the same struggles that career scientists faced (Lin, 1998). If the method of science instruction could be made career-relevant to students taking science, then the likelihood increased that students' attitudes toward science would improve.

Environmental factors

Environmental factors also influenced students' science attitudes. Waldrip and Fisher (1997) examined the relationship between the cultural environment of science students and their attitudes toward science. Their premise was that student attitudes toward science and their inquiry skills were positively affected by culturally sensitive factors in instructional settings. Once these factors had been identified, instructional approaches could be developed which best met the learning styles of individual students.

Crawley and Kobella (1994) noted that an individual's personal experiences define the beliefs and attitudes to which he or she holds.

Personal relationships

Personal relationships had a strong influence on a student's attitude toward science. According to Andre, Whigham, Hendrickson, and Chambers (1997), "... the attitude – achievement relationship must be dynamically reciprocal and continually evolve as the individual develops" (p. 4). This relationship between attitude and achievement was a mutual one that was complicated by how attitude may have been affected by (a) early student achievement in science, (b) teacher and student relationships, and (c) parental and peer influence. In an afternoon science and engineering program, African-American middle school age girls' attitudes toward science were positively affected through cooperative learning and hands-on activities that were conducted by professional engineers who served as instructor role models (Ferreira, 2001). According to another study, teachers appeared to have the greatest effects on students' attitudes (Gibson, 1998). Woolnough (1994) observed that in spite of a low regard extended to science related careers in the United Kingdom, there were students who were inclined to continue their interest in science because they were exposed to such influences as mechanical toys and parents who encouraged scientific pursuits, while they were growing up.

Laboratory instruction

Laboratory instruction was observed as a positive influence on student's attitudes accompanied by increases in ninth grade physical science achievement (Freedman, 2001). Interviews conducted with students following an inquiry-based summer science program revealed that high interest students maintained their interest, preferring the hands-on approach of science instruction to traditional classroom methods of teaching (Gibson, 1998). The study carried out by Jelinek (1998) provided support for improved high school student interest in science through hands-on involvement and the opportunity for students to be actively involved in field related activities. In reference to their study of conceptual change in a high school physics classroom, Adams and Chiappetta (1998) noted:

> However, if the course moves to more student-centered instruction that includes more hands on experiences and opportunities to apply ideas in real world situations and that accommodates individual students' ways of thinking, we may find that the amount of conceptual change will be smaller for the highest ability students with angular world views but, physics would make more sense to a larger number of students and additional educational goals would be met. (p. 1 2)

Computer use

Among high school honors physics students, McFadden (1999) studied the effectiveness of calculator-based technology on the attitudes of these students toward science. His findings showed that students who had access to (a) calculators, (b) software, and (c) data collecting probes in physics laboratory experiments scored significantly higher than students in the control group in three of the attitude test's seven subscales. Three other attitude subscales did not indicate statistical significance. This suggested that the application of current technology to science instruction resulted in increased overall, positive attitude toward science, in this case, physics.

Passage of time

The findings of the study done by George (2000) showed that the attitudes of students toward science throughout middle and high school diminished with each successive year. While the finding suggested that time was the responsible factor for this decline, the author was careful to point out that the types of science courses taken can vary from one school to the next at each grade level of secondary education. Prior to this study, Simpson and Oliver (1990) observed the same attitude decline across grades six through ten with a corresponding drop in student achievement and motivation toward science.

Worldview of student

Finally, a student's worldview, according to Cobern, Gibson and Underwood (1995, April) served as a grid through which he or she filtered perceptions about science. These perceptions influenced students' attitudes about science in a way that required each student to ultimately question whether or not science fit into his or her worldview in the future. The authors Cobern et al. asked, "Is it wise for educators to assume that students coming into the science classroom will fully accept as both appropriate and important the image of nature projected there, when the literature indicates that there are many views of nature?" (p. 4). Preliminary evidence obtained by the researchers suggested that differences in worldview that existed between teacher and students affected the learning and attitude of the students.

Attitude Measurement

Among national science curriculum standards being defined for students are those that address, "… the attitudes and inclinations to apply scientific principles and ways of thinking outside the formal educational system that all students are expected to attain" (Hoffman & Stage, 1993, p. 6). Walker (2005) wrote that the affect or feelings students have toward a subject, like science, became apparent in the attitudes that students exhibited. Walker further explained that unlike behavioral and cognitive traits, affective traits were not observable and must be measured based on how students responded through an attitude instrument.

During the twentieth century, attitude measurement methods developed around two types, observational methods and self-report assessments. Inherent in each method was the potential for the researcher to receive misinformation. Observational methods could be misinterpreted by the researcher. In self-report assessments, misinformation could be given by individuals who respond to a statement or question in a way that they think meets with the approval of the researcher (Dwyer, 1993). Also, individuals could possibly answer in a certain way to avoid giving a "Not Sure" response even when they were unsure of how to respond (Dwyer). Despite their limitations, several attitude scaling techniques came into use that were of a self-report assessment nature and were widely used. These scaling techniques included: (a) Likert Scaling, (b) Thurstone Scaling, (c) Guttman Scaling, and (d) Semantic Differential Technique.

Likert Scaling

Adolphe (2002) explained that the Likert Scale required a respondent to select one of five attitude responses to a single concept statement. These responses were placed along a continuum of extremes for which each response was assigned a numerical response value. These responses included: (a) strongly agree - 5, (b) agree - 4, (c) not sure - 3, (d) disagree -2, and (e) strongly disagree -1. The numerical responses to all of the statements could then be added and a mean attitudinal response could be calculated. Trochim (2002a) pointed out that the response scales have varied in the number and types of responses offered and the value assigned to each one.

Schibeci (1982) noted that Likert instruments were most appropriate when specific attitudes were being investigated. The instruments that included (a) the TOSRA (Fraser, 1981a), (b) the TOSRA2 Pretest (Fraser, 1981b), and (c) the TOSRA2 Posttest (Fraser, 1981c) were all attitude measurement instruments that made use of the Likert Scaling Technique. The TOSRA2 Pretest and Posttest were used in this study.

Thurstone Scaling

There were three different methods of this technique but each one was similarly rated by the respondents. The methods included: (a) paired comparisons, (b) equal-appearing intervals, and (c) successive intervals (Adolphe, 2002). Once a single concept focus was established, a large pool of statements was created which was related to the focus and which did not deviate grammatically or structurally from each other (Trochim, 2002b). From the pool of statements, eleven statements that spanned the continuum of extremes were chosen. In the paired comparisons technique, respondents, were presented with two of the eleven statements at a time and were asked to select the statement to which they were more favorably disposed. Multiple pairings of statements eventually allowed for a hierarchical ranking of the statements. For the equal-appearing intervals and the successive intervals techniques which were similar (Adolphe, 2002), the rating data were analyzed and eleven representative statements were selected for respondents to consider and arrange in a numerical order from most favorable to most unfavorable.

Guttman Scaling

This technique attempted to identify an order of attitude statements where a respondent would agree with a particular statement related to a concept focus and with those statements which came before it. Beyond that particular statement, the respondent would disagree with further statements related to the concept focus (Trochim, 2002c).

Semantic Differential Technique

This technique presented the respondent with, "… a set of bipolar adjective pairs" (Schibeci, 1982, p. 566). These two terms marked the extremes in attitude that a respondent may have had toward a concept focus, e.g. "… exciting – boring, worthless – worthwhile, easy – hard" (p. 566). Separating the terms was a scale of one to five which the respondent selected, simultaneously indicating the relative degree of preference toward one term and away from the other. The scores obtained from each pair of terms that were related to a concept focus could be calculated to obtain a total score. The semantic differential technique found its most appropriate application where general attitudes of high school students toward science were desired (1982).

Test of Science-Related Attitudes (TOSRA)

Following his development of a five-scale attitude test for science teaching which was validated from the testing data of over 1000 science students in the seventh grade, Fraser (1978) made modifications to the test to form a seven-scale attitude test known as *Test of Science-Related Attitudes* or TOSRA. The original TOSRA in its entirety consisted of 70 statements in a Likert-type format. Each of the seven scales was represented by ten statements to which the students responded with: (a) SA – strongly agree, (b) A – agree, (c) N – not sure, (d) D - disagree, or (e) SD – strongly disagree. These responses were then assigned values 5, 4, 3, 2, 1, respectively. In the study conducted by Barnette (1999), there was no evidence that the reverse order in which the five responses were presented had any effect on the results obtained. All Likert-type responses for each TOSRA statement were presented in the order in which they appear above.

Even though the significance of the results of attitude investigations can raise doubts in the minds of some critics, Keeves (2004) noted that in improved attitude questionnaires, "... a range of attitude scales should be constructed to access a range of attitudinal dimensions" (p. 286). Predating this observation, the TOSRA instrument was developed along a range of subscales. The seven subscales within the TOSRA instrument included: (a) Social Implications of Science, (b) Normality of Scientists, (c) Attitude to Scientific Inquiry, (d) Adoption of Scientific Attitudes, (e) Enjoyment of Science Lessons, (f) Leisure Interest in Science, and (g) Career Interest in Science. Fraser adopted and modified the six distinct categories classifications that Klopfer (1971) identified that characterized student attitudes toward science. The relationship between Fraser's TOSRA scales and Klopfer's classifications is reflected in Table 2.1.

Klopfer (1971) explained that the purpose of subcategory H.1 was to identify student attitudes that revealed a positive impression toward further understanding of science and the contributions made by scientists to that end. Subcategories H.2 and H.3 both aimed at how student's attitudes related to scientific inquiry. The objective of

Table 2.1

Name and Classification of Each Scale in TOSRA

Fraser (1978) scale name		Klopfer (1971) classification
Social Implications of Science (S) Normality of Scientists (N) Attitude to Scientific Inquiry (I)	H.1:	Manifestation of favourable attitudes toward science and scientists
	H.2:	Acceptance of scientific inquiry as a way of thought
Adoption of Scientific Attitudes (A)	H.3:	Adoption of "scientific attitudes"
Enjoyment of Science Lessons (E)	H.4:	Enjoyment of science learning experiences
Leisure Interest in Science (L)	H.5:	Development of rest in science and science-related activities
Career Interest in Science (C)	H.6:	Development of rest in pursuing a career in science

Note. The data in Table 2.1 are from *TOSRA: Test of Science-Related Attitudes Handbook* by B. Fraser, Victoria, Australia: The Australian Council for Educational Research Limited. Copyright 1981 by B. J. Fraser. Reprinted with permission.

subcategory H.2 was to determine if the student accepted, "… the processes of scientific inquiry as a valid way to conduct his thinking" (p. 577). Subcategory H.3 focused on student thought patterns that were consistent with the thought patterns practiced and, "… expected by the scientific community" (p. 578).

Klopfer (1971) acknowledged that subcategory H.4 was important because it examined what he considered to be a positive connection between the enjoyment of science and learning. Students obtained this enjoyment by engaging their senses through active participation in science related opportunities. The remaining subcategories focused on student interests toward science. Subcategory H.5 addressed a student's inclination toward a self-directed pursuit of science interests while subcategory H.6 dealt with life decisions that may have led to work or a career in a science-related field.

The importance of attention given by the researcher to the multi-dimensional character of an attitude instrument was emphasized by Gardner (1996) to ensure that meaningful data is obtained. Each of the seven attitude scales in TOSRA consisted of ten statements, five were stated positively and the other five were stated in negative terms. For scoring purposes the order in which the scoring scale was applied for positively stated statements was reversed for statements that were expressed negatively. Lam (1996) pointed out that the use of both positively and negatively worded statements in Likert-type tests had traditionally been used to offset the tendency of subject response acquiescence toward what the subject perceived to be the acceptable response by the researcher.

Barnette (2000) observed that the practice of using negatively worded statements in order to insure the attentiveness of the respondents and to mitigate acquiescence on their part may have been unnecessary. She added that there was no guarantee that a respondent would consider a negatively worded statement as a direct opposite of its corresponding, positively worded statement for the purpose of reverse-scoring of negatively worded statements. Researchers were cautioned that the use of positive and negative item stems could result in confusion for young children and, "... for people with lower educational levels" (Melnick & Gable, 1990, p. 36).

Pipelines to Careers in Science

The science "pipeline" metaphor has gained wide acceptance (Clements & Kifer, 2001; Morrison, 2002; Shanahan, 2005) as a model for explaining the under representation of (a) females, (b) minorities, (c) socio-economic disadvantaged youth, and (d) first-generation college students entering into careers in science and engineering. The model assumed that the science pipeline had a beginning in elementary school (Morrison) that continued through a child's education, carrying each child to a career in science, barring any "leaks" in the pipeline along the way. Although he disagreed with the pipeline model, Dr. David Goodstein (1994) offered a description of the concept:

> The idea is that our young people start out as a torrent of eager, curious minds anxious to learn about the world, but as they pass through the various grades of schooling, that eagerness and curiosity is somehow squandered, fewer and fewer of them showing any interest in science, until at the end of the line, nothing is left but a mere trickle of PhD's. (p. 4)

In part, Goodstein's objection to the pipeline model was that if there were "leaks" in the pipeline, they could be repaired. Schools that have embraced the pipeline model have undertaken programs to repair the leakage. At the Worcester Polytechnic Institute, more than 40 programs were implemented to keep talented students directed toward careers in technology and science (Morrison, 2002). One such program targeted minority middle school age girls by offering them the opportunity, "... to explore engineering issues that have an impact on society" (p. 1). In addition, the program instilled self-confidence in girls and at the same time provided them with an improved image of a career engineer.

Sisters in Sport Science (SISS) was a program that engaged urban girls interest in sports as a means to learn principles of mathematics and science that applied to each sport in which they participated (Hammrich, Fadigan, Green, Richardson, & Livingston, 2003). "In doing so, the program is reaching students on multiple levels of intelligences and strengthening the education of students in science and mathematics by creating a unique and diverse atmosphere" (p. 4). The middle school age girls who were influenced by this three-year program were exposed to career interests that involved science and mathematics concepts in addition to sports. Factors that impacted girls' interest in mathematics and science included the expectations that parents had for their daughters and strong, positive role models that linked mathematics and science interest to future careers.

Not all pipelines addressed gender equity or minority bias, but all pipelines had a post high school education in their construct. Clements and Kifer (2001) identified minimum “pipeline steps” (p. 19) that were necessary for Kentucky high school students to matriculate into a four-year college. Those steps included (a) desiring to attain a four-year degree, (b) obtaining a minimum 2.55 high school grade point average, (c) taking of a college entrance exam, (d) submitting an application to a college, and (e) enrolling in that college. The authors lamented the absence of unified policies that would encourage students to pursue these fundamental steps. With all the good intentions of programs designed to keep young people directed toward future careers in mathematics and science, students who were not advised to attain any one of these steps would be virtually lost from the pipeline.

Career Education and Planning

Noting that career education for high school students was often too late to make a difference in their career decisions, Bruch (2000) maintained that middle school students must be exposed to career education, “… so they will not limit their choices when selecting courses for high school (p. 2). The role of the high school would then be to provide the skills through subjects relevant to careers that students had already researched through their middle school experience. The programs previously identified that were offered by Worcester Polytechnic Institute (Morrison, 2002) and Sisters in Sport Science (Hammrich et al., 2003) supported the importance of emphasizing career interests among middle school age students.

Students and parents interviewed in Bruch’s (2000) study agreed that the career factor in middle school instruction: (a) made the curriculum more relevant to students, (b) increased students’ motivation to learn, and (c) helped students to recognize the connection between their present education and their future careers. While not specific to career planning in science, Wimberly and Noeth (2005) wrote, “Given the long-term course taking and postsecondary planning that college and workplace readiness requires, students must begin the college readiness process as early as middle school” (p. 20). One of their recommendations was that, “Schools should explain to students and their parents the effects of taking a challenging curriculum on their future educational, career, and income options” (p. 18).

Marcos (2003) identified a number of interventions by which a middle school in Virginia attempted to heighten the interest of its sixth, seventh, and eighth grade students in careers. These approaches included: (a) “…computer-based interest inventories” (p. 3), (b) career connections made to the classroom subject, (c) career assemblies highlighting role models, (d) community experiences, (e) college visitations, (f) college planning workshops for parents offered by the Career Center, and (g) informational websites.

In a separate study, an important factor that had a positive impact on middle school students’ motivation to learn was the influence that teachers had on students in the way of guidance in planning a high school program of studies and encouragement to do

> good work (Dunham & Frome, 2003). In the same study high school staff members were influential in determining the number of mathematics and science courses completed by high school students. The practices identified were: (1) the extent to which guidance counselors and teachers provide assistance to students in planning their high school program and (2) the extent to which guidance counselors and teachers encourage students to take more challenging mathematics and science classes. (p. 11)

Summary

The Science Core Sequence Reform, implemented at the school district which was the subject of this study, was developed as a response to a call for higher science standards through higher expectations of all high school students who were required to take science. This reform instituted a physics to chemistry to biology sequence in place of the longstanding traditional sequence of biology to chemistry to physics. The reform sequence recognized the developmental hierarchy of the sciences in which physics laid the groundwork to the understanding of chemistry which, in turn, provided the foundation for understanding concepts in molecular biology. In an additional contrast to the traditional sequence in which the core sciences of chemistry and physics were regarded as electives, the reform sequence required that all students successfully complete the science core subjects of physics, chemistry, and biology for graduation.

It would be difficult to attribute the success or failure in positively influencing student attitudes toward science to the change in the sequence of science core subject alone. An understanding of the effect of the SCSR on the attitudes of students could not be considered apart from an understanding of the methodology with which it was implemented within the Freshman Physics curriculum. In addition there were factors that had an effect on students' science attitudes, among them (a) student career interests, (b) environmental factors such as facilities, and (c) personal relationships between students and their parents, teachers, and peers. These diverse factors made it appropriate to use the Test of Science-Related Attitudes (TOSRA) as an attitude measuring instrument which categorized student responses into seven separate and therefore, more meaningful subscales. Even though the Science Core Sequence Reform was a high school focused science reform, attention needed to be given to middle school students whose attitudes toward science were being shaped well before their high school education had begun.

CHAPTER THREE - METHODOLOGY

Introduction

The purpose of this study was to determine the effect that a Science Core Sequence Reform (SCSR) had on students' attitudes toward science resulting from science instruction that began with students receiving: (a) freshman physics in ninth grade, (b) chemistry in tenth grade, and (c) biology in eleventh grade. This case study was a mixed method research approach which employed both quantitative and qualitative methods of obtaining data. According to Sharp and Frechtling (1997), the combination of quantitative and qualitative techniques in a study can lead to the best results coming from the study. Conducted in the fourth year since the implementation of SCSR, this study was designed to probe the effects that SCSR had on student attitudes toward science.

Subjects

The investigation into the effect of the Science Core Sequence Reform (SCSR) on student attitudes toward science engaged the voluntary participation of senior high school students. These students were administered a variation of the Test of Science Related Attitudes (TOSRA) as TOSRA2 Pretest (See Appendix A). The TOSRA2 Pretest was given to (a) 152 freshmen, (b) 147 sophomores, (c) 104 juniors, and (d) 129 seniors at the beginning of their science courses. A similar TOSRA2 Posttest was administered to (a) 137 freshmen, (b) 138 sophomores, (c) 74 juniors, and (d) 115 seniors near the conclusion of their science courses. Each science course of study in the SCSR was begun and completed in the Fall semester of the 2005-2006 school year and involved approximately one half of the total student population of the senior high school. Twelfth grade student participants, who were scheduled to graduate in 2006, had completed the three year science core sequence reform at the end of the 2004-2005 school year. All twelfth grade students were included in the study, regardless of whether or not they were enrolled in a science elective. Students from the same school in (a) ninth, (b) tenth, and (c) eleventh grade provided data for comparison of science attitudes of students one time period in the three year science sequence. No students were identified for the purpose of recruitment for or exclusion from the study. All student participants were enrolled at the school district in southeastern Pennsylvania where the SCSR had been in practice through three consecutive school years since its inception in August, 2002.

Fourteen teachers of these students who were employed by the same school district where the study took place were also volunteer participants. The teachers who participated included (a) four Freshman Physics teachers, (b) three tenth grade Chemistry teachers, (c) three eleventh grade Biology teachers, (d) two Learning Support teachers, and (e) two Mathematics teachers. Three of the Physics teachers, A, B and D attended a four week Modeling Workshop at Arizona State University where they received modeling methodology training for Physics instruction. Teacher Chemistry A held an advanced degree in biochemistry and has taken a Forensics course. Teacher Chemistry B has had an advanced course in guided inquiry. Eight of the fourteen teachers had nine or more years of secondary science teaching experience while the science teaching experience of the remaining six teachers ranged from one year to six years in secondary education. Four teachers had three or more years of professional work experience before entering the teaching profession. All teachers were employed at the same school district where this study took place.

Design

The design for this study can best be described as a case study, mixed method research approach which employed both quantitative and qualitative methods of gathering data. The purpose of a case study is, "…to gain an in-depth understanding of the situation and meaning for those involved" (Merriam, 1998, p. 19). Merriam has also, "…concluded that the single most defining characteristic of case study research lies in delimiting the object of study, the case" (p. 27). Delimiting the case or the defining of the boundaries of the study has been established by the three research questions set forth in the Chapter One – Introduction. The research questions included:

1. Was there a relationship between the attitudes of SCSR students and their decisions to pursue science related options in their post-high school education and career plans?
2. What changes in students' attitudes toward science had occurred since the implementation of the Science Core Sequence Reform (SCSR)?

3. How had science electives been impacted by the SCSR program?

The mixed method research approach obtained quantitative data from the TOSRA2 pretest and posttest (See Appendix A) employed in this approach. Quantitative data were also obtained through the examination of archival records of high school science course registrations. Teacher interviews provided data that were qualitative in nature. Shank and Villella (2004) likened quantitative research to a window which gives "… a clear and transparent look at things" (p. 48). In the same way, they compared qualitative research to a lantern which is "… used to illuminate dark areas so that we can see things that previously were obscure" (p. 48).

Miles and Huberman (1994) supported the linking of quantitative and qualitative research with a caution to the researcher to be circumspect with regard to how the research will be conducted and for what reasons. The soundness of the mixed method design for the research proposal was founded upon three years of direct professional involvement as a teacher in SCSR by the researcher at the school district which was subject to the study. Research into the literature that examined the historical development of attitude testing and the rationale that supported SCSR also served to strengthen the design of the study.

Instrumentation

Merriam (1998) wrote that *triangulation* occurred when multiple instruments were used to obtain data in a manner that would confirm the results that emerged from the data. The instrumentation used in the research study included (a) a modified form of the original Test of Science-Related Attitudes (TOSRA) administered as a TOSRA2 Pretest and a TOSRA2 Posttest (Appendix A) to all students at the beginning and end of a block-scheduled semester; (b) face-to-face, audio taped interviews with teachers of the students who were subjects of the research study; and (c) an examination of archival high school science course selection records to find data that would be indicative of students' attitudes toward science.

Test of Science-Related Attitudes (TOSRA)

The TOSRA in its original form and its modified forms, the TOSRA2 Pretest and TOSRA2 Posttest, were made up of seven attitude subscales chosen for the purpose of measuring attitudes toward science among secondary school students (Fraser, 1981). These seven subscales were represented by statements that were worded for the purpose of determining students attitudes toward science in the areas of: "(a) Social Implications of Science, (b) Normality of Scientists, (c) Attitude to Scientific Inquiry, (d) Adoption of Scientific Attitudes, (e) Enjoyment of Science Lessons, (f) Leisure Interest in Science, and (g) Career Interest in Science" (p. 2).

Fraser (1981) gave a concise description for each of these science attitude subscales. Student's attitudes related to the Social Implications of Science subscale were those attitudes that acknowledged the benefits and drawbacks to society that were attributable to scientific advances. The Normality of Scientists subscale gauged students' admiration of scientists as being real people, as opposed to the perceptions fostered by the media that scientists are eccentric. The Attitude to Scientific Inquiry subscale measured attitude toward, "... scientific experimentation and inquiry as ways of obtaining information about the natural world" (p. 2). Fraser identified the subscale for Adoption of Scientific Attitudes based upon the input of Australian scientists who valued attitudes of "... open-mindedness [and] a willingness to revise opinions" (p. 2). For each of the remaining three science attitude subscales (a) Enjoyment of Science Lessons, (b) Leisure Interest in Science, and (c) Career Interest in Science, Fraser acknowledged that the title alone for each subscale was sufficient to describe the attitude that each subscale measured.

A modified form and application of the 70 question Test of Science-Related Attitudes (TOSRA), was used to obtain responses from over 500 students with respect to their attitudes toward science. This modification divided the TOSRA into a 35 question TOSRA2 Pretest and a 35 question TOSRA2 Posttest (Appendix A). A quantitative study was conducted that included a horizontal analysis of students' attitude responses across grade levels. In addition, a longitudinal study that examined attitudes at each grade level from the start through conclusion of a science course of study was made of the students' attitude responses by comparing the results of the pretest with the results of the posttest.

The TOSRA2 pretest and posttest were administered to all ninth, tenth, eleventh, and twelfth grade science students in the school district who completed an entire course of science study during the first half of the school year through block scheduling. The TOSRA2 was also administered to twelfth grade students who had completed the SCSR but who had chosen not to enroll in a science elective in their senior year.

The test was written using a vocabulary that could be understood by students at grade levels nine through twelve and the same pretest and posttest was administered to all students involved in the study. The use of a Scantron® Form 40-S answer sheet allowed students to record their answers easily and without confusion. Throughout the TOSRA2 Pretest and TOSRA2 Posttest, the statements were arbitrarily stated positively and negatively in order to avoid student acquiescence to an answer pattern that they may have relied upon in answering questions. Students who took these tests responded to each statement with a response of (a) A – Strongly Agree, (b) B – Agree, (c) C – Not Sure, (d) D – Disagree, and (e) E – Strongly Disagree. For the purpose of data analysis a student response of "Strongly Agree" received a point value of 5. A student response of "Agree" received a point value of 4 and so forth. Student responses to negatively worded statements were scored in reverse order.

To ensure that students answered honestly, students were informed that (a) the TOSRA2 Pretest and Posttest were to be taken voluntarily, (b) the results would be kept anonymous, and (c) students would not receive a score that would affect their grade in science. To minimize the possibility of acquiescence, Fraser (1981) recommended that teachers should clearly convey to their students that as a result of anonymity, the tests results would not have any effect on the course grades of the students who took the test.

Teacher interviews

Teacher participation in interviews was requested by a Teacher Invitation to Participate (Appendix B) and obtained through each teacher's completion of an Informed Consent Form for Teacher Interview (Appendix C). Consistency in conducting teacher interviews and obtaining responses was attained by following Teacher Interview Protocol (Appendix D) which was developed and administered individually by the researcher and signed by each participating teacher. In each interview, the teacher granted permission for the interview to be recorded on audio tape. Each interview began with an open-ended request of the teacher, to share any initial (a) thoughts, (b) impressions, or (c) recollections of when he or she first became aware of or involved in the SCSR. Anonymity was preserved as teachers were individually referred to, in the study, as Teacher Physics A or Teacher Biology B, and so forth.

In Table 3.1 a Teacher Interview Matrix of Demographic Information was constructed in order to provide a background profile of each of the individual professional teaching staff who consented to be a part of the interview process. Among the teachers of Freshman Physics who were interviewed, Teachers Physics A, B, and D had received Modeling Workshop training in physics at Arizona State University. Teacher Physics C had not received modeling training but relied on the support of the physics staff during what was his first year at the high school. This training was formative in the implementation of modeling methodology in their classrooms. The introduction of physics at the ninth grade and the methodology used for instruction was the most critical aspect of the SCSR initiative. As a result, the suitability of this methodology for ninth grade students' would be reflected in their attitudes toward science.

Table 3.1

Teacher Interview Matrix of Demographic Information

Teacher	**Involvement in SCSR From 9/2001 to 01/2006**	**# Years Professional Experience**	**Formal Education**	**Present Role in SCSR (Blocks)**	**Preparation for SCSR**
Physics A	8/2004 to present	5 yr. Engineering 6 yr. Teaching physics	BS Engineering MS Engineering	9th physics 2 honors 1 academic	Arizona State University (ASU) 4 wk Modeling Workshop
Physics B	8/2002 to present	4 yr. Teaching physics	BS Ed. Physics MS Ed. Natural Science	9th physics 2 academic 12th astronomy	ASU 5 Modeling courses leading to M. Ed. Natural science
Physics C	8/2005 to present	1 yr. Teaching physics	BS Ed. Physics	9th physics 12th physics	No
Physics D	09/2001 to 6/2005	15 yrs Teaching physics	BS Physics MS Educational Leadership	9th physics honors 12th physics	ASU 2 summers of modeling workshops
Chemistry A	8/2003 to present	17 yr Industrial Science 9 yr. Teaching biology chemistry math	BS Biology & Chemistry MS Biochemistry MEd	10th chemistry 1 honors 1 academic 12th forensics	MS Forensics (in progress)
Chemistry B	8/2004 to present	8 yr Community College 3.5 yr Environmental Engineering 9 yr Private, international school	BA Biology & Chemistry	10th chemistry 3 academic	Emphasis on guided inquiry in MS studies
Chemistry C	8/2003 to present	3 yr Teaching chemistry	BS Chemistry Education	10th 2 academic 12th AP chemistry	No
Teacher	**Involvement in SCSR From 9/2001 to 01/2006**	**# Years Professional Experience**	**Formal Education**	**Present Role in SCSR (Blocks)**	**Preparation for SCSR**

Biology A	8/2005 to present	1 yr. Teaching biology	BS – Biology BS Ed.	11th biology 3 academic	No
Biology B	8/2005 to present	10 yr. Teaching biology anatomy chemistry	BS Ed. – Biology and History MS Ed. – Biology	11th biology 2 academic	No
Biology C	**Involvement in SCSR From 9/01 to 01/06**	**# Years Professional Experience**	**Formal Education**	**Present role in SCSR (Blocks)**	**Preparation for SCSR**
Biology C	09/2001 to present	3 yr. pharmaceutical sales 15 yr. teaching biology	BS Biology MS Biology	11th biology AP Biology Honors Biology Science Dept. Chair over-sight of SCSR	Reading journal articles from NSTA and ARISE
Mathematics A	Not Applicable	31 years teaching math courses in junior high and high school.	BS Mathematics Education MEd Mathematics	None	No
Mathematics B	Not Applicable	22 years teaching math in MS and wide range of HS courses	BS Mathematics MEd Mathematics	None	No
Learning Support A	8/2002 to6/2004	25 yr. Teaching	BS Special Education MEd Emotional Support	To assist students who come to Alternative Education room for help	No
Learning Support B	4/2004 to present	2 years teaching	BBA Marketing MBA Marketing Management M Education Ph.D. (in progress)	To assist learning support students	No Has since taken Nursing Chemistry 102

Archival records

The analysis of archival data records instrumentation began with the collection of "The District" high school science course registrations which dated back to the 1997-1998 school year until the present 2005-2006 school year. These records were obtained from the files of the chairperson of the science department and from the files of the "The District" High School administration. Registrations for science core subjects such as (a) Physics, (b) Chemistry, and (c) Biology were distinguished from elective non-core science course registrations. Non-core science courses, such as Astronomy and Forensic

Science served to broaden rather than deepen student understanding of the core sciences in those subject areas.

Reliability

Efforts to achieve reliability by the researcher were guided by consideration given to the highest standards of ethical conduct (Merriam, 1998). "Reliability in a research design is based on the assumption that there is single reality and that studying it repeatedly will yield the same results" (p. 205). Kobella (1989) asserted that the assessment of attitude change is not possible in the absence of reliability and validity (p. 5). Molinaro (2002) emphasized that the "… evidence for reliability and validity must be reflected" (p. 15). Fraser (1981) provided that evidence by citing α reliability coefficient values to be high among each of the seven TOSRA scales. Adherence in this study to established ethical principles of (a) beneficence, (b) honesty, and (c) accurate disclosure consistently served to provide assurance that future research will produce data that are consistent with the findings of this research.

Validity

Validity or verification according to Creswell (1998) asks, "'How do we know that the qualitative study is believable, accurate, and 'right'?'" (p. 193). Fraser (1981) provided cross-validation data that supported the validity of TOSRA in Australia where it was developed as well as in the United States. Examples of verification procedures that were employed in this investigation in order to diminish misgivings about the findings were described by Creswell (1998). These verification procedures included *triangulation* which utilized three or more sources of data to provide supporting evidence. Data from (a) the TOSRA2 pretest and posttest, (b) teacher interviews, (c) and archival data from high school course selection records made triangulation possible. *Peer review* solicited the observations of an outside consultant who, "… asks hard questions about methods, meanings and interpretations …" (1998, p. 202) of the research. For this research study, peer review was received through the counsel and critique of members of the researcher's dissertation committee members as well as through consultations with professional teachers. An early statement of the researcher's past experiences and prejudices that are brought to bear on the research is *clarifying researcher bias* which was presented in the Chapter One - Introduction. Finally, *member checks* was an ongoing procedure that "… involves taking data, analyses, interpretations and conclusions back to the participants so that they can judge the accuracy and credibility of the account" (1998, p. 203). This was done by submitting transcriptions of interview to interviewees for their confirmation.

Procedure

Approval to conduct this study was obtained from the Superintendent of "The District" chosen as the subject of the study (Appendix E). Before the collection of data for the research study could begin, permission was obtained from the Research Ethics and Review Board (RERB) of Immaculata University (Appendix F). Permission to conduct the study at the high school where the research study took place was requested and received from the High School Principal (Appendix G).

Students in the ninth, tenth, and eleventh grades who were involved in the Science Core Sequence Reform (SCSR) at the high school subject where this research study took place were given a Parent and Student Consent Form (Appendix H) by their science teacher which allowed students to be administered the TOSRA2 Pretest and Posttest anonymously. It was anticipated that not all twelfth grade students elected to take science. Since all of these students were required to take a fourth year of English classes, teachers of these agreed to administer both the pretest and posttest to these students. This was done to insure that the pretest and posttest would be administered to a sampling of all seniors, not only to seniors who were taking science, but to those seniors who did not elect to take science courses following their completion of the core science requirements. Students returned the signed consent forms to their respective science or English teachers who collected them and placed them in a secure envelope.

The TOSRA2 Pretest was administered in September of 2005 in the third full week of the 18 week, block scheduled semester. The TOSRA2 Posttest was administered in January of 2006 with only two weeks remaining in that same semester. An attempt to obtain data from the maximum number of student subjects was made by administering and collecting the student responses for both the TOSRA2 pretest and TOSRA2 posttest during the same class period by their SCSR teachers. The teachers received instructions in advance at a science department meeting or individually by the researcher who provided each teacher with a copy of instructions for proctoring the tests entitled, Instructions to the Teachers Administering the TOSRA2 Pretest and Posttest (Appendix I). The students had the purpose and importance of the TOSRA2 pretest and posttest explained to them by their classroom teacher prior to the administration of the survey through the reading of the Right to Know Protocol for Students Taking the TOSRA2 Pretest and Posttest (Appendix J). At the time that each test was administered, every student was given a copy of the pretest or posttest and a Scantron® Form 40-S answer sheet on which to record their answers whether or not they had returned a signed consent form. This was done to eliminate the possibility of having a teacher or the researcher identify any student as one who did not take the test. Teacher feedback indicated that students needed about 15 minutes to complete either the pretest or posttest.

Pretests and posttests were collected anonymously and scored using a Scantron® 888P+ OMR Test Scorer. The student responses for both the TOSRA2 Pretest and Posttest were recorded with No. 2 pencils on Scantron® Form 40-S answer sheets. The answer sheets were scanned using a Scantron® 888P+ OMR Test Scorer. The number of each of the five possible Likert-type responses for each numbered statement was tabulated on a Scantron® Form No. 9870, Survey Results Tally Sheet for both the TOSRA2 Pretest and Posttest. The tally sheet results for each grade level were then entered individually into a Microsoft® Excel spreadsheet prepared by the researcher. No attempt was made to determine who did or did not take either the pretest or the posttest.

Science Core Sequence Reform (SCSR) science teachers, math teachers of science students, and teachers of learning support students were interviewed by the researcher who recorded their expert observations and impressions of the influence of the SCSR on student attitudes and interest in science. Teachers signed an Informed Consent

Form for Teacher Interview (Appendix C) which granted permission to the researcher to conduct a personal face-to-face, tape recorded interview. All interviews were conducted in the middle of the Fall Semester during the months of October and November, 2005. The researcher conducted all interviews following a list of discussion points in the Teacher Interview Protocol (Appendix D) to insure consistency in the interview process of each teacher. Prior to each interview, each teacher was given the opportunity to review the Informed Consent Form for Teacher Interview (Appendix C) which the teacher had signed previously. A transcription was made of each interview by the researcher and a copy of each transcription was presented to each interviewee for his or her confirmation.

At the beginning of the interview, each teacher was asked to describe what initial impressions he or she had upon first learning of the Science Core Sequence Reform. This open-ended approach into each interview revealed issues for discussion that may have been otherwise overlooked within the narrow range of the interview protocol. During each interview the researcher took handwritten notes of the conversation that he later personally transcribed. The researcher was aided by the audio tape made of each interview to ensure an accurate account of the conversation. For the purpose of ensuring validity through member checks, a copy of an individual interview transcription was given to each teacher who had granted an interview. An accompanying letter requested that each teacher review the transcription and respond with any corrections needed to ensure an accurate representation of the interview.

An analysis of archival records was conducted of the high school science course selection records of previous graduating classes dating back to the 1997-1998 school year. No personal student records were examined or represented in a way that would compromise any confidential nature of the records. Only the science courses offered and the enrollment numbers in each class were collected and analyzed. Science enrollment records for every science subject offered for each year from 1997-1998 until the current 2005-2006 school year were gathered for the purpose of determining what effect the SCSR may have had on student patterns of science course selection. A listing of science courses can be found in “The District” High School 2005-2006 Program of Studies in Science (Appendix K).

Data Sources

Student science attitude data obtained for this case study in qualitative research were obtained through the administration of the two modifications of the Test of Science-Related Attitudes, TOSRA2 Pretest and the TOSRA2 Posttest. Teacher interview data were obtained through the use of the Teacher Interview Protocol. Archival data of high school science course selection records were obtained from the files of “The District” science department chairperson and from the administrative files at the high school where the study was conducted.

Data Analysis

“Data analysis is the process of bringing order, structure, and interpretation to the mass of collected data” (Marshall and Rossman, 1999, p. 150). To ensure the credibility of the study, data collection and analysis employed triangulation of three instruments of research that included (a) the TOSRA2 Pretest and Posttest, (b) individual teacher protocols, and (c) the archival data obtained from the examination of past high school science course selection records (Appendix L).

For the purpose of this research proposal, the scoring of the TOSRA2 pretest and posttest was based on the total number of points obtained from the one to five point Likert scale upon which the responses to each of the 35 statements on each test were scored. Students responded to each statement with a response of (a) A – Strongly Agree, (b) B – Agree, (c) C – Not Sure, (d) D – Disagree, and (e) E – Strongly Disagree. Subscale regions of assessed attitude were examined for the purpose of comparing the relative scores of students in each attitude region at each grade level determine if continued exposure to science or age maturity had any effect on student attitudes toward science.

Attitude comparisons were made in each of the seven distinct attitude subscales related to science that are addressed in both the TOSRA2 pretest and posttest. These seven subscales consisted of questions worded for the purpose of measuring: "(a) Social Implications of Science, (b) Normality of Scientists, (c) Attitude to Scientific Inquiry, (d) Adoption of Scientific Attitudes, (e) Enjoyment of Science Lessons, (f) Leisure Interest in Science, and (g) Career Interest in Science" (Fraser, 1981, p. 2). These comparisons were made of the numerical values calculated for the average student response to each of the 35 TOSRA2 pretest or posttest statements recorded in the TOSRA2 Pretest Results (Appendix M) and the TOSRA2 Posttest Results (Appendix N). Data collected from teacher interviews was compared to the TOSRA2 data. The analysis of archival data examined the specific science courses and the number of students who had preregistered to take them according to the records obtained. The data can be found in High School Science Required and Core Course Registrations (Appendix L).

This study was characterized by the attention given to the ethics of data collection to insure that the data collected was accurate. Likewise, the exclusion of data for the purpose of supporting a particular point of view was not considered in the process of conducting this study (American Psychological Association, 2001).

Summary

This mixed method case study of the effect of a three year high school science reform sequence upon student attitudes toward science was both qualitative and quantitative in its research methodology. The study was guided by the three research questions that related to the attitudes of Science Core Sequence Reform (SCSR) students toward science. The first research question concerned itself with students' decisions to pursue science related options in their post-high school education and career plans. The second research question examined the broad effect of the implementation of SCSR on students' attitudes. The final question studied the impact of the SCSR program on science electives.

As outlined in Chapter Three, the methodology was comprised of (a) a description of the subjects involved in the research study, (b) a design which identified instruments and the methods by which data were obtained, (c) the data sources, and (d) the means by which data were analyzed. Student participation was limited to taking pretest and posttest surveys which were intended to reveal students' attitudes toward science. The participation of teachers was limited to individual interviews that were designed to gain data coming from their experiences and perceptions about students' attitudes toward science.

The instruments selected for the purpose of conducting this mixed method study provided data which were both quantitative and qualitative in character. The data were obtained from (a) pretest and posttest surveys of students' attitudes toward science, (b) teacher interviews, and (c) the examination of archival records of science course selections. Over 500 students participated by taking a modified form of the Test of Science-Related Attitudes (TOSRA). This modified form divided the original TOSRA, which consisted of 70 statements, into a TOSRA2 Pretest and a TOSRA2 Posttest. Each pretest and posttest consisted of 35 statements to which students responded using a range of five, Likert-type responses. Quantitative data were examined through the analysis of student responses in each of seven attitude subscales which were incorporated into the design of the TOSRA2 Pretest and Posttest instruments. Students' responses were recorded on Scantron® Form 40-S answer sheets. Qualitative data were obtained through interviews with fourteen teachers of SCSR students, conducted by the researcher, using a Teacher Interview Protocol. These interviews allowed for the attainment of teachers' observations of students' attitudes toward science that were not necessarily limited by the design of the Teacher Interview Protocol. Copies of high school science course selection records were obtained from the personal file of the science department chairperson and from the records of the high school administration office where the study took place. The examination of these archival records of student science course selections also provided quantitative data that allowed for the analysis of student course selection patterns in the core sciences over a period of nine years.

CHAPTER FOUR – RESULTS

Introduction

The purpose of this chapter was to report and analyze the data of this research study. The attention of this case study was limited to a single school district in southeastern Pennsylvania that implemented a Science Core Sequence Reform (SCSR) initiative in the 2002-2003 school year. This study was a mixed method research approach which engaged both quantitative and qualitative methods of obtaining data. Triangulation was implemented into this study through: (a) attitude pretest and posttest surveys administered to students in grades nine through twelve; (b) interviews obtained from teachers of these students; and (c) the examination of archival data that consisted of high school science course selection records. Data were collected and presented for interpretation by the use of (a) charts, (b) data tables, and (c) expository narrative. Throughout the study, a subject and letter code was assigned to each teacher interviewed for the purpose of insuring the anonymity of the teachers.

The data collected from the above mentioned instruments provided original information that addressed the following three research questions that were foundational to this research study:

1. Was there a relationship between the attitudes of Science Core Sequence Reform (SCSR) students and their decisions to pursue science related options in their post-high school education and career plans?
2. What changes in students' attitudes toward science had occurred since the implementation of the SCSR?
3. How had science electives been impacted by the SCSR program?

Results of the TOSRA2 Pretest and Posttest

The Science Core Sequence Reform (SCSR) was implemented for the purpose of providing high school students with instruction in a three year, core science program of studies. The three year program introduced a change in the sequence in which science courses were taken by introducing (a) physics to ninth grade students, (b) chemistry to tenth grade students, and (c) biology to eleventh grade students. The sequence was determined to be pedagogically sound for science instruction that would equip students with a complete background in science for the future (Lederman, 2001). An indication of the effectiveness of the SCSR was revealed by the responses of students to an application of the Test of Science-Related Attitudes (TOSRA). Ninth through twelfth grade students who voluntarily agreed to participate in the research study were administered a TOSRA2 Pretest and Posttest (Appendix A) at the beginning and at the end of their science courses of study respectively. This instrument was described in detail in Chapter Three.

The results of both the pretest and the posttest can be found in the TOSRA2 Pretest Results (Appendix M) and the TOSRA2 Posttest Results (Appendix N). Each of the first four pages of Appendix L listed the data obtained for each of the four classes that was administered the TOSRA2 Pretest. The four pages of Appendix M listed TOSRA2 Posttest data for the same four classes. Each of the four pages in both Appendix M and

Appendix N were organized in the same way. In the column closest to the left, the number of the statement in the test to which the students responded was identified, 1 through 35. Immediately to the right of this column were five columns identified as A through E. Each letter corresponded to a student response of (a) A – Strongly Agree, (b) B – Agree, (c) C – Not Sure, (d) D – Disagree, and (e) E – Strongly Disagree for each statement. The total number of students that responded with a particular letter was recorded in the column of that letter in a row that corresponded to the number of the statement. The next column to the right was labeled "Straight SUM" for the total number of students who responded to each of the 35 statements.

For the purpose of data analysis, a student response of "A - Strongly Agree" to a statement received a scale value of 5 points. A student response of (a) "B - Agree" received a value of 4 points; (b) "C – Not Sure" received 3 points; (c) "D – Disagree" received 2 points; and (d) "E – Strongly Disagree" received one point. To the right of the Straight SUM column was the column labeled "SUM Values". This column showed the total number of value points that were recorded by students for each statement. The "Mean Response" column showed the average value of the student responses calculated by dividing the SUM Values by the Straight SUM. This was done for the purpose of first calculating the mean response for each of the positively worded statements. Because negatively worded statements required a scoring correction, student responses to negatively worded statements were scored in reverse order. The column labeled "Negative Statement Receiving Reverse-Scored Correction Enter 'X'" identified each negatively worded statement with an "X". The column for "Absolute Mean Response" retained the same "Mean Response" value for each of the positively worded statements but corrected for each of the negatively worded statements which required a reversal in the scoring of the responses. The Absolute Mean Response was the numerical value on the Likert-type scale that represented the average value response to each statement obtained from the pretests and posttests conducted at each class level.

The column farthest to the right was identified "Subscale Designations" for the purpose of identifying each of the seven science attitude subscales addressed by each particular statement. There were five statements that were exclusive to each of the seven subscales. In the column a letter code was assigned to each statement according to the science attitude subscale to which it was associated. A key at the bottom of each page provided the name of each subscale with its corresponding letter code. The key was organized accordingly: (a) S - Social Implications of Science, (b) N - Normality of Scientists, (c) I - Attitude to Scientific Inquiry, (d) A - Adoption of Scientific Attitudes, (e) E - Enjoyment of Science Lessons, (f) L - Leisure Interest in Science, and (g) C - Career Interest in Science.

In the lower right hand corner of each page in Appendix M and Appendix N, a column was labeled "Mean Subscale Values". The mean value for each of the seven science attitude subscales was determined by adding the Absolute Mean Response values of the five statements associated with each attitude subscale. The sum of the five absolute mean values for each subscale was divided by five in order to determine the mean subscale values for each grade level. The mean subscale values were used primarily for the purpose of analysis in comparing pretest and posttest results for each grade level. These same values were used for a longitudinal analysis as mean subscale values obtained at each grade level were compared to each other.

At the time that this research study was conducted, ninth grade students were enrolled in a core science course of study called Freshman Physics. There were 152 ninth grade students who completed the TOSRA2 Pretest and 137 ninth grade students who completed the TOSRA2 Posttest. In Figure 4.1, seven pairs of bars represented, the subscale values of students' attitudes toward science increased in the subscale categories of: (a) S - Social Implications of Science, (b) N – Normality of Scientists, (c) E – Enjoyment of Science Lessons, and (d) L - Leisure Interest in Science. A decrease in mean subscale values of students' attitudes toward science was evident in the subscale categories of: (a) I – Attitude to Scientific Inquiry, (b) A - Adoption of Scientific Attitudes, and (c) C – Career Interest in Science.

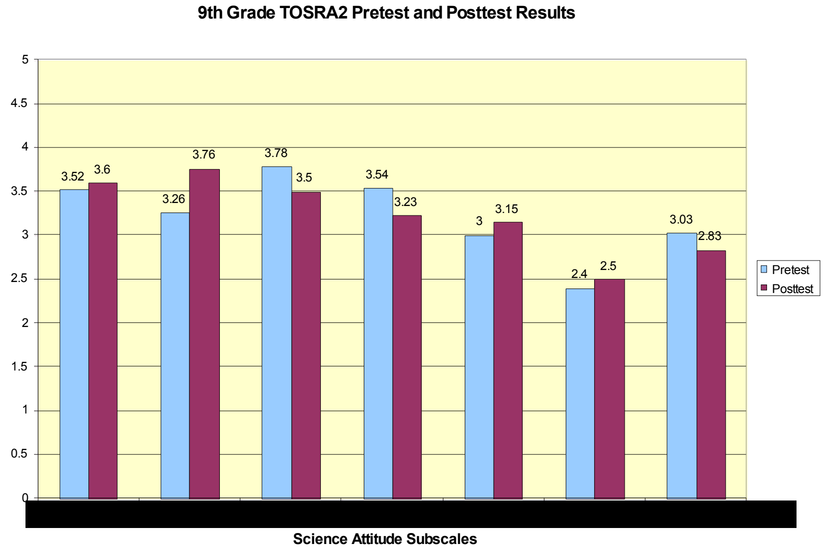

Figure 4.1. Science attitude subscale comparisons of ninth grade TOSRA2 Pretest and Posttest mean subscale values.

During this study, 147 tenth grade students who were enrolled in Chemistry completed the TOSRA2 Pretest and 138 students completed the TOSRA2 Posttest. In Figure 4.2, seven pairs of bars represented, for the purpose of comparison, the mean values of the pretest and posttest for each of the attitude subscales. The results showed that at the end of the course of study in Chemistry, mean subscale values of students' subscale values of students' attitudes toward science increased in the subscale categories of: (a) S - Social Implications of Science, (b) N – Normality of Scientists, (c) E – Enjoyment of Science Lessons, and (d) L - Leisure Interest in Science. A decrease in mean subscale values of students' attitudes toward science was evident in the subscale categories of: (a) I – Attitude to Scientific Inquiry, (b) A - Adoption of Scientific Attitudes, and (c) C – Career Interest in Science.

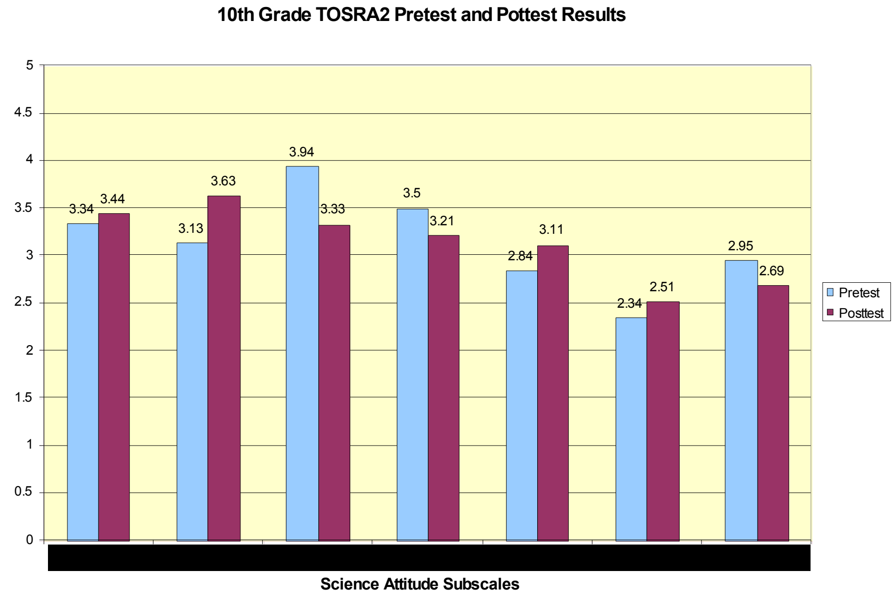

Figure 4.2. Science attitude subscale comparisons of tenth grade TOSRA2 Pretest and Posttest mean subscale values.

104 eleventh grade students enrolled in Biology completed the TOSRA2 Pretest and 74 students completed the TOSRA2 Posttest. In Figure 4.3, seven pairs of bars represented, for purpose of comparison, mean subscale values of pretest and posttest for each of the attitude subscales. The results showed that at the end of the course of study in Biology, the mean subscale values of students' attitudes toward science increased in the four subscale categories of (a) S, (b) N, (c) E, and (d) L. The attitude subscale categories of (a) I, (b) A, and (c) C showed decreases in their mean subscale values.

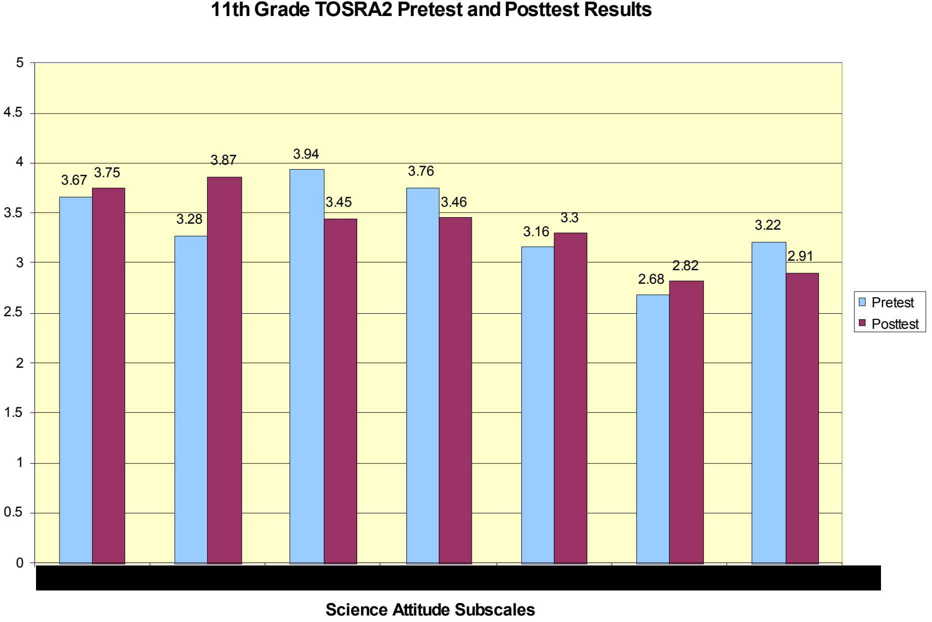

Figure 4.3. Science attitude subscale comparisons of eleventh grade TOSRA2 Pretest

and Posttest mean subscale values.

In the twelfth grade, 129 students completed the TOSRA2 Pretest and 115 of them completed the TOSRA2 Posttest. These seniors were made up of students who were enrolled in various science electives as well as those who were not enrolled in a science course of study. Figure 4.4 displayed the seven pairs of bars of the mean subscale values of the seven categories of science attitudes. The results showed that at the end of the block semester over the course of which this pretest and posttest took place, the mean subscale values of students' attitudes toward science increased in the four subscale categories of (a) S, (b) N, (c) E, and (b) L. The attitude subscale categories of (a) I, (b) A, and (c) C showed decreases in their mean subscale values.

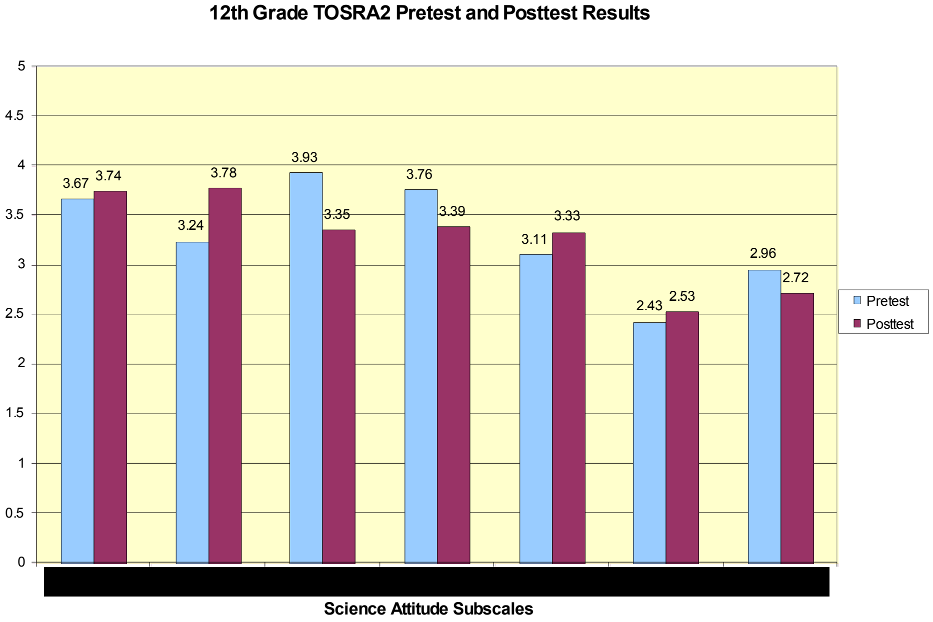

Figure 4.4.. Science attitude subscale comparisons of twelfth grade TOSRA2 Pretest and Posttest mean subscale values.

It became apparent from the examination of Figures 4.1 through 4.4 that student science attitudes improved at all four grade levels in the subscale categories of (a) S, (b) N, (c) E, and (d) L. All pretest mean subscale values in these categories were in the Likert scale range of 1 to 5 that leaned toward the Agree response valued at 4.0 from the midpoint value of 3.0 for the Not Sure response. The lone exception was the tenth grade which was 2.84 in the pretest. The posttest results revealed that the greatest increase in the mean subscale value among the 4 subscale categories for all grade levels was the Normality of Scientists (N). This was an indication that students' admiration of scientists as real people increased over the duration of the science course of study.

An examination of the same Figures 4.1 through 4.4 showed that all four grade levels experienced a pretest to posttest decline in mean subscale values of (a) I - Attitude to Scientific Inquiry, (b) A - Adoption of Scientific Attitudes, and (c) C - Career Interest in Science. This was a significant finding in the determination of the effect of SCSR on student attitudes toward careers in science. All three of these subscales could possibly be identified with career interest in science which explained their mutual decline from TOSRA2 Pretest values to TOSRA2 Posttest values. Declines in the values of subscales I and A still remained above the Not Sure response value of 3.0 on the Likert scale. The C – Career Interest in Science mean subscale response showed that students' attitudes moved away from previous science career inclinations that were evident in pretest responses of students. It was apparent that of all seven subscales, the pretest mean subscale value was highest for Attitude to Scientific Inquiry (I). With the exception of ninth grade, the drop in value in this category as revealed by the posttest results was greatest in grades ten, eleven, and twelve. In all grades, the posttest results for subscale (I) still remained between the Likert scale values of 3.0 for Not Sure and 4.0 for Agree.

In each of the four classes, the greatest single science attitude subscale increase occurred in the N - Normality of Scientists subscale. With the exception of ninth grade, the greatest science attitude subscale decrease occurred in the I – Attitude to Scientific Inquiry subscale. The declines in Subscale I for ninth grade was only slightly behind the greater decline for the A – Adoption of Scientific Attitudes. In Table 4.1 and Table 4.2 the science attitude subscale values were provided for the purpose of the comparison of data between the ninth through twelfth grade classes. Such a comparison allowed for the examination of data as if the data were generated from a longitudinal study conducted over the course of four years. Tables 4.1 and 4.2 provided an examination across four grade levels that may be comparable to a longitudinal study that followed a single class through four years of high school science. On the pretest ninth grade was at or above the Likert scale value of 3.0. Only the Leisure Interest in Science (L) subscale category with a value of 2.4 leaned toward the Disagree response which carried a 2.0 value. At each pretest category, tenth grade lagged behind ninth grade with the exception of subscale category Interest in Science Lessons (I) which received a mean subscale value of 3.94 points. Tenth grade posttest results followed a similar trend in lagging behind ninth grade in all categories with the exception of Leisure Interest in Science (L) that barely exceeded the 2.50 point value of ninth grade with a value of 2.51 points.

Comparisons using Tables 4.1 and 4.2 of eleventh and twelfth grade mean subscale values on the pretest showed that eleventh and twelfth grade results exceeded both ninth and tenth grade results with the exception of slight declines in twelfth grade for the Normality of Scientists (N) and Career Interest in Science (C). The eleventh and twelfth pretest mean subscale values of the categories (a) S, (b) N, (c) I, (d) A, and (e) E were nearly identical to each other. Twelfth grade students scored below eleventh grade students in pretest categories of Leisure Interest in Science (L) and Career Interest in Science (C).

Table 4.1

TOSRA2 Pretest Science Attitude Mean Subscale Values

Grade	S	N	I	A	E	L	C
9	3.52	3.26	3.78	3.54	3.00	2.40	3.03
10	3.34	3.13	3.94	3.50	2.84	2.34	2.95
11	3.67	3.28	3.94	3.76	3.16	2.68	3.22
12	3.67	3.24	3.93	3.76	3.11	2.43	2.96

Table 4.2

TOSRA2 Posttest Science Attitude Mean Subscale Values

Grade	S	N	I	A	E	L	C
9	3.60	3.76	3.50	3.23	3.15	2.50	2.83
10	3.44	3.63	3.33	3.21	3.11	2.51	2.69
11	3.75	3.87	3.45	3.46	3.30	2.82	2.91
12	3.74	3.78	3.35	3.39	3.33	2.53	2.72

Eleventh and twelfth grade posttest mean subscale values remained close to or exceeded ninth grade values. Twelfth grade was the exception in the subscale categories of Interest in Science (I) and Career Interest in Science (C) which both displayed values below both ninth and eleventh grade levels, barely exceeding tenth grade levels. This decline may be attributed to the fact that twelfth grade students were in the only grade level in which science is not required of all students. Numbered among the twelfth grade students who took both the pretest and the posttest were those who did not elect to take a course in science.

Relationship of TOSRA Data to Research Questions 1 and 2

The TOSRA instrument, which consisted of a pretest and a posttest, was used to yield data that address Research Questions 1 and 2 of this study. Those questions asked respectively, “Was there a relationship between the attitudes of Science Core Sequence Reform (SCSR) students and their decisions to pursue science related options in their post-high school education and career plans?” and “What changes in students’ attitudes toward science had occurred since the implementation of the SCSR?”. The only subscale, relevant to Question 1, which measured student attitudes toward careers on the TOSRA2 Pretest and the TOSRA2 Posttest was subscale C which measured student attitudes toward Career Interest in Science. All seven subscales were relevant in arriving at an answer for Question 2.

Relationship of TOSRA2 Findings to Research Question 1

Research Question 1 asked, “Was there a relationship between the attitudes of Science Core Sequence Reform (SCSR) students and their decisions to pursue science related options in their post-high school education and career plans?” The TOSRA instruments provided data which indicated that career interest in science (Subscale C) increased in values between the Freshman year and the Junior year but declined in the senior year. The comparison of the TOSRA pre and post instruments showed a decline in value from the beginning to the end of the science courses of study. The mean subscale values of the data obtained rarely equaled the whole number value assigned to each of the five responses on the Likert scale. For the purposes this research study, mean subscale value ranges of responses will be defined in the following way. A response that fell between 0.50 and 1.49 on the Likert scale would be considered Strongly Disagree. A response between 1.50 to 2.49 would be considered Disagree. A response between 2.50 to 3.49 would be considered Not Sure. A response that fell within the range of 3.50 to 4.49 would be considered Agree and responses above 4.50 would be considered Strongly Agree. Based on these definitions, the declines in Subscale C at each grade level remained within the definitional range of mean subscale values categorized as Not Sure.

Because of their close relationship to each other, Subscale I, Attitude to Scientific Inquiry and Subscale A, Adoption of Scientific Attitudes could be considered to be related to Subscale C, Careers in Science. Declines in the mean subscale values for Subscales I and A were observed as well. In Subscale I, the TOSRA pretest values dropped from the low end of the Agree range to the high end of the Not Sure range following the TOSRA posttest. The exception was the freshman class that marginally remained in the Agree range following the posttest. The mean subscale value results for Subscale A showed a decline in all classes from the low end of the Agree range to the high end of the Not Sure range. The mean subscale value decline of Subscales I and A in combination with the decline of the mean subscale value of Subscale C indicated that the implementation of SCSR did not raise career interest in students.

Relationship of TOSRA2 Findings to Research Question 2

Research Question 2 posed the question, “What changes in students’ attitudes toward science had occurred since the implementation of the SCSR?” While declines in the mean subscale values were observed in Subscales (a) A, (b) I, and (c) C, increases were observed in (a) Subscale S, Social Implications of Science; (b) Subscale N, Normality of Scientists; (c) Subscale E, Enjoyment of Science Lessons; and (d) Subscale L; Leisure Interest in Science. In Subscale S, all grade levels, with the exception of grade 10 advanced from the higher end of Not Sure to the low end of Agree. For Subscale N, all classes emerged from the high end of Not Sure to the low end of Agree. While all classes showed an increase for Subscale E, all mean subscale values for the pretest and the posttest remained in the definitional range of Not Sure. For Subscale L, the mean scale value response from ninth, tenth, and twelfth grades transitioned from the higher end of Disagree to being marginally, Not Sure. Eleventh grade’s increase began and remained in the lower end of Not Sure.

The pretest and posttest results for Subscale S showed a very slight increase at each grade level pertaining to the Social Implications of Science. Students' attitudes toward the advantages and disadvantages that science brings upon society were barely affected. Subscale N pretest and posttest results revealed the greatest increase of all seven subscales regarding students' attitudes toward the acceptance of scientists as normal people. Subscale E results revealed that students' enjoyment of science lessons increased although limited to the high end of Not Sure. Although the mean subscale value of Subscale L improved, students' attitudes in all four grades toward Leisure Interest in Science were lowest of the seven subscales.

With the decline in attitude scores in the Subscales (a) I, (b) A, and (c) C which were related to student interest in careers came an increase in attitude scores in the Subscales (a) S, (b) N, (c) E, and (d) L which were not necessarily related to careers. These shifts in students' attitudes in the areas of these subscales caused the researcher to wonder how the average of the seven mean subscale values for each grade level in the pretest and the posttest compared. This was done by determining the sum of the seven Mean Subscale Values and dividing the sum by seven for each grade level pretest and posttest to determine the Average Mean Subscale Values displayed in Table 4.3.

Table 4.3 revealed that over an entire course of study in science, the collective attitude of all students toward science at each grade level essentially remained unchanged as a result of the implementation of the SCSR. The greatest change occurred in the 12th grade where a mere decline of 0.04 was detected. It was also observed that all Average Mean Subscale Values ranged from 3.13 to 3.39 the high end of the Not Sure response which was defined to exist in the range of 2.5 to 3.5. The decline in career related science attitudes as indicated by Subscales (a) I, (b) A, and (c) C was offset by the increases in non-career related science attitudes of Subscales (a) S, (b) N, (c) E, and (d) L.

Because of the inseparable presence of multiple factors that were associated with the Science Core Sequence Reform such as (a) personal relevancy, (b) block scheduling,

Table 4.3

Comparison of TOSRA2 Pretest and Posttest Total Average Mean Subscale Value

Grade Level	Pretest Average Mean Subscale Value	Posttest Average Mean Subscale Value
9	3.22	3.22
10	3.15	3.13
11	3.39	3.37
12	3.30	3.26

(c) the influence of science teachers and (d) the methodology chosen for science instruction, it was not possible to determine conclusively how the implementation of the P-C-B core science sequence alone influenced science attitudes of students. However it appeared from the results in Table 4.3 that there was no discernable net negative effect on students' attitudes resulting from the implementation of the Science Core Sequence Reform of which the P-C-B core science sequence was a component. This was significant, taking into consideration that all students were required to complete the P-C-B sequence as a requirement for graduation.

Results of Teacher Interviews

Teacher interviews were conducted in an attempt to gain insight into possible changes in students' attitudes that they observed that may have been related to the influence of the Science Core Sequence Reform. After the researcher received consent from each teacher to be interviewed, a time and place was set for the audio-taped interview at the convenience of the teacher being interviewed. Fourteen teachers who were associated with the Science Core Sequence Reform or who taught the students who were affected by the reform volunteered to be interviewed by the researcher. The researcher gave each teacher a copy of his or her interview transcription for review and approval. The individual interviews of each teacher are related as follows.

Teacher Physics A

Teacher Physics A had previously taught physics to seniors in another school district. Since the time he was hired in August, 2004, he was responsible for teaching the modeling physics curriculum to ninth graders in the school district which was the subject of this study. The ongoing development and refinement of the modeling freshman physics curriculum for ninth grade had been demanding and time-intensive for him. His previous physics teaching experience allowed him the use of text related materials which reduced his workload outside of the classroom.

Teacher Physics A is supportive of the SCSR concept which allowed him to engage ninth grade students in visible, concrete science. He admitted that it was a challenge to adapt instruction to learning support students. This teacher noted that modeling methodology promoted a skill emphasis in physics which was good, however it may have come at the expense of, "... playfulness and wonder" (personal communication, October 18, 2005) for ninth graders that is absent, for the most part, in the program. "I think it [modeling] may need some other dimension to it to make it more palatable for the typical freshman" (personal communication, October 18, 2005). He observed that students took a mature attitude when they were in laboratory stations and toward their whiteboarding presentations that displayed their data and analysis of the laboratory in a concise form to the class.

Some suggestions that Teacher Physics A had for creating a more positive attitude in students toward science would be to infuse the curriculum with the construction of creative devices and science projects produced by students. He recommended that science instruction take advantage of ninth graders' inclination toward, "... playfulness and fun" (personal communication, October 18, 2005). He further endorsed the theatrical benefit of teacher conducted demonstrations. Teacher Physics A was in agreement with the SCSR concept and as far as his philosophy of education is concerned, he responded, “I am being shaped by it” (personal communication, October 18, 2005).

Teacher Physics B

Having no prior knowledge of the SCSR initiative, Teacher Physics B embraced it in accepting her teaching assignment in this school district. As a recently graduated physics major, she was drawn to teaching ninth graders as a result of her brief, previous teaching experience. She became one of the original three Freshman Physics teachers in the first year of the implementation of SCSR. She was now in her fourth year at the high school. Each year she continued to develop the curriculum to be more in step with ninth graders’ learning preferences. She taught two blocks of Freshman Physics and one block of Astronomy as an elective to seniors who completed the SCSR requirements for graduation.

She observed that the Freshman Physics course was one in which every student could succeed if each student puts forth the effort in class. She thought that students enjoyed the hands-on, inquiry-based instruction, noting that different students had different struggles. While the course was not designed to be driven by mathematics skills, she heard the students complain about there being too much mathematics. Students’ attitudes still appeared to be positive. The course afforded peer interaction but at the same time opened the door for students to get off task. Teacher Physics B observed that the benefits outweighed the disadvantages because the course was agreeable to the students’ social nature, adding, “I think the way we arrange the topics is much easier to go through and to spend more than one week on a topic, developing concepts is a lot more appropriate for ninth grade” (personal communication, October 21, 2005). Now in her fourth year of Freshman Physics, she observed that student achievement seems to get better each year, especially in the important skill of graph interpretation. She was in full agreement with the SCSR concept, identifying a need to make physics relevant to the students by bringing in more “real world” (personal communication, October 21, 2005) experience.

Teacher Physics C

The first reaction that Teacher Physics C had to the concept of Physics First was, “Wow, what kind of physics is this?” (personal communication, October 24, 2005). He explained that in taking the position as a Freshman Physics teacher at “The District” High School, he was concerned but excited about the prospect of teaching physics to ninth graders. Having recently graduated with a Bachelor of Science Education in Physics, his concern stemmed from the fact that he was in his first full year of teaching, implementing modeling physics methodology that was new to him as well. His class load consisted of two blocks of honors freshman physics and one block of AP Physics. During this year, he had been assigned Physics Teacher B as a mentor. Modeling instruction and resources were provided by the mentor throughout the year. Teacher Physics C had already planned to attend the four week, Modeling Workshop in Mechanics at Arizona State University in the summer of 2006.

This Freshman Physics teacher sensed frustration initially from incoming freshman when they became aware that the teacher was not giving them the answers and that they had to obtain the answers themselves through experimentation. Midway through the course, he observed that students developed more positive attitudes toward Freshman Physics once they understood what was expected of them in doing science. Teacher Physics C was surprised by how easily students understood physics concepts and how they no longer resisted physics and the modeling methodology. He felt that the course provided academic challenge for his students especially where mathematics was involved and through it, students gained a better appreciation for the scientific method and procedures. In terms of student behavior, the cooperative learning aspects of the daily classroom had a positive effect. Teacher Physics C enjoyed the inquiry oriented, lab-based physics approach and affirmed his belief that, “All students can learn and do science” (personal communication, October 24, 2005).

Teacher Physics D

In the year prior to the startup of the Science Core Sequence Reform, Teacher Physics D and the researcher were very closely involved with the development and implementation of the Freshman Physics component that inaugurated the reform. Teacher Physics D was hired by the high school in August, 2001, “... with the mandate to research the best way to teach physics to [all] freshmen” (personal communication, November 14, 2005), and not just to the academic elite. Both he and the researcher visited several schools that were engaged in the physics – chemistry – biology sequence.

Teacher Physics D was quick to embrace the rationale of the science sequence but was not impressed with the physics instructional methodologies that were being used for ninth grade students. He described the opportunities to observe the Physics First programs in operation at other schools as unprecedented. This was especially true of the opportunity to visit a high school in St. Louis, Missouri where a physics instructional methodology called “modeling” had successfully been in place for over seven years. This led to his participation along with the researcher and Teacher Physics B in a four week Modeling Workshop in Mechanics conducted at Arizona State University in the summer of 2002. The value of this experience impressed modeling methodology skills on each of the three participants and developed a strong sense of teambuilding among them prior to the first year of Freshman Physics. The realization that he would be taking his previous physics teaching experience with seniors to ninth graders was, in his words, “... a paradigm shift” (personal communication, November 14, 2005). As the year progressed, he found that he was pleased, “... with the openness of ninth graders to try new things in science” (personal communication, November 14, 2005).

By the end of the year, he was very happy with the skills that the students had retained. Training in transferable skills that would follow students from one year to the next in SCSR was one of the goals of the program. He recalled that students came back to tell him that what they had done in Freshman Physics helped them in mathematics classes.

Academic rigor took a different form in which the student was not sent home with problems to solve every night. Instead, students were sent home to find another way to represent a phenomenon that they had seen in class or to find that phenomena elsewhere beyond the classroom. “There is more in-class rigor than there is homework rigor” (personal communication, November 14, 2005). He observed that students were more likely to be free thinkers at the end of the year than they were at the beginning of the year.

As the interview drew to a close, Teacher Physics D was asked to describe what things could have been done to create a more positive attitude in students toward science. He explained that in the first years of Freshman Physics, he as a teacher was very intent on doing modeling correctly with students doing the experiments. As a result, some of the “wow” factor that was achieved best through teacher demonstrations was absent.

Teacher Chemistry A

Teacher Chemistry A came to this high school in August, 2003, bringing an extensive background of industrial and educational biochemistry experience to the classroom. This teacher expressed a very high regard for the physics to chemistry to biology sequence. Her course load for the first semester of 2005 consisted of teaching two Honors Chemistry classes to tenth graders and a Forensic Science class to seniors. The seniors who attended the Forensic Science class completed the SCSR sequence and chose Forensic Science as an elective. Teacher Chemistry A’s experience in teaching this elective, in its first year of implementation, was very positive. At the same time, she shared a concern for teaching traditional Chemistry (not Applied Chemistry) to all students. She noted that among tenth graders there was a resentment expressed by some students at being required to take chemistry. “My biggest concern is teaching chemistry the way it’s always been taught to every student as if every student was going to be a chemist. So I think what they should get out of a chemistry course could be so much more. It could deal with more real life issues, make them better informed thinkers” (personal communication, October 20, 2005). She was disappointed by students who did not want to be involved with “hands on” activities.

Teacher Chemistry A’s observations of students revealed that the SCSR program brings out the best of students who would not be considered at the top of the class. She also expressed a “gut feeling” (personal communication, October 20, 2005) that students in the SCSR were being academically challenged. Evidence that students’ attitudes were positive toward chemistry came in the form of students asking more questions and wanting to know more about the subject. In this inquiry learning environment, student behavior was better because they were often actively engaged in activities. In terms of student achievement, students had a higher conceptual understanding and were definitely more curious. Teacher Chemistry A emphasized that it was “extremely important” (personal communication, October 20, 2005) that instructional materials be developed that were relevant to the students. When asked if SCSR was compatible with her philosophy of science education and her methods of instruction, she responded enthusiastically, “Absolutely!” (personal communication, October 20, 2005).

Teacher Chemistry B

Teacher Chemistry B brought a varied background of educational and industrial professional experience to the classroom. Her experience included: (a) eight years as a community college lab instructor, (b) three and a half years working for an environmental engineering firm, and (c) nine years teaching mathematics, chemistry, and general physics overseas at a private, international school. She received her Bachelor of Arts in Biology and Chemistry and presently is pursuing a Masters of Chemistry Education degree. She is now in her second year of her present high school assignment, teaching three blocks of academic chemistry to tenth grade students.

At the calendar midpoint of this block, Teacher Chemistry B noticed how her students had become more comfortable with not being told what their results from lab activities and investigations should be in advance. She acknowledged that students did well at group work and hands-on activities and in general did well in conceptual chemistry. Even with these observable positive qualities, she felt that the bridge between freshman physics and chemistry needed to be improved because students did not understand connections between freshman physics and chemistry. She found it difficult to assess her students' (a) attitudes, (b) behavior, and (c) achievement under the SCSR because she was relatively new to this teaching situation. Comparisons made with students at the international school where she had previously taught would be unfair, since chemistry at that school was an elective course, not a required course for all students. She also noted that her students who came into chemistry at the international school, "... had a taste of chemistry and physics" (personal communication, October 27, 2005) in a middle school experience that was, "... a layering and swirling [of science subjects and concepts] which is more of an Asian, Australia, European way of doing things" (personal communication, October 27, 2005).

Teacher Chemistry C

Since August, 2003, Teacher Chemistry C taught academic chemistry to tenth graders as well as AP Chemistry to twelfth grade students in what has been her first professional teaching experience. In entering into the SCSR program, she had no reservations about teaching chemistry to sophomores. Her initial response to the concept was that it made sense. Her own high school science experience followed the traditional path of (a) biology, (b) chemistry, and (c) physics that eventually led to a Bachelor of Science in Chemistry Education which she received in 2003. Her student teaching experience was in a high school where chemistry was an elective course for juniors that was content driven, involving a lot of bookwork. By comparison, the tenth grade students she now teaches, "... have a better grasp of hands-on, how to handle equipment, lab techniques, computer skills with graphing" (personal communication, November 1, 2005). Her students refer to the textbooks, which are kept on a shelf in her classroom, only as needed.

In her first year of teaching, Teacher Chemistry C found it difficult to adapt to the wide range of student abilities in her homogeneously grouped academic classes. These classes were descriptive as opposed to the problem solving emphasis of honors chemistry classes. Her workload exceeded expectations and she discovered that the students coming into her class in her first year had perceptions that chemistry would be too difficult. These students were in the first class to have completed Freshman Physics. She recalled that these students remembered concepts learned in physics which was helpful for her instruction. Each year since then, her students have been less resistant to taking chemistry as a required science course. Since the first year of the reform, student academic ability became more evenly distributed in her classes which had a settling effect on student behavior. In her opinion, "... their achievement is great", (personal communication, November 1, 2005) noting that the enthusiasm of the teacher and the availability of fine facilities and equipment have had a positive effect on students' attitudes.

Teacher Biology A

Teacher Biology A entered his first year of teaching in August, 2002. He taught three classes of eleventh grade Academic Biology which was carried out within a block schedule. The course of study was a systems approach to the study of biology, designed for students to grasp the big picture of biology through their involvement in laboratory activities. The placement of Academic Biology in eleventh grade made sense to this teacher because of the experience his students had with chemistry in the previous year. He added that since biology was a required course for graduation, and not an elective, the receptiveness of his students to biology was varied. Although he was new to biology teaching, this teacher observed that students entered into his course knowing (a) laboratory procedures, (b) laboratory safety rules, and (c) the proper use of laboratory equipment. Teacher Biology A did observe that students needed some refresher chemistry although he had no previous teaching experience to which he could compare this year.

This teacher admitted that it was difficult to tell how the SCSR has impacted his students although he felt that, "It almost has to help" (personal communication, October 18, 2005). He found that the attitudes of his students varied between those who liked it and those who did not. He recognized that block scheduling may be a factor. With the increased class time, students tend to be more restless and that the lesson for each day must be varied in addressing various learning styles. Midway through the course of study, he felt that the students were doing quite well academically and that he was pleased with their performance, however a few students were sliding. He recognized that his students were inquisitive to science topics outside of biology. He agreed that it is good for biology to come at the end of a P-C-B sequence and that the course should be made relevant to students. To accomplish this would be difficult although not impossible.

Teacher Biology B

Learning of a "… different approach to science teaching" (personal communication, October 24, 2005) attracted Teacher Biology B to apply for a position at "The District" High School. Her formal education included a Bachelor of Science in Education, majoring in Biology and History and a Master of Science in Education in Biology. In her first year at "The District" High School, her public school experience included ten years of teaching (a) biology, (b) chemistry, and (c) anatomy at the high school level. Her teaching load included two blocks of academic biology to juniors and one block of an anatomy elective to seniors who she described as highly motivated.

Teacher Biology B was pleased to find that her biology students had a chemistry background and that they required a minimal amount of time in reviewing chemistry concepts needed in the study of biology. Expressing that it was definitely an advantage for students to have already had chemistry she remarked that, "I am having to go back to reinvent biology for kids who have had chemistry" (personal communication, October 24, 2005). At the halfway point of the biology course in the block schedule she observed that students are mature and focused. Midway through the block course of study in biology, she noticed that negative remarks made by students about science at the beginning of the course of study were less frequent.

The block scheduling of biology was recognized by this teacher as being beneficial to student achievement in SCSR. "I am very pleased with what they have accomplished" (personal communication, October 24, 2005) was her response. Teacher Biology B has found the SCSR concept to be compatible with her own philosophy of education as well as with her inquiry based instructional methods. So far this year only several of her students have expressed an interest in science as a career. She suggested that opportunities for students to study careers in science and to find relevant applications would help to improve students' attitudes toward science.

Teacher Biology C

As a teacher of tenth grade biology students in the traditional sequence, Teacher Biology C saw that her students were becoming increasingly frustrated with science. This was due to the absence of sciences like physics and chemistry in their science instruction that were necessary for the study of (a) DNA, (b) biotechnology and (c) advances in medicine that increasingly were becoming a part of molecular based contemporary biology. As science department chair at the school district that was the site of this study, she brought the concept of a physics – chemistry – biology sequence to the attention of the science department amid some objections and later to the school district administration in 1999.

During the past thirteen years she served as the Science Department Chair for the school district. Until the 2004-2005 school year, she had taught all levels of biology to tenth grade students and to upperclassmen who were taking a second year of biology. Since then her role has been to teach biology to eleventh grade students. "I directly evaluate the effectiveness of the program and how much my students retain, understand, transfer, [and] carry forward as I teach them modern biology" (personal communication, November 15, 2005). In the 2004 – 2005 school year, Teacher Biology C received her first class to be affected by the reform as juniors and who had previously taken Freshman Physics and Chemistry in the two previous years. She observed that these students were much more open to learning. They also had familiarity with chemistry principles and were not intimidated by molecular concepts in biology. A challenge that faced this teacher at that time was that of providing Advanced Placement Biology to juniors who had no prior biology background in a traditional, year long schedule.

Teacher Biology C has observed that her students had an increased interest in science and were more inclined to do outside reading because they had a better grasp of the subject matter. She noted that students who had taken Freshman Physics, which was complemented by their math instruction, had excellent graphing skills and were comfortable interpreting data. Her students also had a high expectation that they would be active participants in biology class which spurred more of a genuine interest in her course. Prior to the reform her students were disengaged and unable to make connections between science subjects that shared in common concepts such as energy. Her approach to instruction evolved as her students recognized the interdisciplinary nature of science. As far as career interest she felt that juniors were still pliable, adding that, "... one of our great responsibilities is to make them aware of various careers in which they would use [the information learned in class]" (personal communication, November 15, 2005). That information went beyond biology content to include development in analytical and critical thinking skills that began in Freshman Physics.

Viewed subjectively, students' attitudes toward biology were positive, evidenced in improved self-esteem that came from taking on a challenging subject. This in turn brought about an improved work ethic that was characterized by very good academic achievement. When asked what measures would create a more positive attitude in students toward science, Teacher Biology C suggested (a) more inquiry opportunities, (b) field trips, (c) industrial experience, and (d) the study of the local landfill as a culminating course to study the environment, (e) explore careers and (f) understand responsible citizenship. According to Teacher Biology C,

> I think the emphasis on concept based education is critical. As kids get lost in all the detail it's like they were taking notes all the time, they just mindlessly copy notes. There's no point to that. Whereas, if you give them conceptual questions to work out in groups and solve problems, they get it and I believe they will retain that. (personal communication, November 15, 2005)

Teacher Mathematics A

The professional teaching career of Teacher Mathematics A spanned 31 years, all served in the district where this study was conducted. He received a Bachelor of Science degree in Mathematics Education and a Master of Education degree in Mathematics and has engaged in a lifelong interest in astronomy. He taught Pre-Algebra and Algebra to ninth and tenth grade students. When asked about his initial reaction to the Science Core Sequence Reform concept, he responded, "I remember when I first heard about it, I thought, 'What an exciting idea!'" (personal communication, November 16, 2005). He understood that for physics to occur at the ninth grade level, the emphasis of physics could not be on the mathematics used by traditional senior physics students, but rather on the wonder and effects of physics that would capture students' imagination at a level of mathematics which was within their capabilities.

As a teacher of ninth graders, he noticed occasions when students would come into his class on a day when the mathematics lesson focused on a particular concept such as the slope of a line. Shortly into the lesson students would remark that the slope of a line was determined in a Position vs. Time graph in a Freshman Physics class. In several similar instances, Teacher Mathematics A found personal satisfaction when students found such applications outside of his mathematics class. In an indirect reference to students' attitudes, he observed, "I don't get so much anymore [from his students], 'What am I going to use this for?'" (personal communication, November 16, 2005). On occasions when students came into his classroom, having learned a different approach to working a problem, he welcomed such a situation as an opportunity to show students that they were studying the same concept which was represented or applied in a different way from the way they first learned it. In the absence of a coordinated mathematics curriculum between the mathematics and science departments, Teacher Mathematics A felt that both departments were, "... pulling in the same direction" (personal communication, November 16, 2005).

He indicated that something that could be done to improve students' attitudes toward science through his math classroom would be for him to be made more aware of the kind of mathematics that was expected of students in the science classroom. From time to time, he noticed that math concepts in science coincided with his own instruction but he admitted that he really did not know what, in particular, was being taught in Freshman Physics. "I wouldn't mind sitting down and taking a look at what the curriculum [Freshman Physics] is, so I can say [to the students], 'Here's something you're going to be using next week or next month or in the Spring in physics or in science'" (personal communication, November 16, 2005).

Teacher Mathematics B

A veteran teacher of 22 years, Teacher Mathematics B had thirteen years of mathematics teaching experience with middle school students at a previous school district. She served as the mathematics department chair for ten years at that same school district where she also served as the K-12 mathematics coordinator for six years. For the past seven years she has taught every mathematics course, at every grade level, with the exception of calculus and statistics. Her personal experience with physics as a high school student was calculus based, however she described the influence of her father when she studied science as a middle school student. She stated,

> I had a father, who was an electrician, who helped me when I was a child, helping me to build a lot of these physical pieces that you get in your freshman physics classes and I had that rich experience at home [that] most students don't. (personal communication, November 17, 2005)

Her role in the start up of SCSR was limited to an observation trip with science teachers to a school district where the physics – chemistry – biology sequence was already in place. Shortly after the SCSR was implemented the mathematics curriculum was changed, "... to a much more data based analysis based program with a focus that was much more on the graphing of data" (personal communication, November 17, 2005). At the time, this was an independent decision made by the mathematics department that was not coordinated with the science department but the thought process behind that decision was that, "... it would dovetail nicely..." (personal communication, November 17, 2005) with the Freshman Physics curriculum. Teacher Mathematics B noticed that after the first year of Freshman Physics, "... students coming, right away, out of physics in the ninth grade knew a lot more about graphing data and the analysis of that than they ever did before" (personal communication, November 17, 2005). For her the negative side of this was that Freshman Physics students were instructed in the use of a graphing software program which provided the line of best fit and they no longer want to produce graphs by hand. She added,

> But I will say that the students are so much more comfortable with analyzing data and getting lines of best fit and [understanding] 'What does this mean and what can you draw out of this graph?' They are so much better at that than they ever were before. (personal communication, November 17, 2005)

Owing to the combined influences and reinforcement of the new mathematics and science programs, she acknowledged that students are better prepared, "... to deal with any kind of math problems that have practical applications" (personal communication, November 17, 2005). For this reason, students have been less inclined to question the usefulness of what they were learning since they were dealing with real data and not the data created for some abstract situation.

Teacher Learning Support A

From the beginning of the SCSR in August, 2002 until June, 2004, Teacher Learning Support A volunteered to serve learning support students enrolled in Freshman Physics. Initially she thought that physics as a required science for learning support students would be too difficult compared to biology. She would later observe, "In the first quarter of the first year I saw that so much of it [Freshman Physics] was hands-on ..." (personal communication, October 19, 2005), that for her learning support students, "... this course matched perfectly with their style of learning" (personal communication, October 19, 2005). During this time her role was to help students focus and understand the concepts addressed by the coursework. She noted that her students' confidence and esteem grew from their involvement in the modeling physics methodology. In the first year of SCSR, two of her learning support students achieved the two highest scores on the modified Force Concept Inventory of all the students in the ninth grade. While some learning support students behaved immaturely with equipment, she observed that there were those students who had a natural ability using physics (a) equipment, (b) sensors, and (c) the integrated graphing software program responsibly.

From August, 2004 until the present, she served as learning support teacher for alternative education students who came to her for help in science. In her 16 years of experience in the high school of this school district she observed that learning support students have always struggled with chemistry. Subjectively she observed that attitudes of her students toward chemistry were negatively affected by the abstract nature of chemistry concepts and the challenge of the mathematics needed for problem solving. Now that chemistry was required of all tenth grade students, she saw that there was no difference in learning support students' attitudes toward chemistry than in previous years when some students took it as an elective. This teacher saw that chemistry became overwhelming for her students when the mathematics required to succeed exceeded their mathematics ability. She recommended that an applied chemistry course be introduced to make chemistry more relevant in her students' lives along with the beneficial implementation of instruction that addresses multiple learning styles.

Teacher Learning Support B

Teacher Learning Support B came into the SCSR in the fourth marking period of 2004, assisting learning support students in Freshman Physics. Her role was to assist learning support students although she admitted to being intimidated at the prospect of being involved in physics instruction. “I was surprised that they (her students) were doing physics and was further surprised by the way the information was presented and the amount of information that could be covered, because when I went to school, physics was AP seniors only” (personal communication, October 19, 2005). She favored the inquiry approach of modeling physics that engaged her students in physics activities and laboratories. She found that students were enthusiastic and “... not dreadful” (personal communication, October 19, 2005) which was indicative of their positive attitudes. Further positive evidences of improved student attitudes toward science became apparent in student group interactions which revealed that different students were better suited than others to do different things. Negative elements stemmed from student mobility which resulted in distractions due to close proximity with each other. Still, she observed that student attitudes and behavior were best when students were actively engaged. While the course was intellectually challenging, she felt that it was not academically rigorous to the extent that her students would suffer poor or failing grades.

This teacher recommended that cross-curricular reinforcement, between mathematics and science, should standardize terminology and processes that are addressed in both subjects, such as in solving for the slope of a line. Students’ achievement was typically characterized by their performance of an activity before their ability to understand a concept. Lessons that implemented multiple learning styles that included experience and involvement were beneficial for her students. Teacher Learning Support B noted that it was desirable to have a personal application in instruction. She suggested that physics projects be assigned in which students could take a personal interest. Demonstrating the relevancy of physics in students’ lives, apart from the understanding of physical laws and concepts, was something that presently was not done well.

Teacher Perceptions about Student Attitudes and SCSR

Research Question 2 posed the question, “What changes in students’ attitudes toward science had occurred since the implementation of the SCSR?” Teacher interviews served as a qualitative instrument that provided subjective data related to students’ attitudes toward science that were observed by those teachers. While the interviews conducted by the researcher followed an established protocol that followed specific lines of questioning, the use of this instrument also provided an opportunity for anecdotal observations of students’ attitudes to surface that would otherwise have been unanticipated.

Table 4.4 provided a concise representation of observations of students’ (a) attitudes, (b) behavior and (c) achievement made by each of the fourteen interviewed teachers. All four Freshman Physics teachers were in full agreement with the appropriateness of placing physics in ninth grade and that attitudes, reflected by the students’ receptiveness to instruction, were positive. Teacher evaluations of student attitudes toward science were complicated by the inherent maturity level that ninth grade student brought to the classroom. Teacher Physics D noted that ninth grade students grew in maturity during the course of the school year evidenced by their gradual acceptance that they were to take greater responsibility for their learning. Alluding to the issue of

Table 4.4

Teacher Interview Matrix of Student Observations

Teacher	**Student Attitudes Observed**	**Student Behavior Observed**	**Student Achievement Observed**	**SCSR in Agreement with Educational Philosophy (Phys. – Chem – Biology) Sequence**
Physics A	Generally positive	Generally positive	Uncertain Scores of adapted FCI consistent with last yr.	Yes Teacher Physics A sees need for "... more playfulness and fun".
Physics B	Many positive attitudes although little previous experience on which to base comparison.	Social, peer interaction comes naturally but offers opportunities for off-task behavior. Benefits outweigh setbacks.	Gets better each year. Graph interpretation is an important skill.	"Absolutely" Teacher Physics B sees need for "... more real world experience".
Physics C	Positive attitudes are evident when students know expectations.	Positive. Cooperative learning works well at 9th grade level..	Students receptive to physics and modeling. Math applications are challenging, not overwhelming.	Yes. Agrees with inquiry oriented, lab-based approach to modeling.
Physics D	Generally positive. Difficult to determine if student maturity was due to Freshman Physics or maturity over time.	In time students accepted the shift from a teacher centered class to a class in which students take a greater responsibility for their learning.	Pleased with skills students retained. In-class rigor replaced homework rigor.	Yes Teacher Physics D noted absence of "wow" factor that is best achieved through teacher demonstrations.
Chemistry A	Positive "Students want to know more and ask more questions."	Positive Students are busy through active inquiry approach to instruction.	Higher conceptual understanding	"Absolutely" Teacher Chemistry A felt that students should deal with more real life issues apart from what chemists would deal with.
Chemistry B	Difficult to tell although some positive qualities were observed	Difficult to tell	Difficult to tell Suggested that the biology teachers would be in the best position to assess.	Yes Teacher Chemistry B saw a need for physics and chemistry to be made more purposeful for students
Teacher	**Student Attitudes Observed**	**Student Behavior Observed**	**Student Achievement Observed**	**SCSR in Agreement with Educational Philosophy (Phys. – Chem – Biology) Sequence**

Chemistry C	Student attitudes improved gradually from year to year.	In the first year the student class assignments were uneven. Better homogeneous student distribution resulted in better behavior.	"I think their achievement is great!"	Yes
Biology A	Varies	More restless. This may due to block scheduling?	Most doing well. Pretty happy with performance.	Yes
Biology B	Fewer negative remarks about science compared to the beginning of the course.	Described students as mature and focused.	Students with prior background in chemistry is beneficial	Yes Teacher Biology B suggested opportunities for students to study careers and make science more relevant might improve student attitudes toward science.
Biology C	Students had increased interest in science which led them to do more outside reading.	Familiarity with lab environment and expectations	Improved inquiry skills	Yes Emphasized need for science career awareness and responsible citizenship among students.
Mathematics A	Science attitudes not observed.	Science behaviors not observed.	Science achievement not observed.	Sees need for students to make connections between mathematics and physics.
Mathematics B	Science attitudes not observed.	Science behaviors not observed.	Science achievement not observed.	Yes. Students see relevancy between mathematics and science
Learning Support A	9th Physics "rewarding" 10th Chemistry "overwhelming" 11th Biology "easier"	In time students accepted the shift from a teacher centered class to a class in which students take a greater responsibility for their learning.	Not different from traditional. "Good with less lecture and more activity.	Yes Different learning styles are addressed: visual, auditory, tactile-kinesthetic
Learning Support B	Positive "less dreadful"	Positive when actively engaged	Positive. Students' performance of activities comes before their understanding of concepts.	Yes Multiple learning styles addressed. Sees need for personal interest in projects and in a need for relevancy.

maturity, Teacher Physics C emphasized the importance of making expectations for student behavior clear in advance in order to insure positive attitudes. Teachers Physics B, C, and D observed student development in areas of (a) inquiry, (b) graphing, and (c) laboratory skills. Even with evidence of student learning taking place, Teachers Physics A and D felt that there was a need for more opportunities for ninth graders to engage their natural tendency to have fun and experience a "wow" response to teacher demonstrations which were rarely performed. Teacher Physics B cited a need to expose students to real world science opportunities which would give students more meaning to the purpose of studying science.

Teachers Chemistry A, B, and C adapted instruction in Chemistry that was traditionally reserved for eleventh grade students for all learners in tenth grade. Teacher Chemistry A expressed the most positive observations of student attitudes, evidenced by them asking more questions and engaging productively in science activities of an inquiry nature. This same teacher felt that student science attitudes would be more positively influenced if they were exposed to the real life issues in chemistry beyond the classroom. Although Teacher Chemistry B had observed some positive attitude qualities in her students, she expressed that it was difficult to tell objectively. She also acknowledged a need for physics and chemistry to be made more purposeful for students. Teacher Chemistry C was pleased with student achievement and noted that her students' attitudes toward chemistry seemed to improved each year. All three chemistry teachers were in agreement with the physics to chemistry to biology sequence that was in place.

Teachers Biology A, B, and C were in agreement that it was beneficial to have students who had a background in chemistry and previously developed laboratory skills. All three teachers were in agreement with the sequence of core science courses which placed biology in eleventh grade. Teachers Biology B and C both suggested that opportunities to make biology more relevant to students should be introduced into the curriculum in order to improve student attitudes toward science.

Of the teachers interviewed who were not science teachers, Teachers Mathematics A and B both agreed that students needed to make connections that were relevant to their lives between mathematics and science. Both teachers appreciated the interdisciplinary connections that students recognized existing between mathematics and science. Both Teachers Learning Support A and B felt their students were best served by the multiple learning styles that were addressed in science classes. Teacher Learning Support B recognized a need for students to be able to take a personal interest through science projects that had relevancy to their lives.

Relationship of Archival Records to Research Question 3

The third research question that was foundational to the purpose of this research study was, "How had science electives been impacted by the SCSR program?" The examination of archival records was limited to the procurement of high school science course selection records which dated back to the 1997-1998 school year and continued up to the present 2005-2006 school year. Data were obtained from the records maintained by the science department chair at the high school where the research study took place. Additional records were provided by the administrative office of the same high school.

The purpose of examining these records was to determine how trends in student course selection of core science elective subjects may have been affected by the implementation of the Science Core Sequence Reform. The definition of a core science was described in Chapter One as being one of “the three primary disciplines in high school education - biology, chemistry and physics” (ARISE, 2003, p. 7). Core science electives serve to deepen a student’s understanding of the core science as opposed to being comprehensive overviews of science subjects that are of general interest.

Listings of core sciences and core science electives that were offered at the “The District” High School during each school year in which archival records were examined can be found in the High School Science Required and Core Course Registrations (Appendix L). Also included in Appendix L was a compilation of these records which showed student enrollment by specific subject. A listing of all science courses can be found in “The District” High School 2005-2006 Program of Studies in Science (Appendix K). A representation of those records can be seen in the Figure 4.5 bar graph depicting the core science course registrations and the core science electives that were selected by each academic year. The dark column of each bar in the Figure 4.5 bar graph represented the total number of students enrolled in the core sciences of (a) physics, (b) chemistry, and (c) biology. Included in the data were Earth and Space Science enrollments from the 1997-1998 academic year up to and including the 2001-2002 academic year. For the purpose of this research study, Earth and Space Science was not considered a core science subject. Because Earth and Space Science was a subject required for graduation during those academic years, it was included as a required science among the data in Figure 4.5. All core science subjects were subjects that could be applied toward science high school graduation requirements.

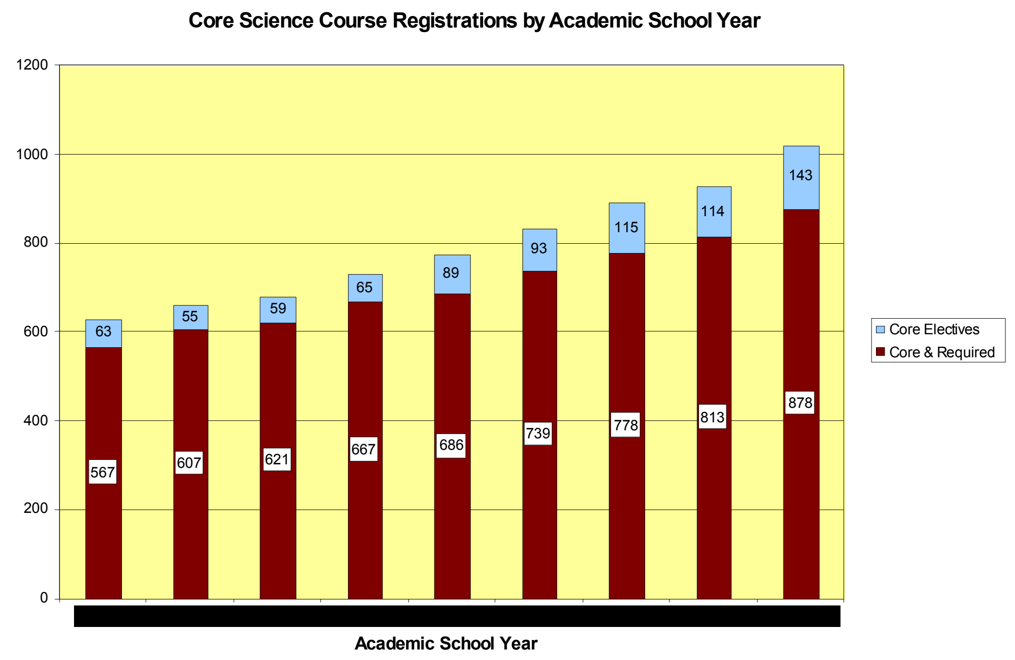

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Figure 4.5. Core and Required Science Registrations Compared to Core Science Electives

The data in Table 4.5 displayed the data in tabular form that were represented in Figure 4.5 bar graph. It showed steady but gradual gains in student core science enrollment due to the population growth that occurred in the school district between 1997 and 2006. In addition to the Figure 4.5 data, Table 4.5 showed the calculated percentage of the core science electives compared to the total number of core science electives. A decline in core science electives enrollment between 1998 and 2001, evidenced by single digit percentages on Table 4.5, coincided with a high school renovation program that temporarily, but adversely, impacted science facilities during that time. Completion of the renovations came one year before the implementation of the SCSR that began with the 2002-2003 school year.

With each successive year that followed the 2002-2003 school year, students were required to enroll in core sciences required for graduation. During this time, except for a small percentage drop in 2004-2005, the student enrollment in elective core sciences continued to grow. This increased interest in second year core science electives served as an indication that students' attitudes toward science were not adversely affected by the Science Core Sequence Reform. It was during the 2005-2006 school year, when twelfth

Table 4.5

Comparison of Core and Required Science Registrations to Core Science Electives

School Year	TOTAL Core and Required Science Student Registrations	Core Science Elective Student Registrations	Percentage of TOTAL Number of Core Science Elective Registrations
1997-1998	630	63	10.0 %
1998-1999	662	55	8.3 %
1999-2000	680	59	8.7 %
2000-2001	732	65	8.9 %
2001-2002	775	89	11.5 %
2002-2003*	832	93	11.2 %
2003-2004*	893	115	12.9 %
2004-2005*	927	114	12.3 %
2005-2006*	1021	143	14.0 %

Note: * Years of SCSR program implementation and institutionalization grade students had completed their high school science graduation requirements, that the science core electives enrollment reached its highest percentage at 14.0 % of the total core science enrollment. A total of 62 juniors and 81 seniors were enrolled in core science electives for the 2005-2006 school year. What was significant was that core science electives were being selected by these same juniors and seniors who would soon meet or who had already met the science graduation requirements. In addition, these same students opted for core science electives in favor of non-core science electives. This trend served to advance the possibility that SCSR had a positive influence on students choosing to take core science electives among other options. Equally significant was the enrollment of juniors and seniors in non-core sciences in which 35 students enrolled in Astronomy and 25 students enrolled in Forensic Science in the 2005-2006 school year.

Summary

This mixed method research study focused on how the attitudes of students toward (a) science careers, (b) science interest in general, and (c) science electives were affected by the implementation of a Science Core Sequence Reform (SCSR). This reform introduced a P-C-B science sequence in grades nine through eleven which was required of all students for graduation. The investigation into students' attitudes toward careers in science showed that student interest in science careers declined while the SCSR was in operation. In terms of general interest toward science, student attitudes declined in the Subscales I, A, and C that were related to career interest but showed an increase in Subscales S, N, E, and L which were not necessarily career related. The consequence of these changes appeared to have a mutually offsetting effect that resulted in no perceptible change in students' general interest in science. Teachers' impressions of students' attitudes toward science were somewhat ambiguous owing to the limitations of subjective expression of those impressions. Their greater contribution came from their specific recommendations as to how student's attitudes toward science might be improved. Using student enrollment in core science electives as a positive indicator of student's attitudes toward science, an increase in enrollment was observed but could not be conclusively linked to SCSR in view of the multiple variables that came to bear on this research study.

Triangulation of three research instruments was used to insure validity when drawing conclusions related to the attitudes of students toward science from the quantitative and qualitative data obtained in this study. Interpretation and clarification of data obtained from these instruments were provided in the form of: (a) expository narrative, (b) data tables, (c) bar graphs, (d) teacher interviews and (e) matrixes.

CHAPTER FIVE – DISCUSSION

Summary of the Study

The purpose of this mixed method research study was to examine the effect that the implementation of a Science Core Sequence Reform (SCSR) had on the attitudes of high school students toward science. The reform consisted of two components that included the adoption of a science sequence of physics to chemistry to biology for all students beginning in ninth grade. The other component of the reform included the implementation of new methodologies of science instruction, especially for physics instruction in ninth grade, to carry out the reform effectively. The study was guided by the three research questions:

1. Was there a relationship between the attitudes of Science Core Sequence Reform (SCSR) students and their decisions to pursue science related options in their post-high school education and career plans?

2. What changes in students' attitudes toward science had occurred since the implementation of the SCSR?

3. How had science electives been impacted by the SCSR program?

During the course of a high school semester in which science courses of study were built around a block schedule, science students in grades nine through twelve received science instruction in a three year Science Core Sequence Reform. Over 500 of these students voluntarily participated in the study by taking part in pretest and posttest evaluations of their attitudes toward science that were administered at the beginning and end of the semester, respectively. The changes in students' attitudes towards science were determined by a modified application of the Test of Science-Related Attitudes (TOSRA). By means of the data resulting from the TOSRA2 Pretest and Posttest, variations in the seven science attitude subscales were analyzed. These subscales included (a) Social Implications of Science, (b) Normality of Scientists, (c) Attitude to Scientific Inquiry, (d) Adoption of Scientific Attitudes, (e) Enjoyment of Science Lessons, (f) Leisure Interest in Science, and (g) Career Interest in Science.

Fourteen teachers of these students were interviewed face-to-face in order to gain their perceptions as to how the SCSR, as they experienced it, had affected students' attitudes toward science. Of these teachers (a) four taught Freshman Physics, (b) three taught Chemistry, (c) three taught Biology, (d) two taught Mathematics, and (e) two were Learning Support teachers.

The examination of archival records focused on high school science course selection records dating back to the 1997-1998 school year and continuing up to the 2005-2006 school year. Data were obtained from the records maintained by the science department chair at the high school where the research study took place. Additional records were provided by the administrative office of the same high school. The purpose of examining these records was to obtain insight into student's attitudes toward science as reflected through their patterns of course selection as influenced by the implementation of the Science Core Sequence Reform.

Importance and Interpretation of Findings

Research Question Number One

The intent of research question number one was to determine the extent to which students' attitudes toward post-high school education and career plans were influenced by the Science Core Sequence Reform. Analysis of the pretest and posttest findings showed that each grade level, nine through twelve, exhibited identical patterns of attitude change through all seven science attitude subscales. For each of the four grade levels, the TOSRA2 Posttest data showed a decline in (a) I, (b) A, and (c) C attitude subscale values that could be related to student career interest. This could also be interpreted as a decline in students' interest in science with respect to their post-high school education plans.

The data reflected by the percentages of students taking core science electives revealed a modest increase in core science electives registrations for the 2005-2006 school year compared to previous years. This was significant since this was the first school year in which the juniors were in their final required core science course and seniors were the first class to have completed the required SCSR courses. The number of juniors and seniors (143) choosing core science electives in 2005-2006 was greater than it was for juniors and seniors (114) who chose core science electives in 2004-2005. This trend seemed to be consistent with the TOSRA2 Posttest data that showed an increase in students' interest in sciences that were relevant or of personal interest to students.

Teacher interviews provided qualitative insights into the influence of SCSR on students' career interests. Ninth and tenth grade teachers saw a need to emphasize relevancy and real world experiences for their students. Teachers of eleventh and twelfth grade students pointed to the need for more of an emphasis on introducing their students to science-related careers. For all 14 of these teachers, the appropriateness of placing (a) physics in ninth grade, (b) chemistry in tenth grade, and (c) biology in eleventh grade was not in question. Most of the teachers expressed a need to adapt each science program in appropriate ways that would maximize students' interest in science at each grade level.

Research Question Number Two

Research question number two prompted investigation into how students' attitudes toward science were affected by the implementation of the Science Core Sequence Reform (SCSR). Student response to the SCSR initiative was a concern for the administration and the teachers from the beginning. The purpose of implementing SCSR was to increase science literacy among all students in the core science subjects of (a) physics, (b) chemistry, and (c) biology. While improved student achievement in science was the object of the reform, a change in students' attitudes toward science may have signaled the appropriateness of SCSR in either favorable or unfavorable terms. The information obtained regarding students' attitudes toward science provided the opportunity for teachers to make the necessary adaptations to the SCSR program as indicated by the interpretation of the findings of this research study.

The administration of the TOSRA2 Pretest and the TOSRA2 Posttest provided two sets of data in which changes in seven science attitude subscales could be examined. The four subscales S, N, E, and L, showed an increase in students' attitudes toward relevancy and personal interest at each of the four grade levels. This trend suggested that the instructional methodology adaptations that teachers made that accompanied the change in grade levels to which (a) Physics, (b) Chemistry, and (c) Biology were introduced appealed to students' interest. The mean subscale values for Subscales S, N, and E in the TOSRA2 Pretest were above or close to the Likert response midpoint mean subscale value of 3.0 for all four grade levels. These same grade levels all finished above the midpoint mean subscale value of 3.0 where the highest values occurred in the eleventh and twelfth grade classes.

The subscale that experienced greatest increase across all four grade levels was Subscale N, Normality of Scientists. This increase may have reflected favorably on the science department instructional staff, if the students perceived their teachers as scientists who lived lives much like their own. Comments that originated from teacher interviews did not indicate that students got this impression from their personal involvement with scientists, since real life experiences in science were noted as a deficiency in students' science instruction.

The same TOSRA2 Posttest data showed a decline in I, A, and C attitude subscale values that could all be related to student career interest. These declines were experienced at all four grade levels, nine through twelve. In all four grade levels Subscale I, Attitude to Scientific Inquiry and Subscale A, Adoption of Scientific Attitudes, began with relatively high mean subscale values above 3.0 yet still remained above 3.0 after the posttest descent. This may be explained by students' relatively high regard for inquiry science methods of instruction but who still need to see the relevancy of science inquiry applications to their lives.

Subscale C, Career Interest, finished next to last in posttest mean subscale values, in all four grade levels. This data suggested that students did not regard science as something to which they would make a long term commitment. Of the four grade levels, eleventh grade students obtained the highest posttest mean subscale value for Subscale C which fell just short of the midpoint value of 3.0 at a value of 2.91.

Research Question Number Three

The research that was undertaken to investigate the impact of the SCSR program on science electives was limited to the examination of archival records obtained from the files of the high school department chairperson and high school administration records which provided statistics on student science course registrations over a period of nine years. The data showed that the student population of the high school increased with each successive school year beginning with the 1997-1998 school year. Beginning in that same academic year, the percentage of students who registered for core science electives remained at 10.0% or less each year through the 2000-2001 school year.

In the 2001-2002 school year that preceded the inaugural year for the Science Core Sequence Reform in 2002-2003, the percentage of students who chose science core electives reached 11.5 %, and rose irregularly to 14.0 % through the 2005-2006 school year. This occurred in spite of the fact that the vast majority of seniors had completed all science courses required for graduation by the end of their junior year. At the very least, this trend suggested that students' attitudes toward science did not suffer, in fact, they may have benefited from the implementation of SCSR. This could be explained in terms of students' attitudes that led them to select core science electives in increasing numbers. The archival records in this research study showed that there was a positive relationship between students who had increased exposure to SCSR and their decisions to select core science electives. This could be due to the trend in increased enrollment in core science electives through the cumulative exposure to SCSR over successive years.

Limitations of the Study

In the year that this research study was conducted, the school was in the first year of a change in its academic calendar from a traditional 180 day schedule to a 90 day block schedule. The responses given by students at each grade level to the pretest and posttest statements must be considered in terms of the age maturity that typified each of the four grade levels, nine through twelve. Of grade levels nine through eleven, all students were required to take core science courses. Only the twelfth grade included students who were not enrolled in a science course when the TOSRA pretest and posttest instruments were administered. This could account for attitude declines in the twelfth grade class below eleventh grade levels.

Unfortunately the number of juniors and the number of seniors in 2004-2005 was not available. The Grade 12 column for 2004-2005 contained the combined number of juniors and seniors. The comparisons between 2004-2005 and 2005-2006 became difficult because Honors and CP Physics, which were offered in 2004-2005, were replaced by AP Physics which was introduced in the 2005-2006 school year. Upper class enrollment in physics dropped considerably in 2005-2006 from the previous year but a total of 60 students elected courses from among the non-core science offerings of Astronomy and Forensic Science. Further limitations included the sample sizes of students surveyed and teachers interviewed. No generalizations from this study should be made and applied to other instructional settings owing to the unique demographics of this one high school that was the subject of this study.

Relationship to other Research

The primary purpose of the Science Core Sequence Reform (SCSR) was to increase science literacy among the high school students at the high school where this research study took place. Research which was cited in Chapter Two of this study showed different attempts to identify individual factors that were directly related to improved science literacy. Bottoms and Feagin (2003) reported in their key findings that a challenging academic course of studies in the core sciences could greatly impact student achievement. The purpose of SCSR was to raise the science literacy of the student population by providing a challenging course of study in which the core sciences of (a) Physics, (b) Chemistry, and (c) Biology were science subjects required of all students for graduation. This P-C-B sequence was adopted in response to Lederman (ARISE, 2002) who advanced the need for reform in the order in which high school science subjects were taught. Driver and Simon (1998) recognized the need for variety in science instruction to sustain student interest in science but expressed doubt as to whether there existed a science teaching method that had universal appeal. A modeling physics approach for the instruction of Freshman Physics was selected as the teaching method that would have the greatest appeal to ninth grade students. Teachers were selected who enthusiastically embraced the modeling physics methodology and who were willing to make the necessary modifications that were appropriate for instructing ninth grade students. The enthusiasm of SCSR teachers for this instructional methodology conformed to Woolnough's (1994) observation that inspirational influence of teachers and the active involvement of students in science were effective factors that encouraged student interest in science. Each of these studies examined a different science attitude factor, each of which were connected to SCSR.

This particular research study focused on student attitudes which resulted from the whole influence of SCSR. The data gained from the TOSRA2 Pretest and Posttest changes in mean subscale values at each grade level and from the teacher interviews allowed for the individual factors that affected student's attitudes toward science to be examined independently of each other. Through the examination of TOSRA2 Pretest and Posttest mean subscale value data of individual subscales and teacher interviews, solutions offered by other research that addressed those topics that were related to the attitude subscales could be identified and considered for future adoption. For example, the work of Driver and Simon (1998) may have held answers to determine what science instructional methodologies would be most effective to the most students. Woolnough's (1994) work could have provided options that would possibly increased students' leisure interest in science. The research of Munro and Elsom (2000) provided observations that students were more inclined to take science courses when they learned that science was needed for a particular career that interested them. This data could lead to the development of science interest activities and the selection of the kinds of science electives to be offered.

Recommendations for Future Research

The purpose of SCSR was to improve science literacy for all students but it was not known if it would come at the expense of students' attitudes toward science resulting in unwanted negative consequences. The data obtained from this research study suggested that the Science Core Sequence Reform, as evidenced by the change in students' attitudes, did not have an overall negative impact resulting from this departure from the traditional science instruction that students would otherwise have received. The real impact of the SCSR should be decided through the examination of the results of students on future achievement tests. These results would provide the best indication of whether the goal of SCSR, to increase science literacy in all students, had been successful. The results of achievement tests could then be examined in light of the results of this study to identify possible relationships that might exist between students' attitudes and their achievement in science. This study provided the first step to determine what relationships existed between student attitudes toward science and their science achievement.

In the future this research could be validated by being carried out at different high school venues that had adopted a program of science studies in which the physics to chemistry to biology sequence was the centerpiece. Future research in students' attitudes toward science may find common experience in the same factors that produced attitude changes. In all existing and proposed P-C-B sequences, attention should be given to the alignment of the adopted program of studies with No Child Left Behind regulations and state mandated science standards.

An area of widespread concern was the decline in women involved in the various fields of science (Greenfield, 1996; Taber, 1992). Future research could target female populations in high schools for the purpose of identifying those attitudes that reflect a disinterest among young women toward science. Once those attitudes that reflected disinterest were identified, measures could be taken to address the concern through curriculum modifications.

This research study did not presume to insist that there was only one way in which data could be obtained. Future research that followed could possibly be effective in obtaining data related to (a) personal relevancy, (b) post-high school education plans, and (c) career pursuits.

Conclusion

The Science Core Sequence Reform was the initiative of a high school science department and the administration of that school district to bring about a program of science instruction that would raise the level of science literacy among all high school students. This initiative was developed in response to multiple calls for more stringent standards in science to be implemented. Strengths that were evident with this program were that students had a greater appreciation for science in society and the role of scientists in it. Students also seemed to have a greater enjoyment of science lessons. The attitudes of students toward science at each of the four grade levels, if considered collectively, remained stable.

The study revealed that student attitudes toward science had remained somewhat positive throughout the Science Core Sequence Reform. Among science attitude subscales that were related to relevancy and personal interest between the TOSRA2 Pretest and Posttest, there was an attitude increase toward science. The relatively high student enrollment in non-core science electives such as Astronomy and Forensic Science lent support to this observation. Career interest and career related subscale differences between pretest and posttest results showed that student attitudes toward pursuing science as a career declined. The need to emphasize career education was underscored by teachers who perceived a need to address career related issues in the classroom.

It must be emphasized that with the implementation of SCSR, the sequence of the core sciences that included (a) Physics, (b) Chemistry, and (c) Biology was required of all students. Since the data showed that the average attitude toward science of the seven mean subscale scores in each of the four classes remained nearly unchanged, the SCSR could be considered to have been successful in its goal to raise the level of science literacy in all students. Since the reform included students who might never have had an interest in taking a core science subject such as Physics or Chemistry, their dispositions toward science may have contributed to the decline in career related subscale scores.

A characteristic of the SCSR was its adoption of instructional methodologies, especially in Freshman Physics, which promoted multiple forms of scientific inquiry and critical thinking skills. This approach offered students an in-depth science experience in fewer science topics, differing from comprehensive approaches that included more science topics with less in-depth experiences in scientific inquiry for the students. The question as to whether the SCSR raised the level of science literacy among science students can not be known until students have been administered a science achievement test. Only then could the results of this study be correlated to the results of the achievement test which would be an indication of the effectiveness of the SCSR on student achievement in science. The possibility exists that the results of a science achievement test would be different from the attitude results of this research study.

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Appendices A (partial), D, K, and L are included here. For other appendices, please contact the author.

Appendix A: Test of Science-Related Attitudes (Note: 35 questions are included. Only the first three are printed here, because permission hasn't been granted to Arizona State University to post them. Please contact the author for further information.)

TOSRA2 Pretest and TOSRA2 Posttest

1. Money spent on science is well worth spending.
2. Scientists usually like to go to their laboratories when they have a day off.
3. I would rather find out why something happens by doing an experiment than by being told how it works.

Appendix D: Teacher Interview Protocol

Teacher (A, B, etc.),

1. Did you have a role in the start up of the Science Core Sequence Reform (SCSR) at this school? If so, please describe that role.
2. Please describe your educational and professional background.
3. How many total years of science teaching experience do your have?
4. Describe your present role in the implementation of the SCSR at this school.
5. Did you prepare for this role in any special way? If so, describe in what way or ways?
6. Please describe your present responsibility and involvement in the SCSR.
7. How would you describe your initial response to the SCSR concept when it was first proposed?
8. In what ways were you pleased with the response of your students to your science course(s) of instruction as it eventually became affected by the SCSR?
9. In what ways were you disappointed with the response of students to your science course(s) of instruction when it became affected by the SCSR?
10. What unexpected observations did you make that were the result of the implementation of SCSR?
11. In terms of academic challenge, describe any significant effect that the required science core subjects of freshman physics, chemistry, and biology has had on your students.
12. In general, how have your students' attitudes towards science under SCSR been affected?
13. In general, how has the behavior of your students under SCSR been affected?
14. In general, how has the achievement of your students under SCSR been affected?
15. Is the Science Core Sequence Reform concept compatible with your philosophy of science education in general and with your method(s) of instruction in particular?
16. What measures would create a more positive attitude in students toward science?

Appendix K: “The District” High School: 2005-2006 Program of Studies in Science

SCIENCE

Science and technology are the most rapidly advancing fields of study in the twenty-first century. To prepare students to meet the challenge, *all students are required to take three years of science: Freshman Physics (9th grade), Chemistry (10th grade), and Biology (11th grade). Exploration of these basic sciences will provide all students with a strong foundation for the study of elective sciences in senior year. Computers, graphing calculators. and other technology are integrated for data gathering and analysis. Because mathematical reasoning is an integral part of any modern science course, the appropriate* ***math prerequisites*** *are listed for each course. Several exciting new electives offered this year will deepen the student’s understanding of one of the four major science disciplines, or, in and interdisciplinary science, build connections among the sciences he or she has studied as an underclassman.*

FRESHMAN PHYSICS HONORS – 1 credit (301) Weighted
FRESHMAN PHYSICS – 1 credit (302)

Welcome to the fun and exciting world of physics! Freshman Physics is the first science course for all students at “The District” High School. Physics provides a systematic understanding of the fundamental laws that govern our world and provides the basis for the chemical and biological processes that will be studied in sophomore and junior year. Because physics concepts are easily observable and measurable with simple apparatus, students will have the opportunity to design their own experiments and gain direct experience in the scientific process as they discover the laws of physics. The labs are equipped with up-to-date technology to help students collect and analyze data easily and accurately. Course topics will include uniform motion, uniformly accelerated motion, Newton’ laws, conservation of energy , circuits, and electrostatics.

Because physics also offers a natural context for the development of analytical and mathematical reasoning skills, registration in honors and academic physics is directly correlated with mathematics preparation and registration. Students enrolled in Geometry will take honors Freshman Physics; students enrolled in Algebra will take academic Freshman Physics.

SOPHOMORE CHEMISTRY HONORS – 1 credit (311) Weighted
Recommendation Minimum grade “C” in Freshman Physics Honors and teacher recommendation.

Honors courses are fast-paced and challenging requiring independence and initiative on the part of [sic] the student.

SOPHMORE CHEMISTRY – 1 credit (312)

This is an introductory, hand-on course designed to provide the student wih a good foundation in chemistry for future study in the biological, environmental, and medical sciences as well as chemical technology and other related fields. The course develops the model of the atom from an historical perspective and studies the relationship of the periodic properties of the elements to modern atomic theory. Topics studied include chemical reactions, formulas and equations, the mole concept, chemical bonding, molecular structure, acids and bases, and nuclear chemistry. In the laboratory, students will learn to design and perform experiments in a safe and efficient manner. Oral and written communication skills will be emphasized.

BIOLOGY AP SEMESTERS I AND II – 2 credits (341, 342) Weighted

Recommendation:
1. **Minimum grade "B" in Honors Chemistry**
2. **Teacher recommendation**

Note: Semester II will be open to seniors who took Honors Biology in 2004-2005.

Motivated students will experience the challenge of a college-level biology course while still in high school. This course is strongly recommended for any student intending to pursue a science major in college or a medical related career. Units determined by the College Board include molecules and cells, genetics, biotechnology, evolution, populations, plant and animal (human) physiology, and ecology. Twelve required quantitative labs will be supplemented with many additional lab experiences including dissection. Students will be expected to read and organize textbook material on their own so that the class period can be devoted to concept clarification, activities and laboratory experience. Written expression will be emphasized in essays and lab reports in preparation for the AP exam.

JUNIOR BIOLOGY – 1 credit (343)

Biology is the study of living things and their environment. Students will investigate cells as the basic unit of living things, including the biochemistry of cell structure and metabolism, the role of DNA in cell function, how cells reproduce themselves, differentiate, and ultimately organize into complex organisms. Students will explore evolution, genetics, the physiology of mammalian systems, and ecology. Lab experiences include dissection of a cat and current biotechnology research techniques.

ASTRONOMY: Grades 11-12 – 1 credit (345)

Astronomy is the oldest of the natural sciences, deeply rooted in the history of almost every society. People have always stared at the sky in wonder at how the universe works ad used their observations for timekeeping, marking the seasons, and navigation.

Modern astronomy continues to explore the origin of stars, planets, and life itself. Continually advancing technology reveals a universe that is vas, varied, and beautiful, and promotes curiosity, imagination, and a sense of shared exploration and discovery. Out exploration of astronomy will include topics such as the earth and the moon, the solar system, stars, galaxies, origins of the universe, and tools of astronomers. Come develop your understanding and enjoy a lifelong interest.

CHEMISTRY II: Grades 11-12 – 1 credit (313)

This course serves as a second year of chemistry to follow sophomore chemistry for students who want to explore additional topics in chemistry as well as learn first-year topics in more depth. The course will encourage students to inquire and make connections to biochemical, environmental and industrial concerns as they study organic chemistry, thermochemistry, reaction rates, oxidation and reduction, and electrochemistry. The course would benefit any student who is interested in real-world chemistry or wants additional preparation for college chemistry.

ADVANCED PLACEMENT CHEMISTRY: SEMESTERS 1 and 2 – Grades 11-12 – 2 credits (314) Weighted

Recommendations: A or B in Honors Chemistry, successful completion of Algebra II, teacher recommendation.

AP Chemistry is designed for motivated students interested in the challenge of a first year college general chemistry course. The course integrates conceptual understanding with significant quantitative analysis. Students will deepen their understanding of chemical phenomena and improve their ability to think and solve chemical problems. In accordance with College Board syllabus, topics include atomic theory, atomic structure, chemical bonding, molecular models, nuclear chemistry, kinetic-molecular theory, liquids and solids, solutions, reaction types, stoichiometry, equilibrium, kinetics, thermodynamics, descriptive chemistry, electrochemistry and organic chemistry. Emphasis will be placed on development of laboratory skills, and oral and written communication of experimental results. Due to the extensive amount of material to be covered, students will be expected to keep up to date on all assignments and come to class well prepared. High scores on the AP exam may result in earning as many as eight college credits.

ADVANCED PLACEMENT PHYSICS: SEMESTERS 1 and 2 – Grade 12 – 2 credits (331) Weighted

Recommendation: Concurrent enrollment in Calculus or higher

Physics AP will expand upon topics first seen in Freshman Physics, such as kinematics, dynamics, forces and energy. As determined by the College Board, topics also include the work-energy theorem, momentum, rotation, gravitational field and forces, conservation laws, rigid bodies and equilibrium.

This will prepare students for the AP Physics-C Mechanics exam. In addition, electricity will be explored as an introduction to an in-depth unit on light, including particle, wave and photon models. Students will develop advanced lab and problem solving skills that require the use of calculus. This course is strongly recommended for students pursuing engineering or science majors in college.

ACADEMIC PHYSICS: Grades 11-12 – credit (322)

Recommendation: Concurrent enrollment in Math Analysis or Pre-Calculus

Physics Academic is a second year of physics for students who want to explore a deeper understanding of force and motion using math skills acquired since the freshman year. Additional topics include electricity and magnetism, mechanical waves, and light. Emphasis will be placed on laboratory skills and problem solving. This course would benefit any student who is interested in real-world physics or wants additional preparation for college physics.

HUMAN ANATOMY AND PHYSIOLOGY: Grade 12 – 1 credit (344)

Anatomy and physiology is a study of the relationship between body structures and their functions. Students with a strong interest in health and learning how the body functions will benefit from this challenging course. The course is strongly recommended as an essential introduction and foundation for any student considering health-related or physical education related careers. An emphasis on hands-on learning using models and activities helps students develop an in-depth understanding of the skin, bone, muscle, digestive, respiratory, nervous, cardiovascular and excretory systems. Additional systems will be covered as time permits.

FORENSIC SCIENCE: Grade 12- 1 credit (346)

Forensic Science is the application of science knowledge and technology for the enforcement of laws. Because forensics is an integrated science requiring background knowledge in earth science, physics, chemistry, and biology, the course is open to seniors who have completed these required courses. Students will further develop the laboratory and analytical skills by investigating case studies involving toxicology, entomology, physiology, pathology, ballistics, accident reconstruction, geology and the instrumental analysis of hair, fiber and DNA.

ANIMAL SCIENCE I: Grades 10-12 – 1 credit (652)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science)

Animal Science is a course in which students will learn the basics of animal husbandry and production, and learn about PA’s animal industry. Students will be given hands on opportunities by assisting in the care and management of the school’s small animals. Units on horses and livestock and small animals such rabbits and dogs will be covered in this class. Anatomy and physiology of domestic animals will be covered in this class. Careers in the animal industry as well as animal food product so will also be covered in this class. Basic record keeping will be included and students will be required to complete a record. FFA membership will be open to anyone taking this class.

ANIMAL SCIENCE II: Grades 11-12 – 1 credit (653)
Prerequisites: Agriculture Science I (previously called Environmental Agriculture Science) and Animal Science I

Animal Science II is designed to be a continuation of Animal Science I. Students will be responsible for the care and management of the school’s animals. Units in hors / equine science will be covered in greater depth than in Animal Science I, as well as units in small animals, animal nutrition and reproduction. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to anyone taking this class.

HORTICULTURAL SCIENCE I: Grades 10-12 – 1 credit (663)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science)

Students will learn the basics of greenhouse and nursery management. Students will assist in the production and care of the school’s greenhouse and nursery plants. Students will learn the basics of landscape design, as well as care and maintenance of common landscape and nursery plants. Basic record keeping will be included and students will be required to complete a record. FFA membership will be open to any taking this class.

HORTICULTURAL SCIENCE II: Grades 11-12 – 1 credit (664)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science) and Horticulture I

Horticulture II is designed as a continuation of Horticulture I. Students will be responsible for the management of the school's greenhouse and plants. Units in landscape design and floriculture will be covered in this class. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to any taking this class.

NATURAL RESOURCES MANAGEMENT I: Grades 10-12 – 1 credit (600)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science)

This course emphasizes careers in forestry, wildlife management and conservation. Students will learn tree identification, the basics of tree production, wildlife management, and conservation. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to any taking this class.

NATURAL RESOURCES MANAGEMENT II: Grades 10-12 – 1 credit (601)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science) and Natural Resources Management I.

This class will be primarily an individualized, independent study program that will be cooperatively planned and agreed upon by both the teacher and student. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to any taking this class.

AQUACULTURE I: Grades 10-12 – 1 credit (668)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science)

Students will study the basics of aquaculture and aquatic organisms. Students will design and operate aquaculture systems in the aquaculture room. Students will learn the biology of fish and other aquatic organisms. Students will also learn identification and habits of the common fish of PA and other aquatic organisms. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to any taking this class.

AQUACULTURE II: Grades 10-12 – 1 credit (669)
Prerequisite: Agriculture Science I (previously called Environmental Agriculture Science) and Aquaculture I.

This class will be primarily an individualized, independent study program that will be cooperatively planned and agreed upon by both the teacher and the student. Basic record keeping will be included and students will be required to complete a record book. FFA membership will be open to any taking this class. ("The District" High School, 2005, pp. 12-14)

Appendix L: High School Science Required and Core Course Registrations

Pre Assignment for 1997-1998 - Compiled 4/27/97

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
E&S - Honors	56	56			
E&S – CP	109	109			
E&S – C	30	30			
Biology - Honors	32		32		
Biology – CP	111		111		
Biology – C	68		68		
Chemistry – Honors	19			19	
Chemistry – CP	66			66	
Physics – Honors	12				12
Physics – CP	64				64
AP Biology	11			*	*
Biology II	30			*	*
Human A&P	22			*	*
TOTAL	630	195	211	*	*

Key – E&S (Earth and Space Science) Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

* Number of students is not known.

High School Science Required and Core Course Registrations

Pre Assignment for 1998-1999 - Compiled 5/4/98

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
E&S - Honors	82	82			
E&S – CP	122	122			
E&S – C	14	14			
Biology - Honors	40		40		
Biology – CP	89		89		
Biology – C	74		72	1	1
Chemistry – Honors	26			26	
Chemistry – CP	102		1	92	9
Physics – Honors	9				9

Physics – CP	49				49
AP Biology	15		1	1	13
Biology II	23		1	16	6
Human A&P	17			7	10
TOTAL	662	218	204	143	97

Key – E&S (Earth and Space Science)   Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

High School Science Required and Core Course Registrations

Pre Assignment for 1999-2000 - Compiled Spring 1999

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
E&S - Honors	58	58			
E&S – CP	128	128			
E&S – C	45	45			
Biology - Honors	28		28		
Biology – CP	129		129		
Bio – Applied	66		66		
Chemistry – Honors	19			19	
Chemistry – CP	71			71	
Physics – Honors	28			*	*
Physics – CP	49			*	*
AP Biology	4			*	*
Biology II	38			*	*
Human A&P	17			*	*
TOTAL	680	231	233		

Key – E&S (Earth and Space Science)   Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

* Number of students is not known.

High School Science Required and Core Course Registrations

Pre Assignment for 2000-2001 - Compiled 4/25/00

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
E&S - Honors	*	*			
E&S – CP	*	*			
E&S – C	*	*			
Biology - Honors	43		43		
Biology – CP	116		116		
Bio - Applied	57		57	1	
Chemistry – Honors	37			36	1
Chemistry – CP	101			93	8
Physics – Honors	13				13
Physics – CP	48				48
AP Biology	14			2	12
Biology II	40		2	26	12
Human A&P	11			1	10
TOTAL	732	251	218	159	104

Key – E&S (Earth and Space Science) Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

* Number of students is not known.

High School Science Required and Core Course Registrations

Pre Assignment for 2001-2002 - Compiled 4/9/01

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
E&S - Honors	57	57			
E&S – CP	128	128			
E&S – C	48	48			
Biology - Honors	39		39		
Biology – CP	147		147		
Bio – Applied	67		67		
Chemistry – Honors	30			30	
Chemistry – CP	107			107	

Physics – Honors	24			24	
Physics – CP	39			1	38
AP Biology	14			1	13
Biology II	39		4	20	15
Human A&P	36		1	19	16
TOTAL	775	233	258	202	82

Key – E&S (Earth and Space Science) Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

High School Science Required and Core Course Registrations

Pre Assignment for 2002-2003 - Compiled 4/17/02

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
Fr. Physics - Honors	64	64			
Fr. Physics – CP	117	117			
Fr. Physics – C	58	58			
Biology - Honors	42		42		
Biology – CP	134		134		
Biology - Applied	60		60		
Chemistry – Honors	33			33	
Chemistry – CP	130			130	
Chemistry - Applied	25			25	
Physics – Honors	26				26
Physics – CP	50				50
AP Biology	18			1	17
Biology II	37		1	20	16
Human A&P	38		1	20	17
TOTAL	832	239	238	229	126

Key – ***Human A&P*** (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

Black bar separates the SCSR from traditional science sequence classes.

High School Science Core Course Registrations

Pre Assignment for 2003-2004 - Compiled 6/13/03

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
Fr. Physics - Honors	75	75			
Fr. Physics – CP	119	119			
Fr. Physics – C	66	66			
Biology - Honors	51		51		
Biology – CP	131		131		
Biology - Applied	61		61		
Chemistry – Honors	49			49	
Chemistry – CP	117			117	
Chemistry - Applied	46			46	
Physics – Honors	18				18
Physics – CP	45				45
AP Biology	6			2	4
Biology II	51		1	27	23
Human A&P	58		2	26	30
TOTAL	893	260	246	267	120

Key – ***Human A&P*** (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

Black bar separates the SCSR and traditional science sequence classes.

High School Science Core Course Registrations

Pre Assignment for 2004-2005 - Compiled Spring 2004

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
Fr. Physics - Honors	104	104			
Fr. Physics – Academic	210	210			
Chemistry – Honors	63		63		
Chemistry- Academic	220		220		
Biology - Honors	67			67	
Biology – Academic	149			149	
Physics – H	30			*	30
Physics – CP	42			*	42
AP Biology	16			*	16

Human A&P	26			*	26
TOTAL	927	314	283	216	114

Key – ***Human A&P*** (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

* Numbers in the 12th grade column represent both 11th and 12th grade students although the greater majority are 12th grade students

The vertical, black bar separates the SCSR and traditional science sequence classes.

High School Science Core Course Registrations

Pre Assignment for 2005-2006 Compiled 4/27/05

Course	Total	Grade 9	Grade 10	Grade 11	Grade 12
Fr. Physics - Honors	175	175			
Fr. Physics –Academic	127	123	2	1	1
Chemistry – Honors	106		104	2	
Chemistry – Academic	190		177	7	6
AP Biology Semester 1	54			46	8
AP Biology – Semester 2	54			46	8
Biology – Academic	213			204	9
AP Chemistry Semester 2	13			4	9
AP Chemistry Semester 2	13			4	9
Chemistry II	20			11	9
AP Physics Semester 1	13				13
AP Physics Semester 2	13				13
Human A&P	30			1	29
TOTAL	1021	298	283	326	114

Key – E&S (Earth and Space Science) Required Course

Human A&P (Human Anatomy & Physiology)

Bold – Core Science Courses

Italics – Core Science Electives

The vertical, black bar separates the SCSR and traditional science sequence classes.