A case study of the impact of a reformed science curriculum on student attitudes and learning in a secondary physics classroom

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For my wife, my sons, and my parents.
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Abstract
A Case Study of the Impact of a Reformed Science Curriculum on Student Attitudes and Learning in a Secondary Physics Classroom
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This case study examined the impact of the application of an inquiry-based concept related physics curriculum on student attitudes and learning in a secondary physics classroom in southern New Jersey. Students who had previously used a traditional physics curriculum were presented with a 10 week inquiry-based concept related physics curriculum on electricity and magnetism. The study utilized observations, a pre/post attitudinal survey, interviews of students and teachers about their perceptions of the inquiry-based curriculum, and artifact analysis of student work. The results showed a positive change in students’ attitude in four of the eight categories designated in the CLASS survey. The observations, interviews and artifact analysis revealed that students were more engaged in learning physics through their discoveries in relating physics concepts to real world applications, a growing personal interest in the value and relevance of science learning and a disconnect between the students’ and teacher’s perceptions about what is important in learning physics. The study recommends that the rigidity of a traditional physics curriculum with its emphasis on covering many topics and the mathematical language of physics should give way to more inquiry-based concept related curriculum that incorporates exploration, hands-on inquiry activities, and real world connections. The research supports that better efforts be made to familiarize
current and future secondary physics educators with the body of research that establishes the benefits of inquiry-based concept related curriculum on physics students.
CHAPTER 1: INTRODUCTION

The Problem and Its Context

The rigidity of the current curriculum sequence of most high school physics classes calls for a multitude of topics to be covered throughout the school year with little time available to incorporate concept related, inquiry-based teaching practices. In typical high school physics textbooks, this multitude of topics can comprise thirty-seven chapters of information; in physics topical terms, this corresponds to everything including matter, motion, energy, heat, gravity, relativity, light, waves, optics, electricity, magnetism, reactivity, and modern nuclear physics (Hewitt, 2006). In a typical high school classroom this material is taught as a teacher directed activity, one in which students are exposed to material through lecture; cookbook laboratories, and drill-and-practice problem sets (Mee-Kyeong, & Erdogan, 2007). Ministrel and Krauss (2005) discuss the benefits of inquiry-based instruction on student attitude and learning. Reid and Skryabina (2002) documented a falloff in interest and enrollment as students approached traditionally formatted physics curricula and Schwartz and White (2005) found that, “A model centered approach to science education…can be effective in teaching students about…inquiry and physics” (p. 201). Also Mee-Keyong Lee and Ibrahim Erdogan (2007) found that when teachers utilized the practices of connecting material in physics to technology and society, students showed significant improvements in the development of not only more positive attitudes but in their creativity skills as well. All of these studies point directly to the positive impact concept related, inquiry-based physics teaching practices can have on student learning and attitudes. According to the current
literature in physics education in both the United States and abroad, the need for the adoption of more inquiry-based, concept related teaching practices seem readily apparent.

The Trends in International Mathematics and Science Study’s (TIMSS) criticism of the typical American school curriculum in 1993 was that it was a "mile wide and an inch deep" (Gibson & Rea-Ramirez, 2002). While the findings from the TIMSS study have been challenged by many in the U.S. educational system due to issues of comparability and parity among testing groups, what remains true is that, “Too often students engage in futile lessons that attempt to teach difficult concepts in too short a time or in classes that substitute facts and vocabulary for in-depth understanding” (Nelson, 2001, p. 15). When doing so, these classrooms have failed to adopt inquiry-based concept related teaching practices.

It is under no dispute that the passing of national legislation, such as the No Child Left Behind Act, requires regular testing in schools, and the adoption by many states of standards in science that have placed a continuing burden on the classroom teachers. “We are facing what some would call a crisis in coverage…teaching the content in those documents would require 71 percent more instructional time than is now available” (Marzano et al., 2005, p. 83). When teachers are under pressure to cover vast amounts of material within a limited time frame, many teachers revert to traditional teaching practice, or when science standards are not required by the state, reduce the time of science instruction altogether. While the current system has been in existence for almost a hundred years, its effectiveness at encouraging learning and promoting positive attitudes about physics, in particular, has been called into question by the research conducted in secondary students’ attitudes toward physics and their ability to problem
solve and apply physics concepts outside of the physics classroom. (Sheppard and Robbins, 2003)

Thomas Friedman, a noted columnist for the New York Times and bestselling author, helped to identify the effects that emerging technologies are having on the United States. “We're in a quiet crisis where we are not producing the math and science...talent we need” (Friedman, 2006, p. 261). In his book, the *World is Flat*, Friedman touches on the economic impact of the declining numbers of students in the United States that are pursuing careers in math, science and engineering in our increasingly global economy. With 21st century innovations, the very nature of delivering knowledge and content to students needs to be revisited. For Friedman, the traditional teaching practices that attribute to the small amounts of students pursuing scientific careers reaches beyond the classroom and begins to affect the society as a whole.

Schools such as the Massachusetts Institute of Technology and California Institute of Technology have created state-of-the-art digital classrooms that challenge traditional teaching practices and the notions of teacher-directed learning (Brown, 2005). These inquiry-based classrooms allow students to apply concepts of physics and mathematics to themselves and the world around them in a very non-traditional classroom setting and in non-traditional ways. The schools attribute the success of these new learning environments to the willingness of teachers and students to embrace more inquiry-based concept related learning (Brown, 2005). This was done in an effort to engage our brightest students in the advancement of new knowledge. Whether it is a failure to acknowledge the benefits of these new practices by physics teachers around the country
or their ignorance of them, continuing to teach solely in traditional ways can have profound implications for our society.

In 2003 the Business Roundtable concluded that because of the declining interest and ability by American students, industry has been forced to rely on foreign nationals to fill the demand for jobs that require strong fundamental education in science, technology, engineering and mathematics (Business Roundtable, 2003). In 2006 the National Summit on Competitiveness and Innovation encouraged the adoption of several tasks in order to preserve America’s leadership in the global community. The first task set out a long-term commitment to increasing the amount of basic research with a focus on the physical sciences, engineering, and mathematics with the second focus on doubling the number of college degrees awarded to U.S. students in science, math, and engineering. This comes as the report notes that, “U.S. 12th-grade students recently performed below the international average of 21 countries on a test of general knowledge of mathematics and science… [with a] pipeline of science and engineering talent [that] is contracting, not expanding” (Competitiveness, 2006, p 8). Clearly an increase in the amount of basic research in physics and engineering will require more students pursuing these subjects.
In evaluating our current system of traditional instruction we can see from various assessments that it has not placed U.S. students in the lead among their international peers. In 2007, the Program for International Student Assessment (PISA), in conjunction with the U.S. Department of Education, released their report on the performance of American 15-year-olds in Science and Mathematics literacy in an international context.

![PISA Results for the 30 Countries that fall under Organization for Economic Cooperation and Development (OECD) jurisdiction](image)

Figure 1- PISA Results 2006 (Badi et al., 2007) in color.

These results are important since curriculum and teaching practices in the United States differ from those of many of the countries on the list. The students from the United States fall below the average scores of 21 other countries in their combined and specific category scores for scientific literacy (Badi et al., 2007). Now, some critics of the use of international studies for comparison, such as Berliner and Biddle (1995), cite issues of equivalency among the quality of students as a problem with comparison. Since the
United States has compulsory education for all fifteen-year-old students and seeks to retain those students through secondary school as much as possible, their argument centers on the notion that not all countries participating operate under these restrictions: thus, the U.S. sample contains many more average or lower achieving students that may not be part of the educational systems in the comparison countries. Badi et al. (2007) address this criticism by identifying six levels of Science proficiency within the test.

“In combined science literacy in 2006, six of the other 56 jurisdictions… had a higher percentage of students at level 6 than the United States … In contrast, 19 jurisdictions had a higher percentage of students below level 1 than the United States … Nineteen jurisdictions … also had a higher percentage of students at level 1 than the United States” (p.21).

Figure 2- Percentage Distribution on PISA 2006. In color
What is clear from the PISA data is that while American students in general are ranked at or slightly below other nations in the world with regard to Science literacy, when looking at even our best students, Americans are ranked behind five other countries. With our lowest achieving students, only 19 of the 56 countries had students performing lower than those in the U.S. What is not in dispute with these findings is the acknowledgement by countries such as the United Kingdom that their traditional curricula and practices with regard to science education were in need of revision toward more inquiry-based, concept related curriculum (Murphy et al., 2006).

Another indicator for how students in the United States are performing in science is the National Assessment of Educational Progress (NAEP). The test began assessing science performance in 1996 and has been administered two other times, 2000 and 2005, since then. “Performance of the nation’s twelfth-graders in 2005 was unchanged from 2000; however, it was lower than that in 1996. This was true for both overall scores and scores for Earth, physical, and life sciences” (NCES, 2005). The concern raised here in the NAEP performance is not only a lack of growth seen in the performance of twelfth grade students, but a decline since 1996.

Many secondary physics curricula have over the course of the past fifty years attempted to address the issues of science literacy and student performance; however, none of the reform initiatives undertaken in recent years to address performance and attitudes in secondary physics have taken hold on a national or even regional level. While no direct studies have specifically addressed secondary physics curricula reform, influences from politics (Berliner & Biddle, 1995), as well as the direct impact of
teachers (Haussler and Hoffman, 2000; Sadler & Tai, 2001; Seidel & Prenzel, 2006) and
administrators (Marzano et al., 2005) have all contributed greatly to the stagnation of
reform efforts and the continued traditional practices.

Current high school physics textbooks and programs attempt to cover large
amounts of material in a given school year. As Sadler and Tai revealed in their study of
the success of high school physics students at the college level, “deferring to a textbook
for the structure and pace of a high school course was not supported as a viable strategy
for success” (Sadler & Tai, 2001). The result that some students tend to view physics and
science in general in a negative way could be a consequence of this practice. This
negativity, in turn, reduces the number of students who pursue further study in physics
and engineering, further serving to jeopardize the United States’ key role as a leader in
scientific and technological development.

Haussler and Hoffman (2000) performed a meta-analysis of several studies of
physics teaching and curriculum, finding that concept related curricula and teaching
practices created more positive attitudes among students. The data strongly suggested
that physics be taught in such a way that students have a chance to develop a positive
physics-related self-concept and to link physics with situations they encounter outside the
classroom. A curriculum based on these principles proved superior compared to a
traditional curriculum. Students were able to form stronger connections to the material
and create more meaningful learning. “We conclude that the most promising way of
making physics instruction more interesting is by embedding a given content in an
interesting context” (p. 697). Their research is clear about the benefits of using a concept
related, inquiry-based curriculum for secondary physics study and its ability to promote positive student attitudes and better understanding.

Others have come to a similar conclusion about the necessity of inquiry-based teaching practices. Duran et al. (2004) proposed changing the way students learn physics by adopting a more constructivist, inquiry-based model for teaching undergraduate pre-service physics teachers, finding that once students were able overcome their initial resistance, “They felt the inquiry method not only helped them to understand the physics concepts, but also better prepared them to teach these concepts to their future students” (p.165). George (2006) examined how students’ interest in science dropped off dramatically as they progressed through their schooling. He attributed this phenomenon, in part, to the type of science course being offered and the format it takes.

What is lacking from the literature is any sense of why these curricula and teaching practices have had only mild penetration within the U.S. secondary physics community. It may be partly due to teacher hesitations or difficulties (Davis, 2003; George, 2006; Pinto, 2005), the problems that can occur when implementing new curricula or practices (Davis 2003; Donahue, 1993; Feldman & Kropf, 1999; Goodnough, 2006; Haussler and Hoffmann, 2000; Neuschatz & McFarling, 1999) as well as the adoption method of new methodologies (Clark, 2005; Espinoza, 2004; Henderson et al., 2008).

The proposed study would serve to begin to address this gap in the literature by performing a case study of the implementation of one of these inquiry-based, concept related physics curricula. This study will begin by surveying the students in a traditional physics course. This data will establish a baseline by which students’ changes in attitude
and understanding can be measured. The study will then utilize an inquiry-based concept related curriculum that utilizes resources developed and tested in the United Kingdom for use in introductory physics curricula. This treatment will take the traditionally difficult physics topics of Electricity and Magnetism, and by using an inquiry-based concept related approach, make the content more relatable to the students. This curriculum is unique in that it approaches the topics from the perspective of real world applications, specifically electricity power and generation and the social issues associated with them in our culture. At the conclusion of the unit the attitude survey will then be re-administered. The researcher will also conduct an in-depth interview with the teacher. After analyzing the survey results and comparing those to the pre-treatment administration, interviews with 4 purposefully selected students (representing the greatest and least change over the course of the treatment) and 6-8 randomly selected students from the class will occur. The purpose of these interviews will be to clarify and gather information as to the most dramatic changes in attitude that resulted over the course of the unit. Through this study the researcher strives to gain important insight into the teachers’ perceptions of the efficacy of inquiry-based, concept related teaching and the students’ reactions to this methodology.

**Purpose of the Study**

The proposed study seeks to gain insight into secondary physics classrooms by looking at the most direct practitioners of physics education, the secondary physics teachers and their students. By interviewing these individuals, the researcher hopes to can gain insight into the teaching and learning that occurs. Since every reform initiative must eventually be implemented by classroom teachers and experienced by the students,
it is essential to speak directly with those individuals and delve into their processes and more importantly their perceptions.

The findings from this study could have direct applications for the development of new secondary physics curriculum. It could also shed light on the selection and implementation of existing secondary curriculum. The results could also benefit educational researchers, policy makers, curriculum directors, teachers, students and ultimately society in general. The data will also contribute to the literature surrounding the teaching and learning of physics at the secondary level. This study strives to provide important information for parents, teachers, policy makers and educators with regard to curriculum planning and implementation as well as to enlighten the educational community about the factors that are inhibiting the broad based adoption of these research supported practices.

The Research Question

The research question for this case study focuses on how the implementation of an inquiry approach in a traditional secondary physics classroom will alter the perceptions of the teacher and students toward physics education. In essence, how this concept related, inquiry-based, and culturally authentic curriculum will alter the students’ attitudes and perceptions of physics and how implementing such curriculum will affect the attitudes of the teacher. The research question for this case study is: What is the impact, in a secondary physics classroom, of an inquiry-based concept related physics curriculum’s effect on:

1. Attitudes of students toward physics;
2. Student’s application of physics knowledge;
3. The process of learning science;
4. The teacher’s perspective on teaching and learning physics.

**Definition of Terms**

**Concept related.** Barmby and Defty (2006) describes the concept related curriculum as one that relates to the learner within the context of his environment.

**Inquiry-based.** For the purposes of this study we will use the notion of scientific inquiry as defined by the National Science Foundation and the National Science Education Standards. These organizations define it as the ways in which scientists study the natural world and propose explanations broadly based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (Bransford et al., 2005). The abilities required of students to do scientific inquiry include the following: identifying and posing questions, designing and conducting investigations, analyzing data and evidence, using models and explanations, and communicating findings. Understandings include knowledge of how scientists conduct their work and concepts related to the nature of science. (Keys et. al, 2001)

**Problem Based Learning.** Based on the philosophy of constructivism established by Dewey (1938, 1944), Problem Based Learning (PBL) is a part of inquiry-based learning. PBL focuses on the individual construction of knowledge by providing students with experiential learning opportunities that focus on the investigation, explanation, and
resolution of a problem meaningful to them. These problems are defined in such a way such that they are realistic in nature and do not have a specific correct answer. The problem requires students to think and make interconnections (Dewey, 1944) among the topics of the course (Goodnough, 2006; Hmelo-Silver, 2004; Vernon & Blake, 1993).

**Professional Development.** For the purposes of this study, professional development is the process by which current teachers in a subject are exposed to new ideas in educational research. Typically this is done for a delineated period of time either on the premises of the school or at a local site. Short sessions at national or regional conventions will not be considered to be professional development.

**Secondary School.** Using the United States conventional school system as a model, secondary schools will be those designated public high schools with students in grades nine through twelve that offer physics on a yearly basis.

**Science–Technology–Society (STS)** is defined as the teaching and learning of science-technology in the context of human experience (Mee-Kyong & Erdogan, 2007).

**Delimitations**

In this study a teacher and students in a public high school located in southern New Jersey will be interviewed. This case study will be limited to the single teacher and the students with whom they interact with.
CHAPTER 2: REVIEW OF THE LITERATURE

This review of the literature will investigate the contexts and approaches to the teaching and learning of physics at the secondary level. It will begin with a brief discussion into the policies and practices that drive modern school systems in the United States. Then it will discuss the history that led to the traditional physics educational system currently in place, as well as a discussion as to the recent leveling and slight reversals in the decline of physics enrollment. Next a look at the teacher’s perspective and role in the implementation of physics curricula and their attitudes as instructors will be examined to help gain insight into the current process of curriculum adoption within the secondary physics classroom. The review will then discuss the effect of current curricula on student attitudes towards science in general, and physics in particular. The relationship between these attitudes and the studies that link them will be discussed. It will then also address what the implementation of concept related curricula has done to improve the overall numbers of students taking physics without jeopardizing their performance on traditional physics knowledge and problem solving assessments, thus, helping us to understand how studying the implementation of one of these curricula in a traditional physics classroom and discussing the results will add to the current body of literature.

Schools and Society

What modern high schools can be asked to do by the state, community, and local school boards can put tremendous stress onto the individual teacher in the classroom. Alarmingly, the amount of time spent on science education in the middle and elementary schools has declined as compared to previous years (Marzan et al, 2005). Standardized
testing has affected this time allotment dramatically. “One estimate is that in the state of New York, a student in a college-bound academic track will have taken twenty-nine state-mandated tests between kindergarten and the twelfth grade,” (Berliner & Biddle, 1995, p. 31). Typically proponents of such testing seek to address issues they see of ‘accountability’ as well as objective comparison between different school systems. These ideas culminated into the No Child Left Behind Act (NCLB). With its mandatory testing in grades 3 through 8 and once in high school, NCLB represents, for the faithful, the ultimate in ‘accountability.’ NCLB requires that all students be 100% proficient by 2014 (Amrein & Berliner, 2002; Berliner & Biddle, 1995; Nelson et al., 2007).

Contrary to what the proponents would have us believe, there are significant problems with the current standardized tests that are in use and with the mandates that students be given high stakes tests as graduation requirements. Testing changes the focus of schools away from traditional notions of knowledge and learning. “The proper goal of school learning is transfer of learning, that is, the application or use of what is learned in one domain…” (Amrein & Berliner, 2002) Standardized tests, however, do not assess this type of learning. “Far from improving education, high stakes testing marks a major retreat from fairness, from accuracy, from quality, and from equity” (Kohn, 2000).

Standardized testing programs discriminate against women, minorities, the disabled, and the poor while often failing to deliver the promises for objective scientific measurement or prediction of future ability. One proponent argues that, “the truth is that standardized tests are designed to promote fairness…when students take [them] they are all taking the same tests under the same conditions, and will be compared with students of similar age and years of schooling” (Nelson et al., 2007, p. 357). While the conditions of the test may
very well be standardized, what the students bring to the test is not. In truth, there is nothing scientific about the tests which suffer from vagueness, ambiguity, imprecision and bias (Nelson et al., 2007, p. 351).

Even more insidiously, these tests and the mandates that have accompanied them have forced a change in the curriculum methods and material taught in the schools. In Texas, high school teachers report that although teaching skills and drilling students have achieved gains in the scores on the state assessment test, many students cannot transfer those gains into actual class work. At the middle school level, teachers in Texas are also finding that due to the change to drill and skill techniques for reading and analyzing short passages for the state assessment, students are having trouble reading longer stories or novels as part of the curriculum (Amrein & Berliner, 2002).

Having curriculum focused only on the skills measured by the assessment leads to skill based instruction. “Skills based instruction, the kind and type to which most students…[are] subjected, tend to foster low-level uniformity and subvert academic potential,” (Kohn, 2000). This is supported by a recent study by the Center for Education Policy which states that, “the average change in instructional time in elementary schools since the law’s enactment has been 140 additional minutes per week for reading, 87 additional minutes per week for math, 76 fewer minutes per week for social studies, 75 fewer minutes for science (emphasis added), 57 fewer minutes for art, and 40 fewer minutes for gym” (McMurr, 2007). While the future of NCLB remains in the hands of the next President and Congress, what is clear is that lawmakers have indirectly created another obstacle to the implementation of science curricula by reducing the amount of time allocated for instruction in science before students reach high school. The problems
with this system, however, are systemic in nature. They have been present since the inception of the high school physics curriculum as can be seen when we examine a brief history of secondary physics curriculum.

**Historical**

In embarking on a study of physics curriculum it is important to establish the history and progression of the current curriculum in the United States as it has evolved over the past century. Doing so provides an understanding of the values entrenched in the current system and how little the current curriculum and practices have been based on educational research. Sheppard & Robbins (2003) examined the historical development of high school physics in the U.S. Their findings were grouped into several pertinent areas regarding the order of the science courses, enrollment, and time allocation.

![Figure 3](image-url)

Figure 3-From Sheppard & Robbins (2003) showing the percentage of student enrollment
in Physics, Biology, and Chemistry from 1890-1980. Sheppard examined documents from the late nineteenth century that began to establish the subjects that were thought to be most important and the time that should be allotted to each of them. Students have been branded with the creation of the Biology, Chemistry, Physics sequence since its creation in the 1890s, even though the actual recommendations did not list Biology and had Physics preceding Chemistry. By the mid-20th century, this sequence had been altered to put Physics at the end of the sequence. Concurrently, as evidenced in the Figure 3, provided by Sheppard and Robbins (2003), there was a steady decline in physics enrollment across the mid-20th century. This decline occurred even as the United States was engaged in technological race for space exploration and military superiority against the Soviet Union during the cold war. The focus of physics education at this time was on only the best and brightest students and used traditional lecture techniques with little emphasis on conceptual understanding.

David Donahue (1993) did a more comprehensive study of the period from 1930-1965. He noted that reforms began during the 1930’s; however, by the end of the decade little had changed. By 1940 secondary physics was still viewed as advanced study prep by most teachers and university physicists. The decrease in physics enrollment from 22% in 1890 to 5.4% in 1947 is dramatic, and even world events, such as Sputnik and the space race of the 1960’s, did little to alter the trend. Donahue concluded with the notion that physics education reforms require input from a variety of sources: university scientists, university educators, and secondary teachers and that during these periods of declining enrollment this type of consensus was neither utilized nor attempted. During the 1950s and 1960s, the university scientists were seen as the ones who knew best how
to teach physics. The movement of Physics to the end of the Biology-Chemistry-Physics sequence and its university imposed curriculum served to establish high school physics as a subject viewed to be very difficult and only for the best and brightest students.

This perception and the current enrollment trends began to reverse themselves in that late part of the 20th century. After the release of the Nation At Risk report in 1983 and its recommendations to increase the amount of science taken by high school students, the numbers of students taking physics steadily increased (Sheppard & Robbins, 2003). As pointed out by Michael Neuschatz (Neuschatz & McFurling, 1999), the percentage of seniors who have taken physics began a steady increase in 1980. Neuschatz attributes this rise in the percentage of seniors who have taken physics to the introduction of conceptual based physics curricula, allowing more students access to physics (American Institute of Physics, 2007).

While the increasing enrollment presented by Neuschatz (Neuschatz and McFurling,1999) is encouraging, when comparing Physics enrollment as a percentage of total enrollment, as done in Sheppard and Robbins (2003, 2005), these encouraging numbers quickly fade. Looking at Physics enrollment as a percentage of the total secondary enrollment, the growth virtually disappears. More students are taking physics than ever before, but there are more students in high school than ever before. These numbers come nowhere near the percentages of students who take other sciences or core courses, such as English or History. Neuschatz (American Institute of Physics, 2007) also points out that while our advanced science students performed on average with those students in the rest of the world, they are doing so having been crippled with an educational system that does not set Physics education as a priority. Secondary physics is
crippled by the fact that it is still taught as the last course in the high school science sequence by 90% of the secondary schools in the country, with only 40 states requiring even three years of science to graduate from high school (Sheppard and Robbins, 2005).

This sentiment has been echoed by the adoption and attempted implementation of the Physics First curriculum espoused by the American Association of Physics Teachers; the Executive Board of the American Association of Physics Teachers (AAPT) recognizes that teaching physics to students early in their high school education is an important and useful way to bring physics to a significantly larger number of students than has been customary. This approach—which we call “Physics First”—has the potential to advance more substantially the AAPT’s goal of Physics for All, as well as to lay the foundation for more advanced high school courses in chemistry, biology or physics (AAPT, 2002).

Developed by the committee of high school physics teachers and university researchers, the Physics First initiative has had difficulty gaining widespread implementation. As reported by Neuschatz et al. (2008) in their analysis of the 2005 survey of high school physics teachers by the American Institute of Physics, the Physics First movement has been slow to catch on. “… The actual spread of the practice has been more modest. We estimate that 4% of all U.S. high schools – 3% of all public and 8% of all private schools – had implemented some variant of Physics First by 2005” (p. 27). Some of the proponents of Physics First cite the movement of physics to 9th grade as a factor that will increase the number of students taking a 2nd year of physics in high school.
Unfortunately, according to the report, students in Physics First schools, both public and private, are no more or less likely to take a second year of physics than students enrolled at non-Physics First schools (Neuschatz et al., 2008). So while more students may be exposed to physics through the Physics First movement, the curriculum fails to significantly change their attitudes toward the subject. Other concerns inhibiting the adoption of the curriculum range from the notion that the ‘future scientist’ will be harmed by changing the current sequence to a concern for the large influx of teachers necessary to teach to 100% of the high school population. These concerns are valid since only approximately 20% of current high school students are being serviced now (Lederman, 2001). Another factor contributing to the lack of adoption of Physics First in many states is the current standardized testing structure. Very few states have any mandated science component to their testing regimens. Those who do, rarely include Physics among the subjects being tested. New Jersey, for example, has begun to implement science testing for all secondary students; however, they do so only in Biology with no plans for physics in the future. The end-of-course Biology test in New Jersey will require all students to have passed only an end-of-course Biology assessment before graduating and not any other science course.

While the numbers of students taking Physics is increasing, not following suit are the attitudes these students have toward their physics education. We can also see that even when all students are taking physics in their Freshman year, there is little increase in positive attitude toward the subject. With curriculum still mired in the ideas of the mid part of the 20th century, the effect the current curriculum has on student attitudes is obviously a factor.
The Teachers’ Perspective

Any examination of physics curriculum and practices must address the attitudes and current practices of the teachers charged with the task of educating students. A look at teachers’ perspectives can be seen in the research of Feldman and Kropf (1999), where teachers were asked to do a card-sorting task to prioritize different topics and ideas in physics. Feldman and Kropf were in the process of developing a conceptually based curriculum, Minds on Physics, and wanted to determine the topics this curriculum would encompass. While the two major topics, mechanics and E&M (electricity and magnetism), were generally agreed upon, there was variation in the majority of other topics. Interestingly enough, most teachers disagreed with the curriculum that would be created based on the aggregate of their card sorting. They felt, in interviews conducted, that there existed a pull between wanting students to have a conceptual understanding and the feeling that, especially with students who may not pursue physics in the future, they must cover as much material as possible. The teachers felt that, “While teaching for deep understanding would be appropriate for the future physics students….they believe it would be a turn off for the remaining students because it would be too boring or too difficult” (p. 5). For the population of students who will most likely not be future scientists, they reverted to doing a traditional survey course covering topics in a cursory way. As we will see in our discussion of the correlation between student attitudes and curriculum, the research does not support this ‘default’ position as being advantageous to students.
Frank Pajares (1992) emphasized the importance of studying teachers’ beliefs and the disconnect between them and educational research. He noted about teachers’ beliefs that

They travel in disguise and often under aliases—attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertoires of understanding, and social strategy, to name but a few that can be found in the literature (p.309).

He argues for the necessity of investigations into teachers’ beliefs because studies show a strong relationship between teachers’ beliefs and the planning, curriculum, and practices. This was found to be true not only for practicing teachers but for pre-service teachers as well and their subsequent teaching practices.

In 2006 Igal Galili and Yaron Lehavi of the Hebrew University of Jerusalem, Israel conducted just such an investigation into teacher beliefs. Their investigation focused on the teachers’ ability to express their concept definitions of important physics topics
similar to those identified by Feldman and Kropf (1999). The teachers in the study were all actively teaching physics in Israel. The study noted that, “Operational definitions of physics concepts have been strongly advocated by several leading researchers in physics education” (p. 523). They created an open questionnaire that asked teachers to define several physics concepts and to rate their importance in the teaching and learning of physics. The teachers attached a “great importance” (p. 521) to the notion of teaching physics using concept definitions and were quoted as saying, “they [the definitions] are important for the construction of physics as a true scientific discipline…” (p. 532). Despite stressing almost uniformly the importance of teaching physics in this manner, the
teachers, “…admitted to not having engaged their students in defining concepts, because it was difficult and time-consuming” (p. 532). In Table 1, the main arguments the teachers used for promoting concept definitions in physics are presented. Beside them are the shortcomings, identified by the researchers, in the answers the teachers provided to the questionnaire. The authors noted that problems teachers cite as preventing the teaching of concepts and concept definitions may stem from the teacher training programs offered at universities; acknowledging that the programs at their own institution do not reinforce prospective teachers in this regard. They conclude with the notion that at the high school level, the neglect to include concept definitions, “…is a matter of concern from the didactic, epistemological, and subject matter points of view, impeding learning for understanding” (p. 538). This conclusion aligns itself with other research in physics curriculum and student learning and shows the importance of concept related curriculum in physics education.

Mulhall and Gunstone (2008) continue to explore this issue by specifically looking at how teachers’ views and beliefs affect their approach to teaching physics by interviewing groups of teachers teaching from both traditional and conceptual approaches. Interestingly enough, Mulhall and Gunstone note that physics teachers in both groups did not indicate that they had given much thought to the nature of physics and the nature of how students develop physics knowledge: “The findings suggest the traditional teachers saw physics as discovered, close approximations of reality while the conceptual change teachers’ views about physics ranged from a social constructivist perspective to more realist views” (p. 435). They also note that the persistence of traditional physics teaching continues to exist despite the movement of many teacher pre-
service institutions to toward a more constructivist approach to learning. The teachers emerging from these institutions still fall into traditional teaching patterns. The problem with the entrenchment of these traditional practices is that these approaches, “fail to promote adequate student understanding of physics ideas” (p. 456).

In an effort to understand why these and other reform initiatives in physics have not found traction in the physics classroom, Charles Henderson and Melissa Dancy (2008) looked at the relationship between physics faculty and educational researchers to achieve better understanding of the adoption of new techniques in physics education at the university level. In their article Henderson and Dancy discuss some of the barriers to physics education reform that exist among faculty members and researchers at two universities. They discuss that while most physics instructors are aware of current Physics Education Research (PER), proponents of PER claim that most instructors, like most secondary educators, continue to use traditional teaching practices: “All the faculty interviewed expressed beliefs about teaching and learning that were more compatible with research-based instructional suggestions than were their self-described instructional practices” (p. 79). However, when asked how their practices had changed due to the research, a variety of responses were recorded. The faculty members felt that the typical dissemination model of research based curriculum expected the instructors to adopt them with minimal changes or that there was a perceived level of superiority by the researchers. This article provides some insight into the process of curricular reform from a teacher perspective and how the new curricula are presented by the person or persons proposing the change can have a significant impact on its adoption by the teacher.
In 1996, Haney et al. surveyed teachers to determine what factors were influencing their intentions to implement the State of Ohio’s (U.S.) Competency Based Science Model. In their study of recent reform efforts in science, they came to the conclusions located in Table 2.

Table 2: Reform recommendations from Haney et al.

<table>
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<th>Common Recommendations for Reform</th>
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<tr>
<td>1. Use organizing concepts teaching general scientific principals</td>
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<td>2. Infuse global and local environmental issues</td>
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<tr>
<td>3. Include interdisciplinary thinking and planning</td>
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<td>4. Adopt a philosophy that “Science is for All”</td>
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<tr>
<td>5. Use a problem-solving inquiry approach and constructivist models to actively engage students</td>
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<tr>
<td>6. Incorporate the applications of science that are relevant to the students’ daily lives</td>
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<tr>
<td>7. Include science career education awareness</td>
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<tr>
<td>8. Foster positive attitudes toward science and scientific “Habits of Mind”</td>
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These findings are directly in line with the results of the previous studies (Haussler and Hoffman, 2000; Barmby and Defty, 2006), such as the Minds of Physics curriculum developed by Feldman and Kropf, the Thinkertools project, the Physics First initiative, and the project 2061 educational reform initiative from the American Association for the Advancement of Science. They all spoke of the difficulty of the task of gaining the widespread traction necessary for meaningful reform. Evidently reform, initiated from
the top-down by politicians or policy makers does not have greater chances for implementation. Reform, “…should incorporate components associated with fostering positive attitudes toward reform behavior, develop perceptions of social support…and provide for the needed resources associated with educational change” (Haney et al., 1996, p. 987).

When they looked at what mattered most to the teachers, “The obstacles and enablers that the teachers were provided mattered less to them than did their beliefs about the positive and negative outcomes associated with the [reform] behavior” (Haney et al., 1996, p. 986). Grade level differences were also observed; where generally primary teachers held more favorable beliefs than did secondary teachers. Haney suggests that concrete teacher training is associated with teachers achieving success and observing success (Haney et al., 1996). What is clear from the research is that there exists an emotional component to teacher’s adoption of reform efforts. These emotions of fear and anxiety as well as disappointment in previous reforms can have a significant impact on teacher adoption practices. This emotional component has not been addressed by previous science education reforms. In her study of middle school teachers’ adoption of a research-based, concept related curriculum entitled “Change is Hard: What science teachers are telling us about reform and teacher learning practices” (Davis, 2003), Kathleen Davis interviewed teachers who reported that they were very much viewed in a hierarchy with regard to the level of science that they taught with University teachers and high school teachers being above the middle school teachers who were only superior to elementary science teachers. One concern raised by a veteran teacher was the following:
Many years ago ... there was another program that was introduced and piloted. At the end of the pilot ... the district refused to buy the concomitant material to support the effort and as a result, they were stuck back in the old stuff after they made all that effort to look at something new (p.13).

This sentiment of previous failed initiatives is echoed by many teachers when they are faced with new reform initiatives. Their hesitancy to adopt new programs varied. Some of these science teachers felt that they were not being fully informed about the new program; as one teacher explained it, “There wasn't any information on the program ....They had no books for us to look at, they had nothing ...Others felt that they were not being given any choice; if one person wanted to do the program, they all had to do it” (p. 14).

Davis (2003) also points out that teachers approach these reforms with varying values and beliefs about teaching and learning. One teacher reported four years into the study that he was still having trouble with cooperative learning, since it was a significant part of the reform effort. Though the topic had been covered in professional development sessions, he and others still had difficulty. For the teacher involved modeling the behavior of the students with other adults was not an effective means of teaching him how to implement the practice with students. Only through significant professional development and support were these problems allayed.

Peter Senge and others address these issues as well in The Dance Of Change: Challenges to Sustaining Momentum in Learning Organizations (1999): “We have rarely seen any successful change initiatives that did not involve imaginative, committed…
people with accountability for results and sufficient authority to undertake changes in the way that work is organized and conducted at their local level” (p. 16). Without these ‘internal networkers’ or community builders Senge argues that meaningful change will not occur. He argues that with diligence we must move away from “our traditional model of leadership [that] emphasizes omniscience, high degrees of control, and a Patton-esque stance in which the leader was always right and was not to be questioned” (Senge, 1999, p. 207).

Senge also warns against potential problems in creating ‘pilot groups’ or teams to begin change without including the rest of the organization: “A perception may grow in the rest of the organization that the pilot team members are going overboard…or others may grow jealous and unsettled by the enthusiasm of the pilot group members” (Senge, 1999, p. 323). This is how most curricular reforms are first implemented, and here leadership becomes vital for the survival of the organization as a whole. By developing an organizational emphasis, infused with the responsibility of the leader, on instructional improvement, promoting a distinct and unifying vision of instructional quality, creating a community in support of their vision, and restructuring their own priorities, schools can attain the instructional emphasis that leads to an improvement in student performance (Supovitz & Poglico, 2001, p.26). How the change is to be implemented is a crucial question, almost as crucial as how the curriculum is being revised. What is also crucially clear is that the current curriculum is effecting student attitudes in a negative way.

**The Effect of the Current Curriculum on Student Attitudes**

Many researchers have examined the perspective of secondary school pupils on their science curriculum. From the attitudes of students toward physics in the United
States (Andre et al., 1999; Chang, 2002; Crawley and Black, 1992; Ebenezer and Zoller, 1993; George, 2006; Haussler and Hoffman, 2000; Stokking, 2000) to the attitudes of students toward science in the United Kingdom (Barmby and Defty, 2006; Murphy et al., 2006, Reid and Skryabina, 2002) the prevailing research supports the notion that there is a decline in student attitudes toward science as students progress through their schooling.

This negative attitude may originate as early as the elementary level. Andre et al. (1999) points out, in a study of children grades 4-6, that boys perceived themselves as higher or as better in physical sciences than girls and that the girls also expected lower grades in physical science compared to their male classmates. All the students in the study expected lower grades in physical science and attached a lower importance to it.

The author also noted that these cultural stereotypes were present in children as low as grades one through three but were not as dominant. Andre concluded, “..the differences observed in course selection and achievement at higher educational levels….are likely to reflect the cultural bias imposed on our youth” (p. 744). Given the nature of inquiry-based, concept related curricula to improve student attitudes, such curricula can serve as a powerful weapon against these lower expectations of elementary students.

In a study about U.S. students’ attitudes with regard to science, Rani George (2006) found that students’ attitudes toward science generally declined over the course of their primary and secondary education, particularly in the middle to high school years. In the study the attitude scale was linked to the science classes taken by the students, meaning that the decline in attitudes could be related to the type of science courses taken by students in each grade. When looking at the types of courses students were choosing to take the authors found that, “There was a great deal of individual variation in the type
of science courses taken by students in the 11th grade, since these courses were advanced science courses. In other words, when given the opportunity to choose advanced study, physics was not the first preference. In fact, the greatest decline in interest in the sciences, which is seen in the eighth and the ninth grades, could be associated with the physics classes” (George, 2006). This decline in interest is related to the way in which physics and the physical sciences were approached in the classroom. This decline, however, is not a solely American problem.

In the United Kingdom, students of relatively similar ages experienced similar declines. In a U.K. study, Reid and Skryabina (2002) noted several drops in attitudes toward science with, “The first ‘decline’ take[ing] place after the transition from primary to secondary school. The second ‘decline’ take[ing] place after the transition from Standard Grade physics” (Reid and Skryabina, 2002). This decline in attitude is well documented and supported by multiple pieces of evidence and continues even as students approach college level. “The number of 18-year-olds taking science and maths at A-level fell from 42% in 1963 to just 16% in 1993” (Reid and Skryabina, 2002) even as enrollment increased.

In an even larger study, Barmby and Defty (2006) analyzed data obtained by Durham University in England over the period of 1999 to 2004 regarding students’ attitudes and performance in ‘secondary’ sciences in general, and physics in particular. The study looked at whether the students 'liked' or 'disliked' different subjects, and their expected examination grades in these subjects, noting that these examinations have direct impact on post-secondary study. The study found that physics was perceived as the least popular science. The researchers also found a strong correlation between what the
students’ grade expectations were and the strength of their ‘like’ or ‘dislike.’ This article’s sample is the largest of its kind. It addresses the direct correlation between attitude and performance with respect to adjusted physics curriculum (Barmby and Defty, 2006). While student attitude, parental influence, peer influence, and teacher influence were all factors in the students’ decline of interest and attitude toward science, curriculum was also noted by the students. This was evidenced by the more recent implementation of a new physics curriculum in the U.K., which showed dramatic results in student attitude and authentic learning.

Murphy et al. (2006) looked at the impact of the Energy Foresight curriculum on student engagement with physics. The new curriculum was implemented because of the lack of uniformity of the science curriculum across the country. The traditional curriculum was replaced because it failed to take account of the diversity of interests and aptitudes of students aged 14–16, equivalent in the US to high school grades 9-11. The new curriculum for scientific literacy recognized that a diverse range of people create and use scientific knowledge and sought to engage students. Both the non-pilot and pilot groups studied were in Year 11 (15-16 year old students). Pilot teachers rated the curriculum and its direct real-world applications. The pilot students experienced an implementation much more focused on the social issues and dilemmas facing modern scientists and society. Both teachers and students attitudes’ were very favorable toward the curriculum. There was a significant impact on girls’ participation and learning. (20-25% increase) Although the impact on boys was smaller, all students made it clear how much their learning benefited from visualizing complex issues and having access to world views as opposed to the topics in a typical curriculum. This study establishes a
direct link between the curriculum and attitude and achievement of students. It also
addresses the notion that students who are not going to study physics after secondary
school do not need to be exposed to a multitude of topics in order to have physics-
inspired insights into current science-related social issues.

In Germany, Haussler and Hoffman (2000) performed a small meta-analysis of
several studies examining physics curriculum and attitude. The data suggest that physics
be taught so that students have a chance to develop a positive attitude, or physics-related
self-concept. Furthermore it states that when they do, the link they make with physics
and the situations they encounter outside the classroom are much stronger. A curriculum
based on these principles proved superior compared to a traditional encyclopedic
curriculum of a wide range of topics with little depth. This fundamentally corresponds
directly with the results reported by Barmby and Defty (2006) in the United Kingdom.

Haussler and Hoffman analyzed three different studies: a Delphi study of physics
educators across Germany, a survey of over 8000 physics students, and a seventh grade
curriculum that was developed based on the data from the first two studies. Interestingly
enough, a dichotomy existed between what the students wanted to learn and what the
physics teachers were including in the curriculum. What the students were interested in
was situated between the topics the teachers thought were important and what the
students thought was unimportant. They also noted that the teaching time spent on topics
identified as being of student interest was significantly less than the time spent on topics
deemed essential by the teachers. Despite evidence to the contrary, the teachers viewed
Physics as a scientifically challenging intellectual enterprise and felt that its pursuit did
not require an alteration based on student interest (Haussler and Hoffman, 2000).
In Tiawan, Chang (2002) investigated the impact of a traditional versus constructivist learning approach in teaching physics at Feng-xhia University. Two groups of students were taught the same introductory physics curriculum with one using a traditional teaching style and the other a constructivist approach. The study indicated “…significant favorable attitudes of the constructivist students towards the innovative teaching design” (p. 16). The study concluded that the teaching design seemed to have a certain degree of influence on the students’ perceptions of the learning of physics.

In the United States the Physics Education Research community has been studying the teaching and learning of physics at the university level. Some of their studies have also looked at the teaching of physics at the secondary level. In 1998 Richard Hake performed a meta-analysis of the results of over six thousand high school and college students and their pre/post performance using the original Halloun–Hestenes Mechanics Diagnostic test, the Force Concept Inventory, and the problem-solving oriented Mechanics Baseline. (Hestenes et al., 1992; Hestenes & Wells, 1992) Hake looked at the performance of students in traditional instruction versus what he called interactive engagement strategies. For the purposes of the study, traditional instruction was formal lecture-based instruction with limited student interaction during the lecture and with traditional, direct instruction-based laboratory activities. Interactive engagement methods were defined as those that were designed to promote, in some way, conceptual understanding of physics topics through hands-on activities that provide immediate interaction and feedback with peers or instructors. Interestingly enough, not only was there a statistically significant increase in performance on these assessments by the students who received instruction that was interactivelly engaging, “It would appear
that the problem solving capability [was] actually enhanced (not sacrificed as some would believe) when concepts are emphasized” (Hake, 1998, p. 68).

The conclusions reached by Hake are also supported by the work of Eric Mazur (1997) who developed a method for incorporating concept assessments into his introductory physics classes for undergraduates at Harvard University. Mazur notes that in the current system of traditional physics instruction, students are expected to rise like the cream of the crop and see introductory physics courses as competitive and intimidating. His eyes were opened to the importance of concept-based teaching when he began to administer paired questions (quantitative and qualitative) on the same topics to his introductory classes. He was surprised to find a lack of correlation between the scores on the conceptual and conventional problems. He notes, “Clearly many students in my class were concentrating on learning ‘recipes’ or ‘problem-solving strategies’ without considering the underlying concepts” (p. 7). He developed a program, Peer Instruction, which seeks to exploit student interactions and focuses on students’ attentions toward the underlying concepts of the physics topics. Upon implementing the program, Mazur saw a dramatic increase in the performance of the students on the Force Concept Inventory Test (Hestenes et al., 1992) with the post-test group having 96% of the students above the threshold of understanding as defined by Hestenes. Mazur also had his students complete the Mechanics Baseline test, also developed by Hestenes et al. (1992) to determine if the method of instruction affected adversely the performance of students to solve, mathematically, the problems typical to elementary mechanics. He found that “…the average score on this test increased from 67% to 72% the year Peer Instruction was first introduced and rose from 73% to 76% in subsequent years” (p.15). For Mazur, having a
better understanding of the underlying concepts of physics led not to a reduction in problem-solving ability but to an improved performance on conventional problems. This evidence directly refutes the many unsubstantiated claims of physics educators that concept related curriculum adversely affects student performance.

Elby (2001) examined what practices and curricular elements were necessary for students to develop more sophisticated beliefs about knowledge and learning. As measures he used: the Maryland Physics Expectations Survey (MPEX) and the Epistemological Beliefs Assessment for Physics Science (EBAPS). Elby taught several small clusters of physics students in Virginia and California during the period of 1997-1999 by using curriculum and instruction based in part on the Workshop Physics curriculum created at Dickinson University. The Virginia class was a traditional algebra-based honors level class with the California class being more of a concept-based course.

Figure 4- Results of the MPEX for the Virginia Class, Elby (2001)
In the Virginia class (see Figure 4) the MPEX results, displayed in the diagram as the starting value with an arrow drawn to the post-test value, show clear increases in favorable ratings of students’ abilities to deal with Mathematics, Concepts, Coherence, Reality Linkage, and Overall opinions. The California gains were also significant and by Elby’s analysis of the EBAPS data, comparable. With regards to the textbooks used by both groups, Elby found that the texts were in conflict with his notion of teaching physics as a process in which students unearth and examine their own intuitive ideas, refining them. The activity-based conceptual books did not promote this approach and the algebra-based texts sent a message of importance of coverage of topics, not understanding. This emphasis required what Elby called a forced reduction in content, noting that in both cases, “These results came at the expense of content coverage, but not at the expense of basic conceptual development” (p.57).

These results are not surprising. We know from Bransford and Danovan’s (2005) *How Students Learn History, Science and Mathematics in the classroom* that approaches to learning science that conform lockstep to traditional activities work against the important concepts of observation, imagination and reasoning. When students learn in inquiry-based settings, by “actively engaging in processes of scientific inquiry…it has important advantages” (p. 405) because it allows student learning to supersede merely the application of scientific knowledge and move into the realm of its generation and application. As Minstrell and Kraus (2005) note in their chapter, “Learning experiences need to develop from first hand, concrete experiences...” (p.512). These type of inquiry-based settings can take the form of Problem Based Learning (PBL). PBL is learning where students are forced to become active learners because the problems are situated in
the real-world, thus making the students responsible for their own learning. The problem
the students are given becomes the focus of the scientific inquiry in which they engage,
driving the students toward constructing their own explanations (Hmleo-Silver, 2004).
The success of PBL is well documented. In their review Vernon and Blake (1993) report
that PBL in the college setting was ‘significantly superior’ with regard to student
attitudes and opinions about their programs. This was true of their analysis as well as a
parallel one by Albanesse and Mitchell discussed within their article. Both studies found
statistically significant data that consistently favored PBL with regard to student attitudes.
Vernon and Blake conclude with results from their meta-analysis stating that their work
generally supports the implementation of the PBL approach over more traditional
methods, noting that the studies they examined were all consistent with the commonly
expressed notion that PBL provides greater emphasis on in-depth understanding and less
on the rote learning and memorization of facts.

In the United States several new physics curricula are actively engaging students
differently. The ThinkerTools project being conducted at the University of California,
Berkeley, seeks to improve middle school students’ understanding of science and
physics-related concepts through the use of inquiry (Thinkertools.org, 2008). Also, the
developers of the Minds-On-Physics project being conducted at the University of
Massachusetts, Amherst, state that the project “is an activity-based, full-year curriculum
for high school physics. It is intended to be an excellent preparation for college-level
science, and is well matched with the National Research Council's National Science
Education Standards” (Minds on Physics, 2000). Also, as mentioned earlier, the Physics
First initiative by the American Association of Physics Teachers (2002) seeks to expose
more high schools students to physics by teaching it as a ninth grade science course that deals with the concepts of physics without the advanced mathematics. As mentioned above in the study with Elby, Dickenson College has developed the Workshop Physics Curriculum (2004), which describes itself on its website as, “a new method of teaching calculus-based introductory physics without formal lectures. Instead students learn collaboratively through activities and observations. Observations are enhanced with computer tools for the collection, graphical display, analysis and modeling of real data.” While some anecdotal success stories with these approaches have been published in non-peer reviewed physics publications and magazines, a full research investigation, similar to the studies in the U.K. and Germany, has yet to be undertaken by physics education researchers in the United States. No direct case studies appear as to the how these curricula affect student attitude and achievement in secondary physics education.

Physics educational curriculum remains predominately mired in the traditional groundwork established over the course of the twentieth century. The possible benefits of reforming the curriculum on student performance have been demonstrated (Chang, 2002; Elby, 2000; Hake, 1998; Mazur, 1997) with no adverse effects on the traditional ability to problem solve. We have seen that curriculum that stresses concept-based, inquiry-related topics (Barmby and Defty, 2006; Chang, 2002; Ebenezer and Zoller, 1993; George, 2006, Reid and Skryabina, 2002) can be effective in promoting positive attitudes in students. Also, there exists a strong disconnect between what is working for the students and what the teachers perceive as the role of a physics education (Haussler and Hoffman, 2000). We have also noted that while several reforms based in the U.S. (APPT, 2002, Minds on Physics, 2000; Thinkertools, 2008; Workshop Physics, 2004)
have met with success in their limited implementation, large-scale reform remains elusive. As Neuschatz et al. (2008) points out,

Unfortunately, despite more than a dozen years of insightful studies and robust exchanges of ideas within the Physics Education Research (PER) community, only 8% of high school physics teachers report that PER has had an impact on their classroom teaching. Even more discouraging, this percentage had actually fallen slightly from the 10% recorded four years earlier (p.18).

The teachers, and by default the students, continue to follow the curriculum practices established during the last century with strong evidence that the curriculum itself retards student attitudes and understanding.

In the review of the research surrounding secondary physics education, several major themes begin to emerge. First, current practices do not seem to promote positive attitudes toward physics (Barmby and Defty, 2006; Ebenezer and Zoller, 1993; George, 2006; Haussler and Hoffman, 2000; Reid and Skryabina, 2002; Stokking, 2000), nor do they address what students see as important in learning physics (Haussler and Hoffman, 2000). Second, while reform has taken hold in the U.K. (Barmby and Defty, 2006) and other countries, the programs offered in the United States, such as Physics First (AAPT, 2002) and Minds on Physics (Minds on Physics, 2000), have only had minimum penetration into common physics education practices at the secondary level. Third, teachers’ perceptions of these new curricula and the researchers who are presenting them are met with skepticism, distrust, and frustration (Haney et al., 1996; Henderson and Dancy, 2008). Fourth, leadership is required for a second order change initiative, such as
adoption of a new curriculum, and if leadership is not wide spread and supported, it can create issues within the organization (Marzano et al., 2005; Senge et al., 1999). Lastly, these reform efforts face obstacles in the form or reduction of instructional time and resources as a result of the No Child Left Behind legislation and the perception of the public that schools must be accountable (Amrein and Berliner, 2002; Kohn, 2000; McMurr, 2007; Nelson et al., 2007). It is with this knowledge firmly rooted in the research that we begin to explore, in case study form, how implementation of the Energy Foresight curriculum impacts student attitudes and learning in a secondary physics classroom.
CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

Overall Approach and Rationale

While it is clear from the current research on physics education that a relationship among student interest, achievement, and the structure of the curriculum involved exists, there does not seem to be wide adoption of these ideas when developing or implementing secondary physics curriculum. As we have seen in the studies analyzed by Haussler and Hoffman (2000) and others, a dichotomy still remains between the students and the teachers’ perceptions of physics curriculum. Also, there is still debate among teachers as reported by Feldman and Kropf (1999) as to what should be in the curriculum at all with teachers only able to agree on the four most important topics: basic mechanics, gravity, electromagnetism, and optics. This case study investigated how implementing one of these concept related, inquiry-based curricula impacted a traditional secondary physics classroom. More specifically, the research addressed what impact an inquiry-based, concept related curriculum had on student attitudes toward physics and science as well as the impact on student learning.

The researcher performed a case study in order to examine this question in the context of a public secondary school classroom. When selecting a group, organization, or school to evaluate, a case study can be a highly effective way to do so. Case study research arises out of a distinctive need to understand a complex social phenomena or situation allowing the researchers to retain the, “holistic and meaningful characteristics of real-life events” (Yin, 2009, p. 4).

In doing educational research there are two methodologies that are used either exclusively or together, to study some idea, event, phenomena, or situation. In
quantitative research the scientific tradition is followed in that variables are held constant and specific treatments are tested against controls. Traditionally these types of tests look for universal truths that the researchers feel will emerge from their data. In qualitative research ethnographic methodologies are used to study not just the effects of a specific treatment but an entire sense of what is being studied. One of the concerns raised with qualitative research, and more specifically case study research, is the ability for the information garnered to be generalized and therefore helpful in determining educational policy and decisions.

Elliot Eisner (1997) in his book, *The Enlightened Eye*, describes how case studies can be generalized. Eisner states that case studies can be generalized not from formal inference, but from inference based on retrospective analysis and iconic images or events. Retrospective analysis involves the researcher using his or her own past experiences to identify ideas that are common to the research or stand out as a concrete universal.

By choosing a qualitative methodology the researcher will be able to examine the surroundings, interactions, and atmosphere of the environment being studied as well as gain important insight into the individuals being studied. We can then make generalizations about the human condition that extended from within the context being studied as well as garner valid insights into the phenomena being studied (Maxwell, 2002). These conclusions will come from retrospective analysis, iconic images observed or presented to the participants, as well as events and the descriptions of those events that are being observed and recorded by the researcher (Creswell, 2007; Eisner, 1997). These data can then be coded and analyzed for general trends. The researcher also sought out
responses from individuals based on traditional interview questioning as well as the use of artifacts.

The timeline for the case study research was as follows:

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<tr>
<th>Research Process</th>
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<tr>
<td>Proposal Defense and IRB Review</td>
<td>Winter Term 2010</td>
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<tr>
<td>Case Study</td>
<td>After IRB approval 1-3 months</td>
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<tr>
<td>Data Analysis &amp; Dissertation Completion</td>
<td>3-6 months</td>
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</table>

### Population and Site Selection

The site selected for this study is a public high school located in a Southeastern County in the state of New Jersey. Permission to conduct the study was obtained from the superintendent, district curriculum coordinator, principal and the science department supervisor. The Regional School District consists of 2 high schools that while in strict terms are separate, Intermediate and Senior High Schools are physically attached to each other and share many resources, facilities, and staff. The school, “…is a comprehensive high school that strives to meet the needs of all its students. [It] offer[s] more than 200 courses, including nineteen Advanced Placement courses, a professional staff recognized for excellence on state and local levels, class size average of twenty-four students, and a safe and supportive learning environment.” (New Jersey, n.d.) There are three communities that send their students to the high schools. The high schools are considered
a separate school district than the primary and middle schools in each of the three sending communities. The three sending communities contribute to the school population in varying amounts. Community one is an upper middle class community and contributes approximately 70% of the students in the district. Community two is a middle class blue collar community and contributes 25% of the students in the district. Community three is a small middle to lower middle class community that contributes the remaining 5% of the students in the district. Students of various ethnic and religious groups are present in the school in statistically significant numbers, however, the majority of the population is white.

Current school policy suggests, in coordination with the state’s graduation requirement, that all students take one year of physics. Students, at the time of course selection, have the choice of three different levels of introductory physics: College Preparatory, Accelerated, and Honors. The physics enrollment at the High School had the following approximate enrollment figures for 2010: of the students taking physics approximately 230 of the 350 physics students, or 65%, were doing so at the Accelerated level, which is the level where 90% or more of the students are college bound. Eighty of the 350, or 23%, were at the Honors/AP level. The remaining 40 students, or 12%, were at the standard or remedial level, which although named as ‘college preparatory’ does not have the majority of their students planning to attend 4-year universities but seeking either smaller 4-year colleges, community colleges, armed forces service or other vocational plans after graduation. Also, at this and the accelerated level, some classes contain special education support for students.
Maxwell (1996) states that small scale studies benefit from a small deliberately selected group of individuals rather than from a survey of the heterogeneous population. Purposefully selecting a population this small is done so knowing that the homogeneous group selected will still contain, within it, mix of those opinions relevant to this study. Also, according to Creswell (2008), a sample can range from 5-20 interviews and still address the larger issues of the study provided that the individuals participated in the process are central to the study. In this case study, the physics teacher and their corresponding students are the most central to the core issues being researched and will be situated to provide the most relevant data to the research.

For the purposes of this study a secondary physics classroom made up of students who are designated by themselves as being ‘college bound’ was chosen for the case study. They were an Accelerated Physics class. This intact group of students was recruited through direct consultation with the teacher and department supervisor as well as the researcher so as to assure sufficient availability for observation. The physics teacher who has volunteered for the study is a 10+ year veteran of the school district, as a physics teacher, and holds a Bachelors of Science degree in physics. Students in the selected class received a letter from the Principal of the School (sample Appendix E), a consent form (Appendix F) to be signed by the parent or guardian, and an assent form to be signed by the student (Appendix G). On the form parents/guardians had the option to allow / not allow the interviewing or video taping of their child in addition to their choice of whether or not to participate in the study. For the students, it was made clear their choice to participate in the study and /or be videotaped in no way interfered with the normal course of their classroom learning and daily routine. Students in the same room
that had agreed to be in the study will be indistinguishable from those who had not
agreed. The researcher maintained a confidential class roster that had appropriately
identified which students were participating in the study and which of those students had
additional permission to be videotaped. The researcher is the only individual with access
to the list. All data collected by the researcher is coded so that the participant’s privacy is
protected.

Data-Gathering Method

Data collection for this study was done through observations, interviews, attitude
surveys and student work collected over the course of the inquiry-based learning unit
(See Appendix D). Triangulation was used in order to cross-reference the data collected
to insure its corroboration (Wiersma and Juris, 2005). “It is in data analysis that the
strategy of triangulation really pays off, not only in providing diverse ways for looking at
the same phenomenon but in adding to credibility by strengthening confidence in
whatever conclusions are drawn” (Patton, 2002, p. 556).

Observations

Ethnographic research is conducted in a natural setting. The data collected were
interpreted within the context of the environment in which it was collected (Wiersma and
Juris, 2005). The case study also allows the researcher to focus on a contemporary
phenomenon within a real-life context (Yin, 2009). “Ethnographic research involves a
variety of data collection procedures, the primary procedure being observation”
(Wiersma and Juris, 2005). Iconic images and events can also play a role in determining
if information obtained through observation in a case study can be generalized. Simply
describing a high school cafeteria can evoke memories of images and events that all of us who have been formally schooled have experienced. Describing the lunch room as a place of hard tables, floors, and chairs that looks as though all that’s needed for cleaning is a fire hose and mop, can relate to our own experience, or at the very least provide a common reference for the reader to understand the environment. One reader may take away a strong image, another may access a memory, but both will be able to relate that particular image of school cafeteria to the issues discussed in the case study.

In his book, *Horace’s Compromise*, Theodore Sizer (1984) discusses the trials and tribulations of a high school teacher. His story revolves around this teacher’s interactions with his students, the school, his family, and community. Similarly, Jonathan Kozol’s *Savage Inequalities* (1992) describes firsthand accounts of the deplorable conditions in some urban schools. Both authors provide vivid images and specific events that affect the students, teachers, and staff. Both Sizer and Kozol’s works are not irrelevant because they are case studies nor is Sizer’s specifically to be dismissed because it is a work of fiction. On the contrary, they have both helped to shape educational research and provide a context by which to talk about failing schools and the solutions needed to address them. They have much to teach us as educators and citizens about the current state of children, education, and our communities. Their ability to speak to the larger picture is solidified because they provide iconic images of the current state of education and plight of the children and teachers within it. Sizer’s account is not less valid because its events are fictional and Kozol’s is not more valid because it relates factual events.
The role of the researcher in this study was to be one of an observer. The researcher observed classes two times a week during the unit. The researcher played a limited role in the interactions with the students and teacher. The researcher is a physics teacher in the school and has over 15 years of experience dealing with high school aged physics students. Being an observer allows the researcher to describe the learning process as it is unfolding, “…to understand behavior, the observer must understand the context in which individuals are thinking and reacting” (Wiersma, 2000, p. 248). This context also allows the observer to witness interactive situations that may not be articulable, re-countable or constructible in any other meaningful way (Mason, 2002).

**Field Notes**

During the observations the researcher took field notes, which was added to the collective data for the research. The field notes were divided into two sections. The first section recorded descriptions of events as they unfolded within the classroom. These descriptions recorded what has happened in the room and are called the running record (Rossman and Rallis, 1998). The second section, recorded concurrently with the details of the event, contain feelings, impressions, and ideas that are triggered in the observer as the events transpire and are referred to as the observer comments (Rossman and Rallis, 1998). These notes were taken electronically so that they can be easily indexed and coded for analysis (Mason, 2002).

As soon as possible after the observations were completed, the raw notes were augmented by elaborating on skimpy commentary, adding additional commentary and performing some preliminary analysis. By thickening the descriptions (Rossman and Rallis, 1998) the researcher is better able to present details and textures of the situations

**Attitude Survey**

At the inception and completion of the inquiry-based unit students in the case study class were administered the Colorado Learning Attitudes about Science Survey (CLASS see appendix 1) developed by Dr. Carl Wieman of the University of Colorado. This instrument is designed to, “examine the relationship between students’ beliefs about physics and other educational outcomes, such as conceptual learning and student retention” (Perkins et al., 2004). Also students were interviewed at the end of the implementation of the curriculum. The interview group consisted of two students who showed the greatest gains, two students who showed little to no gain, and then three other students determined by random selection. This interview group allows for the confirmation or reworking of information under which an emerging model, as defined by Creswell (2008), is helpful in addressing the research questions. The construction of the survey itself has been checked for unclear, ambiguous language that would lead to null or unusable responses (Adams et al., 2004).

The survey questions for the teacher are based on the 2005 Survey of Physics Teachers by the American Institute of Physics. The survey given in 2005 was the latest version of a continuing series of surveys (1989-2005) administered by the American Institute of Physics. In the 2005 edition, many of the questions were, “Identical to those used in earlier rounds of the study,” enabling the researchers to track “long-term trends” as well as allowing for confirmation of question validity, based on the comparison with previous responses (Neuschatz et al., 2008, p.55). The authors also noted that, “No
statistically significant differences were found between respondents and non-respondents in terms of geographic setting, grade range, or the number of teachers at the school” (p.56), suggesting that the survey instrument itself was not predisposed to be completed by a specific group of teachers but by all teachers equally. The CLASS survey was administered in paper and pencil format.

Nass et al. (1999) investigated how people would rate the performance of a computer that administered a computer-based questionnaire using both a computer based questionnaire and a paper-and-pencil based questionnaire, to evaluate the performance of the computer. Although noting that there does exist a distinct difference between the two media, computer and paper-and-pencil, “In post-experimental debriefings, all of the participants noted…the source of the interview: the same computer, the paper-and-pencil questionnaire…did not affect their answers” (Nass et al., 1999, p.1100). These null effects of the medium on the answers to the surveys help to address bias concerns for an electronically delivered survey verses a traditional paper-and-pencil form.

**Interviews**

Upon receipt and analysis of the surveys, interview subjects were chosen in two ways. Four participants were selected based on their pre/post survey responses. The two students with the greatest positive change in attitude among the eight categories identified in the CLASS survey and the two students with the least increases or greatest decrease were selected. In addition, 3 additional students were randomly selected from the students who have agreed to participate in the study and have also been given parental permission to be videotaped. They were selected using an alphabetical listing of participating students and a random number table. The interviews with the chosen
respondents were conducted in twenty-five to thirty-minute sessions using the questions developed by the researcher in order to clarify the students’ and teacher’s responses to the attitude survey and concepts and practices employed by the inquiry-based curriculum. Analysis of these data will contribute to the body of knowledge of science education. It will also serve as a starting point to examine what factors are inhibiting the advances made in physics and science curriculum adjustments from permeating into the secondary physics curriculum.

A structured interview lasting approximately 30 minutes allows for a guiding of the questions along with the ability to request further explanation if the subject contributes something unexpected. Doing so provides for the unexpected. “It is this explicit provision for contingencies, together with the attention to the sequence and structures of the tasks that distinguishes the ‘structured’ interview from the ‘unstructured’…” (Golin, 2000, p.520 quoted in Creswell, 2007) The interview also allows the researcher to collect and analyze data on the mental processes at the level of the interviewee’s authentic ideas and meanings. It can also expose hidden mental processes and structures that cannot be detected by closed numeric techniques. This hidden world of knowledge substructure can be discovered through an interview. “Clinical interviews…can be designed to elicit and document naturalistic forms of thinking…the investigator can also react responsibly to data as they are collected by asking new questions in order to clarify and extend the investigation” (Clement, 2000, p.547). The guided interview will allow the researcher to explore in depth any specific individual nuances or opinions that relate directly to the study.
In the guided interview process the same opening questions were asked at all interviews with the interviewee being allowed to elaborate on those issues most important to him (Wiersma and Juris, 2004). The interview is ideal in this situation since those being interviewed will have expressed a willingness to do so since they are not inhibited in their desire to speak. They should also be willing to share their ideas comfortably (Creswell, 2008). This helps to avoid interview-bias where the interviewer is given responses that are designed to please the interviewer or provide him with what the interviewee perceives to be the appropriate response. An example of this noted by Nass et al. (1999) is when a female is doing the interviewing; subjects are more likely to give responses that are more feminist in nature than what they may or may not believe.

Most importantly, “Interviewing provides access to the context for people’s behavior and thereby provides a way for the researcher to understand that behavior” (Seidman, 2005, p.10). It is through the use of the language views of the participants that a visual representation can be constructed. It is this ability to create a visual representation that accounts for the power of the interview. The language used the actual words of the participants, can be compared, contrasted, and triangulated so that whether or not things are physically present in the room there is still the ability to relate to them. This power to talk about absent things, real or imaginary, is what enables individuals both to describe and to go beyond their immediate experience. Doing so, provides the researcher with information that can only be obtained through the personal interview and would be overlooked if prospected with other means (Schostak, 2006).

Seidman (2005) provides guidance by suggesting two criteria for determining how many participants to interview: sufficiency and saturation of information.
Sufficiency is defined as the number of participants that are sufficient for determining a reasonable cross-section or spectrum of viable participants. Saturation occurs when successive interviews no longer provide new information to the data collected. There are many different opinions with regard to a reasonable number of participants (Creswell 2003; Creswell 2008; Wiresma and Jurs, 2005) ranging from low values in phenomenological studies to larger numbers in survey related explanatory studies. The researcher in this case had set a target of seven subjects to interview, understanding that their responses will in turn provide both sufficiency and saturation with regard to the survey responses. The Interview Protocol is located in Appendix B.

**Student Artifacts**

As noted by Eisner (1997) visual as well as iconic images can contribute greatly to the understanding of the researcher and others in a case study. Throughout the study the researcher collected selected student works as well as visual photographs and other products of the curriculum. These student works serves as a source of information when added to the attitude surveys, interviews and observations. Researchers often use documents collected during observations that are produced in the course of the research at hand (Rossman and Rallis, 1998). Reviewing these artifacts can help to uncover important clues and connections. The materials serve to support and expand upon the responses of the participants in the data collected in the surveys and interviews. All artifact materials were coded to protect the anonymity of the students.

Content analysis was used to review the artifacts collected in an ordered procedure. Using content analysis (Maxwell, 2005) is vital to the research. Content analysis is a process of methodically reviewing items collected along with the field notes,
interview, and observation data in order to attain a greater level of understanding about the reality of the phenomena being studied.

**Data Analysis Procedures**

The data analysis of the information obtained during the study will result in a descriptive report of the results. “In qualitative studies, data collection and analysis typically go hand in hand to build a coherent interpretation of the data” (Marshall and Rossman, 1999, p. 151). Marshall and Rossman (1999) suggest that “…analytic procedures fall into six phases: (a) organizing the data; (b) generating categories, themes, and patterns; (c) coding the data; (d) testing the emergent understandings; (e) searching for alternative explanations; and (f) writing the report” (p. 152).

**Survey Scoring**

The student attitude surveys, using the CLASS survey, were analyzed using the simplified CLASS scoring sheet provided by the University of Colorado. According to their presentation at the Physics Education Research Conference in 2004, Adams et al. state that when using the CLASS, “One can look at the pre/post-test results and their influence on student learning or retention. One can also look at the change in attitudes over a semester to determine what effect instruction had on students’ attitudes and beliefs” (Adams et al., 2004, p. 3). The CLASS is a Likert-based attitude survey. Scoring is performed by determining the percentage responses for which the student agrees with the experts’ view (percent favorable) and then averaging these individual scores to determine the average percent favorable. The survey is scored overall and then for each of the following 8 categories:
1. Real World connections
2. Personal Interest
3. Sense Making/Effort
4. Conceptual Connections
5. Applied Conceptual Understanding
6. Problem Solving General
7. Problem Solving Confidence
8. Problem Solving Sophistication

These categories were determined using a reduced basis factor analysis (see Adams et al., 2004 for a complete explanation). The preferred method of scoring the CLASS survey is on an ordinal scale,

“In scoring, neutrals are scored as neither agree nor disagree with the expert so that an individual student’s ‘% favorable’ score (and thus the average for the class) represents only the percentage of responses for which the student agreed with the expert and similarly for ‘% unfavorable’. The difference between 100% and the sum of ‘% favorable’ and ‘% unfavorable’ represents the percent of neutral responses” (Adams et al., 2004)

The survey uses a 5-point Likert scale that utilizes the ‘strongly agree’ and ‘strongly disagree’ as the ends of the scale. Since students’ individual discrepancies between ‘strongly agree’ and ‘agree’ will vary, the survey was scored in such a way as to treat ‘strongly agree’ and ‘agree’ as the same answer (similarly with ‘strongly disagree’ and ‘disagree’). If a student should skip a statement the survey was scored as if the statement
was not present on the student’s survey. The student must answer at least 90% of the questions on the survey in order for it to be scored. Pre/Post data was then analyzed and interpreted using the guidelines set forth within the survey design. Specifically, scores were analyzed using a paired \( t \) test. This allowed for analysis of pre/post data for each question on the CLASS survey. Special care was given to not assume that all changes in student beliefs are due purely to the instruction.

**Interviews**

A target of seven student interviews was chosen by the researcher. From the group of students agreeing to be interviewed, four students were selected based on their CLASS surveys. The two students with the greatest change in attitudes and two students with the smallest change in attitudes were purposefully selected in order to gain the best insight into the curriculum implementation. The remaining 3 students were chosen at random using a random number table and the alphabetical student roster of those students who have consented to participate in the videotaped interview and were not part of the previously defined group. The classroom teacher was also interviewed. The interviews were conducted within a two week period following the conclusion of the curriculum unit.

Following the steps defined by Strauss and Corbin (1998) the interviews were transcribed and coded so that themes could be developed by the researcher. This open coding was used to establish these general themes that emerged from the data collected. Then selective coding was used to build a story, “...that creates a discursive set of theoretical propositions regarding the process” (Strauss and Corbin, 1990; 1998). In
Figure 5 the coding of a study on curriculum development is presented. The central phenomenon is located at the center of the map with the other themes that emerged coded axially (Creswell, 2008, p. 460).

In the example in Figure 5 the central phenomenon being studied is the curriculum. The process of axial coding was used to determine that this central phenomenon had several
causal, intervening, and interactive conditions. These conditions were connected to the central phenomenon, as indicated in the diagram. The analysis also showed that contextual issues arose, but those only affected the interactions of those involved in forging the curriculum.

For this study, the open coding phase of the analysis will allow the data to be examined for salient information that is supported by the text. The researcher used a constant comparative approach such that saturation of occurrences can be identified and thus the new information needed is minimal (Creswell, 2008). This first phase will allow for the reduction of the data into a small set of themes that characterize the student and teacher views on the inquiry-based, concept related physics curricula.

**Analysis of Field Notes**

The data gathered in the field notes was analyzed. The comments written in the descriptive sections of the field notes were analyzed through a thorough literal reading of the data (Mason, 2002). Reading the descriptions for their literal content allows for the analysis of language, structure, content, form, and so on. This helps the researcher create a better picture of how events transpired within the classroom. The second sections of the notes, the reflections of the researcher, were analyzed for their interpretation. “An interpretive reading will involve you in construction or documenting a version of what you think the data mean or represent, or what you think you can infer from them” (Mason, 2002). By reading the notes in both a literal and interpretive fashion, the researcher intends to augment the profile that was generated based on the themes that emerged in the student and teacher interviews.
Analysis of Student Artifacts

Similarly, the student artifacts were reviewed both from a literal and interpretive perspective. Items collected were analyzed for not only what they represent, but the process by which they were created and collected. With these artifacts the researcher will not only categorize based upon their sensory value (visual, auditory, etc.) but also upon their production, use, or other meaning in relation to the research. In analyzing these objects the researcher gains access to the full range of meanings inherent within the objects chosen (Mason, 2002). For example, student responses in a lab report or worksheet can provide important insight into how they are processing or understanding a topic more so than a score on a multiple choice test question. Similarly, student projects that require students to demonstrate concepts or explain them to other students also give valuable insights into student thinking. Since the objects collected may contain multiple meanings, in both their production and resulting form, the use of these student artifacts provides an additional dimension of meaning to the study. Their analysis will also serve to further augment the profile generated.

Trustworthiness

Throughout the process of interviewing and coding, reliability was checked by identifying patterns consistent with each of the student interviewees as well as triangulation with researcher observation and pre/post test results. While validity is traditionally seen as the strength of qualitative research (Creswell, 1998; Wiersma and Jurs, 2005), it is still important to verify the accuracy of the findings from the viewpoint of the researcher and the participants (Creswell, 2003).
This was accomplished by incorporating ‘member-checking’ to determine the accuracy of the findings. One of the students interviewed was given the chance to review specific descriptions and themes that emerged from the study in order to determine whether they feel these items accurately represent their participation in the research (Creswell, 2003). Also, ‘negative or discrepant’ information was highlighted to verify the varying viewpoints of the individuals involved.

Finally, the researcher will clearly identify any bias they may bring to the study and through their self-reflection be sure to create an open and honest narrative (Creswell, 2008, 2003). In this way, the trustworthiness of the study was solidified in current qualitative practice.

**Personal Biography**

As a physics teacher for over fifteen years, I have seen my views on physics education evolve substantially. As a student of astronomy and physics at the University of Virginia I viewed physics primarily in terms of its mathematical elegance. During my training as a teacher at the Graduate School of Education at the University of Pennsylvania, I was exposed to the works of Dewey and others that helped me understand the nature of teaching and learning. As a teacher of high school students, I saw my view of physics shift away from mathematical elegance, to a more egalitarian understanding of the nature of matter and motion. In my educational journey, as both student and teacher, there seems to have always been a dichotomy between curriculum and understanding. As a student, curriculum was taught, regardless of understanding. I had a passion for learning, so when understanding didn’t arrive immediately, I pursued it with a vengeance. In teaching, curriculum is mandated, so when understanding does not
occur among the students, the teacher must sacrifice another part of the curriculum to engage in additional teaching. With supervisors suppressing teacher individuality in favor of a homogeneous experience across classes, choosing to engage in additional time creates problems for the teacher. As I sat in a physics curriculum meeting, one that treated the textbook as doctrine and current educational research as questionable, I began to see the necessity of incorporating research into the very basic question of physics curriculum; that is, what is being taught and how are we teaching it?

Much of the science-related curriculum research points to the adoption of inquiry specific, concept related curriculum. However, my personal experiences in my own school and with my own department supervisors over the years have led me to examine the process by which these reforms are disseminated, discussed, adopted, and implemented within my own secondary school district. This has also led me to the research being proposed here in order to identify common themes that may emerge as a function of this process.

**Ethical Considerations**

No individual names or personal information about the interviewees were stored by the researcher. When referring to the participants within the study, pseudonyms were used for both the participants and the school in which they operate. Transcriptions and tapes of the interviews were secured with the researcher until such time that the dissertation is complete, at which point they were destroyed. The anonymity of the participants was respected throughout the process as will their ability to withdraw from the study at any time.
CHAPTER 4: RESULTS

As presented in Chapter 1, the study documented here followed the implementation of a revised physics curriculum in a secondary high school setting. The research questions being investigated with this case study design was the following:

What is the impact, in a secondary physics classroom, of an inquiry-based, concept related physics curriculum’s effect on:

1. Attitudes of students toward physics.
2. Student’s application of physics knowledge.
3. The process of learning science.
4. The teacher’s perspective on teaching and learning physics.

This section will be organized based on these four questions and their relationship to the central research question.

A case study design was specifically chosen so as to best highlight the impact of the curriculum implementation on the students and the teacher. The researcher used many forms of data collected over the course of the research (see Table 4). The researcher observed teacher and student interactions over a ten week period and collected data from pre/post attitude survey results, student artifacts, and interviews. The researcher took detailed field notes on the interactions between the students, teacher, and the curriculum as well as analyzing documents and projects from the students that were typical of the intentions and applications of the curriculum.
Table 4 – Data Collection and Analysis Timeline

What is the impact, in a secondary physics classroom, of an inquiry-based concept related physics curriculum’s effect on:

<table>
<thead>
<tr>
<th>Research Sub-Questions</th>
<th>Method</th>
<th>Timeline</th>
<th>Analysis</th>
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<tbody>
<tr>
<td>1. Attitudes of students toward physics</td>
<td>CLASS Survey</td>
<td>Weeks 1-10</td>
<td>Survey results– Paired t test and Category %</td>
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<tr>
<td></td>
<td>Interviews</td>
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<td>Interview Analysis</td>
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<td>Observation</td>
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<td>2. Student’s application of physics knowledge</td>
<td>Interviews</td>
<td>Weeks 2-10</td>
<td>Interview Analysis</td>
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<tr>
<td></td>
<td>Student Artifacts</td>
<td>Week 11 – post curriculum</td>
<td>Artifact Analysis</td>
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<tr>
<td></td>
<td></td>
<td>interviews</td>
<td></td>
</tr>
<tr>
<td>3. The process of learning science</td>
<td>Interviews (student &amp; teacher)</td>
<td>Weeks 1-11</td>
<td>Interview Analysis</td>
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<tr>
<td></td>
<td>Student Artifacts</td>
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<td>Artifact Analysis</td>
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<td>Observer Analysis</td>
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<tr>
<td>4. The teacher’s perspective on teaching and learning physics.</td>
<td>Interview</td>
<td>Week 11</td>
<td>Interview Analysis</td>
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<td></td>
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<td>Observer Analysis</td>
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Site Setting

The name of the school has been changed as well as the names of individuals who participated in the study. Pseudonyms have been substituted and certain identifiable details omitted to protect the privacy and anonymity of the participants, all of whom, except for the teachers in the classroom, were minors at the time of the study.

This study took place at the Apollo High Schools located in the Southeastern part of New Jersey. The Apollo School District is a regional school district serving three
communities whose independent school districts do not have high schools. The Apollo school district consists of only 2 schools: the Apollo Intermediate High School and the Apollo Senior High School. Both buildings are connected at the same site and share resources. Each school, however, maintains an independent cafeteria, media center, and administrative staff. The study took place over 12 weeks beginning in February 2011 and finishing in April of 2011. The study took place in an ‘Accelerated level’ physics classroom.

Apollo Senior High School contains the original foundation of the school that was built on the site in the 1960s. As part of the development of the suburban region of New Jersey that grew in the latter part of the 20th century, this school was established as a small comprehensive high school to serve a mostly rural population. Over the years additional hallways and facilities were added to the building. In the early 1990s a bond issue allowed for the construction of an additional, comprehensive high school, attached to the current building. In 2000 several of the science classrooms in the Senior HS were renovated to allow for more progressive and laboratory based instruction in the sciences other than chemistry. The physics class observed inhabited one of these renovated classrooms.

A multitude of activities occur at the school building and on a typical day it is used for instruction during the normal school day and by athletic teams, co-curricular clubs, extra-curricular clubs, and community groups until late into the evening. Even some local college courses are taught at night within the school. The school fields, auditorium and courts are used by the community, with advanced reservation, and are also very active with both school and community groups.
The entrance to the Senior High School was recently renovated with a canopy and wheelchair accessible ramp added. Upon arrival in the morning the parking lot is very chaotic with a rhythm that catches the inexperienced driver off guard. Everyone seems to know where they are going and is very aggressive in getting there. There is a police officer directing traffic at the main entrance to the school. The officer helps to negotiate the busses, students, parents, and staff all trying to enter the parking lot and make it to their designated parking or drop-off locations during the 25 minutes before school starts.

The entrance to the Senior High School is very low key, without any signs that welcome or even direct visitors. There are small signs mounted high on the wall. The small foyer is the intersection of three different hallways, with one terminating at the doors to the outside. The principal’s office is located immediately to the right with a small sign on the door. Walking from the doors to the outside, visitors will eventually make it halfway down the long hallway and reach the main office. There are a few college recruitment posters on the door to the office and to the right of the main office door is a collage of student photos each with a caption noting that the pair in the pictures are “Most likely to appear on So You Think You Can Dance” or “Cutest Couple.” The secretary greets some teachers and staff as they enter the main office to sign-in, but not all. Everyone who works or visits the school is required to sign-in and wear an ID badge. It is noted, however, that while all the visitors wear this identification badge, only some staff members do so.

The school’s design has long hallways, which unlike elementary schools are wider and not lined with student work. The hallways are bare extensions of lockers, doors and room numbers with little signs at the intersections to aid in navigation. The
walk from the main office to the classroom is crowded with students talking about their
daily lives and problems as well as teachers trying to negotiate the student ‘traffic’ to get
to their classrooms before the homeroom bell. Occasionally smells of excessive cologne
as well as the locker odor of a student overdue for a shower or change of clothes come
across the researcher’s nose.

The hallways of this school were added at different times and thus create a bit of a
disjointed feeling. There are instances where one must walk outside to get to the other
half of the same hallway since the second half was built at a time different than the first.
This, especially in the winter time, creates a sudden chill every time you need to go from
a warm hallway to the outside for five steps, and then back inside. This created such a
discomfort for the researcher that he would, on severely inclement days, walk a much
more circuitous route in order to reach the classroom without having to walk outside
again. At the far end of the hallway is the student council bulletin board which has
occasional flyers for events that are coming up at the school: talent shows, school
musical, volunteer events, and so on. While some items on the bulletin board are current,
others have long expired. It is clear that the students are responsible for maintaining the
board since it is rarely up to date and the officer’s names and positions are displayed
excessively large and prominently within the display.

The classroom in which the research commenced was one which was remodeled
in the early 2000s. The room was clean and neat and had a few motivational posters
around the room. “What is popular is not always right, what is right is not always
popular!” “Bully Free Classroom.” What the researcher noticed first upon entering the
room is the narrow entrance that must be negotiated. The teacher lecture and
demonstration table has been extended to allow for a teacher computer station and therefore invades the entry way a bit. Immediately to the left upon entering is one of the lab stations and cabinets that surround the perimeter of the room. Each station has counter top and a shared faucet, gas jets, a sink, and many cabinets. The center of the room is filled with student desks. These desks have a separate desk portion and a separate seat. Unlike many of the other science classroom in the building, the separate chairs and desks allow for them to be simply rearranged as necessary during lab activities. While this was not directly observed, the researcher can imagine instances, when teaching topics of motion, that the chairs and desks could be pushed to the side to allow for carts and buggies to be used effectively over longer distances to measure quantities of speed, distance, and acceleration.

At the front of the room is not the traditional blackboard but a white board installed during the classroom remodel. The white board is also the screen for the classroom projector that hangs, quite intrusively from the ceiling and is positioned about 1/3 of the way from the far end of the teacher demonstration table. To the left, when looking from the student’s view, of the teacher demonstration table is the teacher’s desk, which is filled with paper holders of varying sizes and efficiency. Everything is neatly organized and stored in one of these holders on the teacher desk. Against the wall, also hanging from the ceiling is a large, tube based, 27-inch television. Every classroom in the school has a working television that is connected to the schools’ television studio. Morning announcements are broadcast every morning on the television with students from the TV/ Media classes taking turns as the anchors reading the daily list of events and announcements.
At each of the six lab stations that border to the long walls of the room there are older eMac computers (Figure 6). These computers are the replacements for the original computers installed during the renovation but are not the latest in technology in the school. In fact, when it came time to use the Energy Foresight CD-ROM for the power generation project, the class had to be relocated to the library computer lab since the computers in the classroom were unable to execute the CD-ROM, which was developed in 2005. The back of the room was bare except for a cabinet that contained an emergency shower in the center of the back wall with a drain in the floor directly below it. Also in the far right hand corner of the room, behind the last lab station was a large wooden structure used to demonstrate that for a marble rolling down a hill, the amount of kinetic energy the marble has at the bottom is independent of its path. It has a slant with an even slope and a second more curved shaped slope. The device is narrow but is approximately 6 feet long. Various remnants of other projects and demonstrations are littered about the room along the perimeter. A wire from a previous lab, bits of concrete block left over from a demonstration where the teacher lays on a bed of nails and has
another teacher use a sledge hammer to break the cinder block that lays on his stomach, and a large (12 foot long) wooden board, similar to the plank on a pirate ship, that is use to demonstrate torque. Also, at the lab stations there are the mice and keyboards for the computers in the room. Even with the above mentioned lab and demonstration remnants, the room is ordered and the rest of the lab surfaces are clean.

The location in the room from which the researcher observed the class, when not circling to view particular group work, was at the rear of the room. Seated slightly higher than a student desk, the researcher was able to sit on a lab stool that provided him with a view of the student’s actual work as they participate in the class. The researcher, having been seated in the back of the room, quickly became invisible to the students in the room. During the first several observations there were clear indications that the students were aware of his presence. They would glance back at the researcher if the teacher said something that was intended to be funny, to see if the researcher was laughing, or they would check back and look at the researcher with a pleading eye if they were intentionally not paying attention to the teacher in order to complete homework from a different class due after physics class. By the fourth observation by the researcher in the classroom these ‘acknowledgments’ of the researcher’s presence completely vanished. The only other time the researcher’s presents was distinguished was one time during the explanation of the final project where the teacher asked the researcher directly for clarification about the assignment.
Research Questions

Effects on attitudes toward physics and student application of physics knowledge.

As stated in Chapter three, several measures were utilized to assess the effect that the inquiry-based, concept related curriculum had on the students’ attitudes toward physics. They included the CLASS survey, student artifacts, and student interviews. The survey was administered prior to and immediately following the completion of the curriculum. Student artifacts were collected throughout the weeks of the curriculum implementation, and the student interviews were conducted immediately upon returning from the school’s Spring Break, which occurred close to the end of the curriculum implementation. This schedule provided an excellent opportunity for the researcher to allow the students some time and distance to reflect. The interviews being conducted a week and half after the completion of the curriculum provided impressions that were more likely to be lasting as opposed to immediate. Also, the ten day spring break meant that this distance could occur without any influences from a reversion back to the more traditional methods used in the classroom.

The CLASS survey was administered on the day prior to implementation of and on the last day of the curriculum implementation. The survey was administered in paper-and-pencil form with the students given ample time to complete the survey. The survey was then scored using two different independent methods. The first method involved scoring it according to the methods described in Chapter 3, and ascribed to by the survey’s creators. In this method the questions of the survey are categorized into 8 different, robust categories. The results for the pre-post CLASS survey based on category analysis are presented in Table 5. Seven students were also interviewed. Four
were selected based on their survey responses having the greatest and least amount of change. Three others were selected randomly. See Table 6 for identification of the students.

Table 5. Results from CLASS survey (N=12)

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre (% favorable)</th>
<th>Post (% favorable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Real World Connections</td>
<td>55</td>
<td>73</td>
</tr>
<tr>
<td>2. Personal Interest</td>
<td>55</td>
<td>64</td>
</tr>
<tr>
<td>3. Sense Making Effort</td>
<td>72</td>
<td>73</td>
</tr>
<tr>
<td>4. Conceptual Connections</td>
<td>46</td>
<td>64</td>
</tr>
<tr>
<td>5. Applied conceptual Understanding</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>6. Problem Solving - General</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>7. Problem Solving - Confidence</td>
<td>64</td>
<td>82</td>
</tr>
<tr>
<td>8. Problem Solving - Sophistication</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

Table 6  Students selected for interviews

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Type of Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sam</td>
<td>Largest Change</td>
</tr>
<tr>
<td>Mary</td>
<td>Largest Change</td>
</tr>
<tr>
<td>Julia</td>
<td>Smallest Change</td>
</tr>
<tr>
<td>Josh</td>
<td>Smallest Change</td>
</tr>
<tr>
<td>Joe</td>
<td>Random</td>
</tr>
<tr>
<td>Cindy</td>
<td>Random</td>
</tr>
<tr>
<td>Eric</td>
<td>Random</td>
</tr>
</tbody>
</table>
Several of the categories represent a shift in student attitude toward physics upon completion of the curriculum. A large shift occurred in Category 1, Real World Connections. This category seeks to isolate the questions on the survey that identify whether students’ are able and willing to make connections to what they learn in physics class to their outside life. This significant gain in students’ positive responses to questions such as: “Learning physics changes my ideas about how the world works”, “The subject of physics has little relation to what I experience in the real world” and “Reasoning skills used to understand physics can be helpful to me in my everyday life” provide direct evidence that the implementation of the inquiry-based real world curriculum has influenced the students. The amount of favorable responses to these questions increased from 55% prior to the curriculum implementation to 73% after.

Figure 7- Digital Multi-meter with probes in color
This increase was also evidenced in some of the activities inherent within the curriculum unit observed. One of the most notable instances was in week 3 of the unit where the teacher handed out electronic multi-meters to the students in the room. The multi-meter (Figure 7) was capable of measuring commercial grade electrical devices and was therefore safe to use on the standard outlets in the room. The teacher, after making sure each meter was set up correctly, so as not to damage the meter, instructed the students to stick each of the metal prongs of the wires attached to the meter into the two main plugs of the electrical outlets on the lab stations. The horror on some of the students’ faces was quite amusing for the teacher. Here, students were being challenged with something they had been taught from their earliest memories not to do, stick anything but a plug into an electrical socket. Many of the students couldn’t bring themselves to do it until one of the students, James, put the probes into the outlet on the lab table adjacent to his desk. Even he was hesitant and asked the teacher, “Is really okay for me to do this.” “Yes” was the response. “Really!?” “Yes” responded the teacher again. Only after several ‘checks’ was he willing to put the prongs into the outlet. Once James had gotten a reading successfully for the voltage of the outlet, 111 Volts, without getting injured, were the rest of the students, though still hesitant, willing to measure the line voltage of the electrical outlets in the room. This violation of a rule in turn allowed the students to make new connections to the notions of voltage and current that they had been studying in class to the real world usage of these terms.

Another instance in the curriculum that forced students to make real world connections was the Electricity Generation Project (EGP). In this project students had to choose from three distinct locations, one in the mountains, one suburban, and an island.
Each location was in need of a new power plant due to a recent natural disaster. Students had to examine the different types of power generation available to them and the benefits and problems associated with each of them. Students utilized the Energy Foresight CD-ROM (see Appendix I) to access videos about each type of power generation, the power delivery issues, and further background on the core problem for the project. The core problem for the project asked how we should meet the demand for power without continuing to harm the environment. Students were also required to calculate a monthly bill for the residents of the town they selected as well as catalogue their own electricity usage and what their own monthly bill would be. It was in this part of the project that some students felt the strongest connection.

During the interviews each of the students were asked if they thought that any of the knowledge they had gained in class would be useful outside of physics class. Sam noted, “Like when I had to find out like how many watts my…well, how much electricity my like generator uses at my house, I was able to figure that out with physics….it made me realize like how much electricity one person can really use in one month really.” For him, the connections to the world were direct and personal. Joe also felt that the project really helped connect what he was doing in class to the outside word:

“Actually, more so it was kind of was connected to my daily life when you really think about it, you know, considering the wattages in your house and, you know, just that stuff can be used to find out everyday kind of…I don't know really how to put this. Everyday kind of experiences you're going to have like for example your electric bill, you know, you can figure it out when you cement that chapter or so….like now I have a general idea of how much electricity something would
use and how much it would cost and it's a lot less than I would think something would cost. For like I use to think, you know, running your computer would cost a lot more than I found out what it really was. "

For Joe, doing this activity helped to cement the topic and ideas that he had been learning in class to his world outside of physics. The surprise for him was that each individual appliance might not have a large cost associated with that individual item. In Figure 8 we see an example of one student’s individual calculation for the average amount of electricity they use in a day.

Television – 240 W. (Use approximately 4 hours) 240 W. x 4 hours ÷ 1000 = .96 kWh
Computer – 50 W. (Use approximately 7 hours) 50 W. x 7 hours ÷ 1000 = .35 kWh
Refrigerator – 725 W. (Use approximately 24 hours) 725 W. x 24 hours ÷ 1000 = 17.4 kWh
Dishwasher – 1400 W. (Use approximately 1 hour) 1400 W. x 1 hour ÷ 1000 = 1.4 kWh
Phone Charger – 5 W. (Use approximately 24 hours) 5 W. x 24 hours ÷ 1000 = .12 kWh
Light – 100 W. (Use approximately 7 hours) 100 W. x 7 hours ÷ 1000 = .7 kWh
Vacuum Cleaner – 1200 W. (Use approximately 1 hour) 1200 W. x 1 hour ÷ 1000 = 1.2 kWh
TOTAL ELECTRICITY (in kWh) = 22.13 kWh
(.96 kWh + .35 kWh + 17.4 kWh + 1.4 kWh + .12 kWh + .7 kWh + 1.2 kWh = 22.13 kWh)

Figure 8 – Scanned Example of Student Energy Calculation

The research supports that better efforts commence to familiarize current and future secondary physics educators with the body of research that establishes the benefits of inquiry-based, concept related curriculum on physics students
Current world events at the time of the research also served to collide with the project. The EGP was occurring concurrently with the disaster that took place in Japan when a Tsunami caused untold destruction in the northern part of that country and wreaked havoc with the Fukushima Daiichi Nuclear power plant, where experts estimate that it will take almost three months to completely contain the radiation and nearly a year to completely cool the reactors. (Buerk, 2011) Needless to say, this collision of real world events and the students being given a choice of which type of power plant to choose served to reinforce the connections with the real world. One student commented specifically about Nuclear power in the interviews. When asked about how his choice in the EGP might have costs for the environment, Joe commented

“Yeah, I guess I see it like for example nuclear, while is cleaner for the environment for the most part with the exception of radiation or whatever, but you know. There's no fossil fuels though, but it is more expensive to run, you know, things like that. They definitely have their tradeoffs, so there is definitely a connection.”

Joe is actively connecting what he is doing in physics to the real world and beginning to understand the tradeoffs that are associated with making decisions.

Another instance where these real world connections occurred was during the in-class portions of the EGP project. During these portions students were escorted to the computer lab in order to work with the Energy Foresight (EF) CD-ROM. The CD-ROM contains an interactive menu (Appendix I) as well as short video clips that explain all the topics of electricity generation, transmission, and delivery to consumers. Upon initial
contact with the material the students were apprehensive about both the project and the use of the computer software. One student even commenting on the way to the lab for the first time, “This is stupid; do we have to do this?”

Upon arrival at the computer lab, the first time, students had to be walked through a more extensive process than typical to access the CD-ROM on the school’s network. This was due to the fact that the school uses Macintosh computers while the CD-ROM was developed for use with PCs. After complaining about the project and having to watch the videos, the students became very engaged. They were all very interested and asking questions to each other and the teacher. Most students did not do a systematic investigation of the EF videos. They explored the topics based on interest and even explored the power delivery infrastructure portion of the menu, which was not a direct part of the EGP. Some students were watching videos a second or third time, as they zeroed in on their choices for the EGP. When asked if he was surprised by anything he saw in the videos, Jack responded, “Yes, I did not know that you use like the earth's natural resources so much to like power all these different things just by using generation and things like that. I always thought the like you had to use fuel for certain things.”

Category 2, Personal Interest, seemed to have an increase yet the percentages did not fall outside of the margin of error. The category, which contains questions like “I think about the physics I experience in everyday life” and “I study physics to learn knowledge that will be useful in my life outside of school”, contained very polarized responses from the students. This is evidenced by the fact that in the pre-test, only 1 student’s response labeled themselves as neutral and while several others, 55%, were in the ‘strongly agree/disagree’ portion of the scale. The visceral responses of the students
reveal that their feelings and preconceived notions are one of the factors that can account

for this category containing the largest error value. However, the result is still of note because of the movement that occurred in several students. Also, it highlights the fact that inquiry-based real world curriculum does not seem to detract from personal interest and contains the potential to not only influence attitude but interest as well. For example, one of the projects the students engaged in was the electricity generation project. Here students were forced to calculate their own energy usage. While several students were initially intimidated by the scope of the project, the notion of finding out how much electrical energy they used in a day ‘individually’ intrigued them.

Mary specifically found that one part of an inquiry activity called the tape lab was particularly interesting to her. In the lab students use simple transparent tape, like that

Figure 9- Bouncing ball in Tape Lab
used to mend dollar bills or wrap presents, and charge two strips of tape so that each one has an opposite charge. Also, they charge simple objects like aluminum pie tins and Styrofoam plates to see how objects interact. When asked about the lab Mary recalls, “I remember like we did really cool things. One we put…I forget what we did, we put tape like near a ball and the ball kept bouncing back and forth with my finger. That was cool.” The set-up, pictured in Figure 9, shows the activity Mary was referring to. In the activity the students charged the pie plate and then the aluminum foil ball would bounce back and forth between the hand the pie tin. The explanation for this is that the tin transfers excess electrons to the ball, which is now charged the same as the pie tin. Since like charges repel, the ball then touches the hand, discharges any excess electrons, becomes neutral, and then swings back to touch the tin and the process begins all over again. As Mary put it in the interview some weeks later when asked if she remembered why the ball moved, “The electrons bouncing back and forth?” which on a conceptual level is exactly what is happening in that activity. When asked about the EGP, Mary commented, “At first I didn't understand it and then I think once like…like I was explained again I understood it and it was interesting to see…How much electricity that everyone uses.”

Another student, Julia, noted that it was because of her experience in physics class that she was leaning toward becoming an engineer.

Interviewer: Okay. Do you think that the physics knowledge you've gained over the course of the year will be useful in your life outside of school?
Julia: Definitely, I want to become an engineer so, yeah. Definitely.

Interviewer: Cool. To follow up to that, if you're interested in going into engineering, can I ask why you choose accelerated physics instead of honors physics?

Julia: Because I didn't really decide that until like halfway through this year.

Interviewer: Was it something in the physics class or physics itself that helped that decision?

Julia: Yeah, a little bit. I really like the curriculum and I like learning about the stuff that we were doing now. So, it's just a thought. I don't definitely want to be an engineer

Julia’s exposure to physics and its curriculum was crucial to her decision to possibly continue with science, a notion that did not occur to her prior to the course. It is also worth noting that Julia’s solidification of her ideas about becoming an engineer occurred during the implementation of the electricity and magnetism curriculum.

Category 4, Conceptual Connections, also showed significant increase in favorable responses. Student responses here indicate that they are reinforcing their conceptual connections and deemphasizing the importance of memorizing and manipulating specific equations. As noted in Chapter 3, students at this level of physics have selected themselves to be ‘college preparatory’ and have also chosen to not take the algebra based ‘honors’ level physics. This choice has put them on a path that diverges
from the traditional scientific degree path, and it can be assumed, for a significant number of the students in this course, that this may be their first and possibly last physics class. Thus, their aversion to mathematical based physics instruction comes as no surprise. What is important to note is that what has changed is their realization that physics can be conceptual in nature, that is, you can understand physics concepts without specifically focusing on the mathematics.

In one instance the teacher implemented an inquiry-based lesson on wiring electrical outlets and switches in series. Instead of using models and alternate equipment the teacher brought in real outlets, switches, and commercial electrical wire he had purchased at The Home Depot. The researcher observed an immediate increase in the level of attention and engagement of the students. Comments around the room ranged from “Is this really what’s in my house?” to “Isn’t it dangerous for us to be playing with this?” The students spent the majority of the period wiring up the switches and outlets, using wire cutters and screw drivers, so that the teacher would plug a light into the outlet the student had wired. Then he would connect their outlet to the AC outlets in the room, to see if the student had wired the switch correctly. (See Figure 10 for equipment). The notion of using actual commercial equipment stunned many of the students. Julia, a junior, noted during class how difficult it was to work with the real equipment. “I never really got how difficult it might be. We always worked with easy wires and stuff. But real electricians have to work with this stuff [industrial electrical wire with shielding] and it’s like hard to move and cut.”

The level of investment of the students was easily noted by the level of frustration they encountered as they worked. Students were diligently at work thought out the
period. The researcher noted the various expletives he heard students mutter as they tried to get the wires connected correctly, but also noted the sheer joy they exhibited with their smiles and high fives when they connected their circuit and it worked. Sam, a junior, noted in class, “Holy crap, it worked.”

Students also spent several class periods working on inquiry-based projects, such as the pizza box circuit. In this assignment students are asked to combine the concepts they have discussed in the classroom on series and parallel wiring, as well as the electrical box wiring activity discussed above and create their own working circuit with several switches, circuits in series and parallel configurations as well as a master cut off switch to control all the lights. The materials used are simple tungsten based Christmas lights, paper clips, wires, and brass fasteners. Students diagram their own circuits on the inside of the pizza box lid and then have the lights and switches placed so that they poke through the lid, creating a similar effect as what one would find in the home where the wires and connections are behind the wall and only the lights and switches are seen. This
inquiry-based project had students making actual electrical connections while forming the conceptual connection of how the wires in their home are connected behind the walls and the notion of circuit-breakers in the house and their ability to cut off power to lights and switches in the home. (Figure 11)

While working on these boxes in class students had varying degrees of success and help. In the project the students must first create a correct schematic diagram of the circuit by using proper diagraming technique. Students then copy that diagram onto the inside lid of the pizza box. Students then gather their materials and have to cut the lights out of a strand of Christmas lights in order to have individual bulbs that can be connected and wired into place. By physically working with the materials it is clear that some students are making strong conceptual connections to the concepts of current and voltage.
while others may not be. For example, Lauren explains to Julia why she is only using scotch tape to tape down her wires and electrical tape for her connections. “There is a difference and you can't use scotch tape for the connections, only electrical tape.” She is partially incorrect. For the relatively low amounts of electrical current that will flow through these circuits, the thin transparent tape and the vinyl electrical tape will both be sufficient insulators to protect the connections from unwanted contact with other parts of the circuit. She was correct though in the concept that the connections must be shielded with insulators so as not interfere with other parts of the circuit. Lauren’s notion is related to the inquiry lab the students did prior to the pizza box circuits lab in which students charged different pieces of transparent tape in order to investigate whether or not different objects are electrically charged. Students were able to correctly identify plastic and Styrofoam as insulating materials, and began to conceptualize the notion that since they are holding the charged transparent tape, and the since charge is not being conducted to their skin by the tape, that the transparent tape is also an insulating material. While this concept was noted in the lab, it is important to see that it was not successfully transferred completely to the next major activity by the student as she felt that the tape would be insufficient to be used to hold the stripped down wire together.

Other students made stronger connections. As Mary noted in her interview, the Pizza box project helped her out over spring break.

“Well, I learned about like even just wires and stuff like that and last week, in my garage we have a thing that like…it you walk it stops the garage so the wire was loose so my parents had no idea what to do and I
tried to twist it and then as soon as I saw like, I touched it, the light went off so I just remember that was right.”

For Sam, he felt the conceptual connections were always there. “A lot of the topics are kind of like flow with each other, a lot of things are connected in a way.” And for Jack, “I think they all relate like somehow like the equations and stuff like that. Like it all like fits together somehow.” All of these students are in various stages of solidifying their conceptual connections between the topics in physics and their relation to those things in the outside world.

The last category that showed a significant difference was category 8, Problem Solving – Confidence. This category contained questions such as, “If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works” “Nearly everyone is capable of understanding physics if they work at it” and “I can usually figure out a way to solve physics problems.” This gain in problem solving confidence might explain the students’ attitudes toward physics in an important way. By acknowledging physics as a subject that everyone can understand if they work at it the students are reshaping their ideas about the difficulty of the subject. Several students remarked at the introduction of the pizza box project that it was, “impossible to do” and that “I’m going to fail.” However, everyone in attendance in class for the three working days of the project and those who attended after school help finished the project and received an 85% or better on the project. These gut reactions of the students did not speak to the fact that by wiring the real switches and outlets in the activities previously they had formed the conceptual basis for completing the pizza box project. Having completed the pizza box project successfully had given the students additional confidence
such that when the final project, the Electricity Generation Project (EGP) was announced and explained to the class, there were no such statements with regard to whether or not they were capable of completing the project, just grumblings about having to complete it. Students by the end of the revised curriculum were more willing to engage and be engaged by physics concepts.

**Alternate analysis of the CLASS survey.**

Another verification of the changes discussed is the second way in which the CLASS survey was analyzed. Since the survey was administer on a 5 point Likert scale pre and post scores could be analyzed using a paired $t$ test. By entering the raw student numbers to every question for both the pre and post-tests a paired t-test was performed using the SPSS software to determine if there were any questions by which the researcher could be 95% certain ($\alpha=0.05$) that the change in survey score was due to factors other than random variance. When the paired $t$ test was run on the class a whole, none of the questions fell within this 95% confidence interval. There were several questions which had values close to $\alpha=0.05$ but none were below this threshold. This encouraged the researcher to perform a gender analysis on the data sample in order to determine if any of the questions fell within the 95% confidence interval for all the participating males or females in the study. In both instances, six males and six females, there were three questions whose variance from pre to post test could not be attributed to random variance alone. Interestingly enough, they were different questions for each gender.

For the male students ($N=6$), three of the questions were of note in the paired $t$ test. The first question was “Nearly everyone is capable of understanding physics if they
work at it.” For this question there was a significant difference in the scores for the pre-test ($M=3.17$, $SD=1.14$) and the post test ($M=4.33$, $SD=.81$); $t(5)=-2.09$, $p=0.034$, $d=1.57$. Suggesting that, for the male students, their individual views about themselves as well as everyone’s ability to understand physics had shifted in the positive direction.

The second question with a significant difference in scores was “To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.” For this question the scores were for the pre-test ($M=2.33$, $SD=1.21$) and the post-test ($M=3.50$, $SD=1.05$); $t(5)=-3.77$, $p=0.013$, $d=1.68$. These scores suggest that the male students’ attitude toward the application of physics in their everyday lives is more relevant to them after their exposure to the curriculum compared to its onset. The third question of significance for the male students saw a trend in the opposite direction. The question “Learning physics changes my ideas about how the world works” had a pre-test value of ($M=4.17$, $SD=0.41$) and a post-test value of ($M=3.00$, $SD=0.82$); $t(5)=2.907$, $p=0.034$, $d=1.03$. The reduction in favorability here suggests a comfort with the material as it merges with the student’s self-concept of how the world works. This is evidenced by Jack’s comment to the same question in his interview. “Not so much, cause like I had other science classes before and it's kind of like the stuck the same thing...[the E&M curriculum] showed me like other ideas of power sources that could be used and like how you can save energy and use more while saving it too.” Jack’s comments seem to indicate that, for him, he arrived in physics with a strong conception of how the world works and used physics to solidify that view as well as augment it with new information. While other male students did note that other things in physics from earlier in the year, like ‘string theory’, did change their conceptions of the world, the E&M curriculum did
not. This suggests to the researcher that the accessibility and comfort that many students reported with the E&M curriculum served to increase their comfort with their own concepts of how the world works and therefore decreased their agreement that physics causes them to change that perception.

The female students ($N=6$) saw significant changes on two questions. The questions for the females were different than those for the male students. The first question, “If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it,” saw a notable change from the pre-test ($M=4.00, SD=0.63$) to the post-test ($M=2.83, SD=1.3$); $t(5)=3.80, p=0.013, d=1.22$. This change suggests that prior to the implementation of the curriculum students viewed understanding topics in physics as something they either understood, or did not. After the curriculum, more of the female students seem to feel that there are things in the real world that they can relate these physics problems to in order to help them solve the problems. The second question of note was, “I enjoy solving physics problems.” This question saw a decline in the scores with the pre-test ($M=3.17, SD=0.98$) and the post-test ($M=2.5, SD=1.38$); $t(5)=3.1, p=0.025, d=0.55$. This decline suggests a decrease in positive attitude toward solving physics problems, however the vagueness of the questions fails to separate mathematical problems from conceptual ones. In the interviews that followed up the survey results it was made clear by several of the female students that it definitely depended on the nature of the problem. Mary said that she enjoyed solving physics problems, “Sometimes. Easy ones, not the hard ones.” When pressed about what made a problem easy or hard, Mary reposed that it was the mathematics. Cindy responded simply, “No.” When pressed to explain she said,
“Because it’s a like a lot of math and I’m not really good at math.” Cindy’s response emphasizes the point that students may be interpreting this question very differently and so its decline in favorability may very well not be very significant with regard to the teaching and learning in the classroom with the singular question in its current form.

This type of curriculum, challenging students with inquiry-based projects that have real world connections forces students to address their current beliefs and attitudes about physics. Significant movement in four of the eight categories mentioned above in the CLASS survey serve as evidence that a shift in attitudes occurred and that it may be in part attributable to the curriculum and its implementation within the classroom.

**The Process of Learning Science**

Approaches to learning science that conform lockstep to traditional activities work against the important concepts of observation, imagination and reasoning. When students learn in inquiry-based settings, it allows learning to supersede merely the application of scientific knowledge and move into the realm of its generation and application. This was observed in several instances with the inquiry-based real world curriculum.

The first inquiry-based activity the students engaged in was the scotch tape lab. In this activity students used common household materials in order to investigate the properties of static electricity by charging these objects using wool and silk in order to see first-hand how opposite charges attract and repel. The charged pieces of tape attract to each other and either attract or repel from certain objects in the room. While observing both the students and teacher, there was significant interest among the students. They
were actively engaged in the lab after the teacher showed them how to charge the tape. At one point Mr. Taylor, the teacher, is stopped by a student with a question. “Is it one electron that is transferring? Is that why its charged?” Mr. Taylor responds, “That’s a good way to think about it.” The teacher is encouraging the student’s conception of how the tape and other objects are getting charged, and it is reinforcing the concepts of the activity. As the lab continues Mr. Taylor remarks, as some students are getting really high static charges due to the dry cold weather, “Oh, hey, you guys are doing this better than me!” This type of encouragement engages the students even further and helps to refocus the class as they had begun to wander off topic in some of their group conversations.

Interestingly enough one group consisting of Jack, Eric, and Mary, though not working, is talking about their experiences with electricity in elementary school, namely, testing a 9-Volt battery with their tongue and feeling it tingle. Mary reacts with horror at the notion of sticking a battery on her tongue but the boys just laugh about it. This is interesting to note because it is occurring in the section of lab where they are charging a Styrofoam plate in order to use it to light a small neon light bulb, which flashes for an instant. It is the brief flash of light that sparks the interest of the students and allows for the connection to their childhood. Students seem to conceptually understand what is going on but are not very verbal in their ability to express what is exactly happening.

In one portion of the lab students observe a small aluminum ball bouncing back and forth from a metal pie tin that has been charged. The ball bounces very quickly which surprises many of the students when they get it to function properly. When asked to describe what’s happening Sam writes, in Figure12, that both the ball and tin are charged.
She has successfully observed that what appears to be happening is some type of back and forth motion that implies that both the ball and pie tin are charged. This is true, however there are things at work in this particular instance that will be uncovered as topics like polarization and induction are introduced in the chapter. The important thing is that Sam has interacted and conceptualized the notion that objects attract and repel when they are both charged and learned later in the lab that objects that are neutral can behave as if they were charged.

The portion of the lab that introduces this notion of induction occurs towards the very end. In this section the students charge a rod and then place it near a neutrally charged soda can that is free to roll along its long edge. The students were very excited
to wield their ‘magic wands’, so to speak, and make the can roll toward the edge of the table and in some cases fall the ground. It is at this point in the lab that students begin to understand the nature of the concept of induction and how charged objects can make neutral objects, like the aluminum can, behave as if they were charged. For the students, the concept was solidified not though lecture and regurgitation on an exam but by physically interacting with the materials in the lab.

Another activity that was contrary to the traditional activities to which students had been previously exposed was the Dog Collar Activity. In this activity, students are given a set of circumstances that require them to create a dog collar that lights up using either red and white or green and white tungsten based Christmas lights and that also conforms to a pre-determined set of conditions: including being adjustable, comfortable, easy to replace the battery, and sturdily constructed. Students are also given a rubric by which their score on the activity will be determined. The students are given a ‘starter kit’ that consists of lights, wires, tape, a 9 Volt battery, a battery cap with lead wires, and a meter of pink insulating material. They are also given 15 credits for purchasing additional items from the ‘store’ that include more lights, wire, tape, a help sheet, and additional collar material. Now, at this point in the curriculum the students have not been taught how to light a bulb, connect wires, or the proper way in which circuits need to be constructed (the concept of a closed loop). Students are simply given the conditions of the project, the task they have to complete, and are left on their own to work on the project.

Upon initial discussion at the beginning of the project the teacher put the students into groups of three or four. The student groups were a bit hesitant to begin the
assignment. As the teacher handed out the starter kit materials the students groups began to actively engage in discussion and pre-planning for the project. Group 1, consisting of Josh, Jack, and Mary, had particularly strong discussion about the wiring of the collar. This was after they had initial failure and then success in lighting an individual light. "Do you think it matters how we connect them?" was Josh’s question to the group as he began to line up the lights in a line. “I don’t know,” replied Mary, “let’s see.” At this point the group begins connecting the lights in what is known as a series circuit, where there is only one path for the current from the battery, through the lights, before its return to the battery. When they have all the lights connected together, they are stumped about how to get them to light up. At this point Josh, who has taken the lead role of manipulating the materials, grabs a wire and connects the back end of the last bulb in the chain back to the other lead from the battery. Their lights light up and they give each other high fives and there are smiles throughout the group. Their collar (Figure 13) was typical of the collars for the class.
The students had this to say about the Dog Collar Activity:

“It was good. It was nice to accomplish it.”

“Yeah, I liked them [dog collar and other projects].”

“It went pretty smooth for the most part.”

“It was more challenging than I thought it would be. I didn't think that just a 9 volt battery would be able to get the job done, but then I was like able to figure that electricity is able to be transferred from like little copper wires able to power all those lights.”

“Well to be honest, I was absent for a couple of the days so when I got back I only noticed my group made me wear the dog collar.”
“Just like…I guess taught us like how to connect like wires I guess with each other like with each other and…connect that to a battery I guess…I mean…It was alright. It wasn't bad. I liked it.”

“Yeah, that was one a little different. I never did one like that before about lighting the collar up around the dog to keep it alive or something. Yeah, that was interesting. It showed how like you had to connect the wires.”

What was also visible in the students when they got their collars working or were demonstrating how they work to the class was the pride in their work and the smiles on the faces. This activity, by replacing an introductory lesson on the wiring of electric circuits, had taught them the same skills and provided them a context by which those skills could be applied. The teacher commented that he viewed this as one of the strengths of the project. “Now I like the first activity, the dog collar, what it did for them is it made them…build circuits without thinking about, learning about the circuits.” The teacher also commented that the students performed better in subsequent laboratories that included circuits and wiring because of their experiences with the dog collar activity.

These types of activities were different from the ways that the students had been learning science during the previous parts of the year. Most of the students interviewed felt a difference in the way they were learning science in the revised curriculum versus the preceding portions of the year.

“It was a lot more like experiments than it was in the previous units, but as for learning it, it's pretty much been the same for me….I feel like I learned
it better with all the experiments, because it was more of a hands on approach. I had to…I had to like learn what I knew instead of just like cramming it in the day before. Like I had to just keep working and working at this unit to get the project right as opposed to a test where I just crammed the day before and somehow managed to get a good grade.”

Sam’s comments here suggest very strongly that his process of learning science was changed in the curriculum unit being studied. Prior to this curriculum unit, he just ‘crammed’ the night before in order to pass a traditional assessment. With inquiry-based projects and real world connections, he was forced to ‘learn what he knew.’ Mary noted this as well in that she said, “We did a lot more labs than like yeah, and projects. I think it was a nice change from like what we usually did.”

For several students, the effect of the curriculum change on their own sense of their own learning was more dramatic. For Eric, the adjusted curriculum was a real difference. “I’ve gotten better than everything else. Like, I’ve understood it more, like understand it more. I just feel like it was easier for me.” For Jack, he felt that the new curriculum was much better because, “…We did like more like group activities and I learned more from other people and plus what you gave us to do on it like I used that to like see more areas of that subject before [the teacher] just did straight out like the book.” He also commented that he felt that compared to the rest of the year it was, “Easier. A lot easier, actually.” Cindy commented as well that the curriculum, “Well, it seemed a lot easier than the stuff that we learned before, like it was one of the easiest units that we learned.” This is significant as electricity and magnetism are often viewed as one of the
more difficult topics in elementary physics. For these students, the process of learning science took on a new dimension in the curriculum unit. Eric sums it up:

“I think it was easier, because you worked with other people so it was more ideas coming to the table than more just your idea thinking it was wrong and you really could have been right. You just needed like another person to tell you that it could have been right whereas if you did it on your own, sometimes you think nah, this can't be right cause it like doesn't seem like it's right, but most of the times that your right in physics. …I like the projects more so I guess it kind of helped me better understand the subject, because I was actually doing it instead of just reading about it. So, I actually had to physically put the wire things together and things like that. So I thought that was interesting.”

For Eric, the way he learned science required of him others to bounce ideas off of and not to just be relying on his own in an isolated environment. Interestingly, Eric is saying that he learns science best the way that science is actually done in the real world. He is better when he is working on real world projects where he has others to bounce his ideas off of and provide him with feedback as their work progresses.

Now not all students perceived so dramatic a difference between the revised curriculum unit and the previous parts of the year. When asked to give a response about differences they may have noticed between the revised curriculum for E&M compared to the rest of the year a couple of students responded in the following way:
“There was definitely more projects for the electricity and magnetism unit, but not as much. No, I mean it's presented very similarly I should say and it’s a lot hands on working, a lot of math work usually, but that applies to pretty much everything I would say. So, that's pretty universal.”

“I’d say we did a little bit less of the visual stuff, because he usually does a lot of like examples.”

“Not necessarily no, because I mean there's still a lot of information, you know, none the less.”

For these students, the revised curriculum did not seem to deviate from the way they had been learning physics, they had perceived no real change. While they had not perceived a change, none of the students above felt that it was detrimental to their learning. In fact, none of the students interviewed stated in any way that the felt the way in which they had learned physics in the electricity and magnetism unit left them with a shallow or incomplete understanding of the topic. None of them stated that it was harder or more difficult to understand. Nor did they complain that physics was harder because of the inquiry-based concept related curriculum.

In fact, the teacher did not give a traditional topical assessment at the end of the unit, instead counting the EGP as their final grade. He did this in order to synchronize his class that was running the curriculum with the other Accelerated Physics classes he teaches during the day since he did not choose to implement the revised curriculum in all of his classes. Mary was asked in a follow-up question if she felt any less confident about the material since she didn’t have that traditional final assessment but the EGP
instead. She responded, “No. No, I felt like the project was pretty decent. I mean tests are always like but the tests are just what we've already learned, so.” For Mary, and many of the other students, the lack of a traditional formal assessment did not inhibit their understanding of the material.

The teacher is not so sure. When asked directly if he felt that students understood the same amount, he stated that without the traditional assessment, he couldn’t be sure. What the teacher is failing to question is whether the traditional assessment was an accurate measure of what the students were learning or simply a measure of what they were able to cram the night before. It is clear from the student comments that several students felt a profound difference and that they experienced much greater understanding under the revised the curriculum.

**Teacher attitudes towards teaching and learning physics.**

Mr. Taylor is a 10+ year veteran of teaching Physics. He has a strong reputation in the school and the community and has been teaching both the Accelerated level and the School’s Advanced Placement level physics since his arrival in the district. When approached about participating in the study Mr. Taylor was initially a bit apprehensive, having seen many initiatives come and go within the school over the years. However, upon examining the curriculum and discussing its nuances with the researcher, he felt that it was similar enough to his own view of how he was teaching the material that it would not create an undue burden on himself or his students.

Mr. Taylor’s attitudes toward science and physics developed at a young age. He grew up in a working class neighborhood in the suburbs of Philadelphia, Pennsylvania.
I had my neighbor; a couple of doors down from my house was a great physicist. He designed; he invented the photo-responsive circuit. He was one of the pioneers of fiber optics and orthoscopic surgery, and all that. I was just, remember that my dad thought he was the greatest when I was real little…so I always wanted to be a physicist too. As growing up, my dad always pushed it. Physics, Physics, Physics, science and my cousin was a scientist, and it just seemed natural that, you know, that was what I was gonna do. I liked science, I do science, I do science ‘cause that’s what I did.

His working philosophy of the importance of physics stems from his belief that physics is the, “Study of how everything works. It’s the fundamental laws of the universe.” He also considers mathematics to be the ‘language’ of physics and therefore integral to the understanding of the subject. In fact he views the students’ issues with mathematics to be the biggest difficulty in teaching the accelerated level of physics at the school. It’s an issue because, at the accelerated level, “…kids can be at any of the levels of math ability, we’ve got the kids who can walk right through the math, and a lot of kids who don’t really get math.” For Mr. Taylor the student’s math ability is central to their ultimate understanding of physics. He notes:

“You can understand a lot without the math, but there’s a certain point where you’re not going to get past it unless you can see, that you can actually do the math in your head. If it’s all done on paper and all done on calculators then you can’t process it fast enough to see relationships.”
His comment about the ability to process the information is an interesting one. For him, the ability to process the physics concepts being presented on the board requires of the students the ability to do the math in their heads so that they can follow along. This follows from the method he was taught physics as a student. He came from a very traditional physics instruction background and describes it like this:

“I was taught physics like this: You come in, the teacher says write the homework on the board, we put the homework problems on the board, we go over the homework problems, and that’s it.”

Now, he goes further to elaborate that this is not the way he feels that students learn physics best. For Mr. Taylor, he feels that students learn physics best when they are working with both the concepts and their physical manifestations at that same time. For him, when students are working with lab materials and simultaneously working with the equations, they will learn physics better. “I think it causes you to focus on the physics of it and the more formal side of the problem, reading and interpreting the problem, and then seeing the physical manifestation of the problem, simultaneously.”

This emphasis on the requirement of mathematics for the understanding and appreciation of physics is one of the issues the inquiry-based, concept related curriculum attempts to work through. In fact, when asked if he felt the revised curriculum helped him to use the strategy that he favored, or did it work against it, he replied, “They worked with them. They enhanced them, they were good.” Mr. Taylor made the point several times that the revised curriculum was not altogether different than what he includes in his curriculum with other topics in physics. For the mathematically minded students, and in this case the teacher, this may very well be so.
However, it is interesting to note that during the course of the curriculum, Mr. Taylor’s attention was not always on his students, especially during the inquiry-based portions of the curriculum. While he did do several of the mini-type labs that he discussed; in several instances during the dog collar, pizza box, and EGP portions of the curriculum the teacher was not actively engaged in the inquiry lesson. For example, at the initiation of the dog collar lab Mr. Taylor was not prepared with the starter kits necessary for each of the groups. At the beginning of the activity he instructed students to pre-plan while he handed out materials. Other times during the activities he could be found at his computer looking up periodically but not actively engaged with the students in the activity, or sometimes speaking with other faculty members. As noted in the researcher’s log, this allowed the students to lose a bit of their focus on the projects. What was clear was that while some of the students were completely engaged in the project, Mr. Taylor was not.

Now, the level of engagement of the students of Mr. Taylor was significantly greater with the wiring a switch lab activity mentioned above as well as with the pizza box project compared to when the researcher observed the students during times where the teacher was performing traditional lecture and demonstration. In those instances, during the traditional lecture and demonstration only about half of the students were actively engaged in the lesson. The teacher would notice this fact by saying things like, “Now pay attention to this part” or “Take a look up here.”

Now during two of the inquiry-based projects, the switches and the pizza box, the engagement of the students was high. In those instances there were strong connections and interactions with the students that helped to propagate the activities and
the teacher himself would be actively involved and would question students during lulls in the class period as well as encourage the students who were getting discouraged or frustrated during the activities. In one instance, while one student was having a particularly difficult time diagraming the circuit on the inside of the pizza box, Mr. Taylor, called the student up to the front of the room and once again walked him through the requirements of the project and the identified the problems in the student’s diagram.

During the Electricity Generation Project (EGP), the teacher was not prepared. He did not pre-attempt the project so as to identify potential issues and questions his students might have, nor did he preview the Energy Foresight CD-ROM program, so as to help students navigate their way through the program to find the information they needed. During most of the time in the computer lab with the class, until the very last class observed, he would be found at his computer or grading papers. However, during the last class observed Mr. Taylor was actively engaged with several groups answering questions about their projects. They had questions for him and spirited discussions about the nature of the group’s choices and the ramifications of those choices on their final cost figures. These types of conversations commenced throughout the period. Mr. Taylor’s appreciation for the project was reflected in the comment he made during his interview:

“So it’s actually kinda nice in the way that a power plant is way of applying science and all the different obstacles that would come about I think you have to consider when you apply it on this scale and I guess they did get to see the relationships especially between the energy conservations and stuff.”
Mr. Taylor noted the benefits of the project and the potential benefit of this curriculum to his students. He did, however, feel that it would be detrimental for students going on to college for study in the sciences. When asked if he felt that this type of inquiry-based, concept related curriculum would be good for students even if it didn’t cover as many topics as a traditional physics class he responded:

“Yeah you would definitely benefit from it, but you should do it parallel or as a separate class because I think if you do it in place of it, that will hurt you as you move on in science. Because you’ll miss a lot of stuff.”

When pressed about how many of his Accelerated Level Physics students he expected to move onto a career in the sciences, let alone take physics class in college, he replied:

“That’s a good point you’re making, and that’s what I was gonna say. That’s actually not bad for the students who are not going into formal science. Like someone who is not going to be an engineering major or has gotta take freshman physics 101 next year; they’d be at a disadvantage if they only had done this.”

What is interesting to note is that while the majority of the students in the accelerated level may not take physics classes in college, the ones that do will have had additional mathematics under their belts before they attempt such a class. Essentially Mr. Taylor, like many other physics teachers, feels that they must include the mathematics and the mathematical problem based focus of physics because otherwise they feel they are doing a disservice to their students. The research conducted thus far shows this not to be the case. In fact, as the students stated, it shows that students who experience physics in these inquiry-based, concept related curricula do just as well, if not better, when they
arrive at college because even though they may not have been exposed to as many topics, they have a deeper understanding and more confidence about the topics they covered in the curriculum.

Mr. Taylor then concludes the interview by saying that in his opinion this type of inquiry-based concept related curriculum should be relegated to the lowest level of physics in the school (the ones whose population is most likely bound for community college, the military, or no further education). “Not because [the inquiry activities] are of low quality, just because, I’m thinking maybe it might be better if you’re not good enough at science to take the accelerated physics.”

For Mr. Taylor the exposure to the inquiry-based curriculum, while opening his eyes to its possibilities and benefits, did not significantly alter his notion of how his students learn physics and how they are taught. He also seems to be at ease with the contradictions inherent within his own practice of those ideas. A contradiction of how he feels is the best way to teach physics and continuing, in some respect, the ways in which he was taught physics. He readily admits that the projects and activities in the curriculum allowed students to gain insights into the application and connection of science to the world that they had not done before; that the EGP helped them see connections between society and science that his students had never made before. However, for Mr. Taylor, the benefits of the projects and the time they take away from the traditional curriculum do not justify their inclusion at the Accelerated Level of physics. In his opinion, they should be relegated to those students who are currently having a more difficult time in school or who may have other issues that prevent them operating at higher levels of academic success.
Summary of Results

The implementation of the inquiry-based, concept related curriculum in the secondary physics course for the study of electricity and magnetism indicated that student’s attitudes toward physics can be more favorable after such an implementation. Students in the class showed gains in positive attitudes in 4 of 8 categories of the CLASS survey. Students stated that they felt more confident and felt the material was easier because of the inquiry nature of the curriculum. More students were able to make real world connections with the topics they were learning in class. Students also stated that they felt like they understood the topics of electricity and magnetism more than they had understood previous topics in the school year.

The teacher stated that he too felt there were positive aspects to the curriculum and that it did allow for real world connections and applications of physics in ways that had not been done previously in his class. However, the teacher remained steadfast in the belief that such curriculum should only be reserved for students at the lowest level or who may not to go to college and should not take time away from the multitude of traditional topics.
CHAPTER 5: DISCUSSION

In the previous chapters a description of the problem, the research questions, research methodology, and results of the research were presented. In this final chapter the researcher’s conclusions, significance of the study and implications for further research and practices will be discussed.

The results of this case study reveal both the promise and perils of physics curriculum in the United States. Chapter 1 introduced the current state of physics education in the U.S. The rigidity of the current curriculum sequence of most high school physics classes calls for a multitude of topics to be covered throughout the school year with little time available to incorporate concept related, inquiry-based teaching practices. The study focused on the following research question:

What is the impact, in a secondary physics classroom, of an inquiry-based concept related physics curriculum’s effect on:

1. Attitudes of students toward physics?
2. Student’s application of physics knowledge?
3. The process of learning science?
4. The teacher’s perspective on teaching and learning physics?

The research was a case study that examined the implementation of the inquiry-based curriculum on a secondary physics classroom at a suburban high school. The researcher conducted pre and post attitude survey with the secondary physics class using the Colorado Learning Attitudes about Science Survey (CLASS) and evaluated the survey results using two techniques. The researcher also observed the class twice a week for the duration of the curriculum; recording detailed observations and impressions of the
students, teacher, and curriculum. The researcher conducted interviews with 7 of the students from the class, as well as the teacher. Student artifacts were also collected including photographs of student work, student projects and student lab papers. The study was conducted during the months of February, 2011, March, 2011 and April, 2011. The study commenced over a period of 13 weeks, including testing and conduction of interviews.

Results showed that students who were exposed to the inquiry-based concept related physics curriculum had changes in their attitudes towards physics. This attitude change was evidenced by the results based on the analysis of the pre and post survey responses of the CLASS. Students scored an increase in the favorable percentages for 4 of the 8 categories designated by the survey’s designers. The categories were: Real World Connections, Personal Interest, Conceptual Connections, and Problem Solving Confidence. For these four categories students showed a positive change in their attitudes. The remaining categories stayed the same over the course of the curriculum. These results were triangulated through interviews with the students who discussed with the researcher how the curriculum allowed them to connect what they had done in the classroom with the real world. Several students shared how the curriculum helped their personal interest with one student now considering a career in the sciences, an idea for a career path she had not considered prior to this class. It also allowed them to make conceptual connections among the physics topics in the unit.

Results also showed that students found the study of the topic of electricity and magnetism using the revised curriculum to be easier than previous topics in physics. This is important because in traditional mathematics based physics the topics of electricity and
magnetism are generally considered to be more difficult; so much so that the Advanced Placement Physics exam is segmented into sections and the last, considered the most difficult, is electricity and magnetism. In math intensive physics classes so much emphasis is placed on the equations and mathematical problems that the real world applications and connections can be lost, and as evidenced by Mr. Taylor’s opinion, these types of connections should be relegated to a status of lower priority.

Students in the class reported that the revised inquiry-based concept related curriculum helped them make connections to the real world and apply those connections. In many of the inquiry projects discussed by the students they felt more engaged with the material and enjoyed the learning process more. One student recounted an experience where she was able to fix the garage door opener in her home as her parents stood dumbfounded because she saw that the wires had lost their connection with each other and knew what to do from physics class. While a few of the students noted that they did not see much difference between the revised curriculum and the other material taught throughout the year, the ones who did notice a difference felt it to be very significant for their understanding.

Conclusions

The first conclusion from this case study is that implementation of this inquiry-based, concept related curriculum improved the students’ attitudes towards physics and the process by which they learned physics. In fact, gains in student attitude were measured across 4 of the 8 categories established by the CLASS survey. While this comes as no surprise based on the research previously discussed in Chapter 2, it is an important finding nonetheless. This finding supports the work of Murphy et al. (2006),
who first studied a curriculum focused on social and real world applications of physics in the United Kingdom, from which this curriculum was adapted. He also found that students had an increase in positive attitude towards physics. The revised curriculum addressed the needs of many students in the room who found physics difficult prior to implementation. These students reported a more favorable attitude towards physics and went as far as to report liking physics more when it was taught in this manner.

In none of the instances from the classroom observations, student interviews, and student responses to the CLASS survey was there an indication that the curriculum worked against students being able to better understand physics or that the inquiry-based concept related activities worked against the students’ ability to learn science. The study found quite the contrary for several students in that they reported better understanding and felt the curriculum was ‘easier’ and that they were getting better grades because of it in physics. These results occurred even though topics presented in electricity and magnetism traditionally are thought of as more difficult.

The curriculum also enhanced the process by which the teacher interacted with his students and the teacher’s attitudes toward teaching and learning physics. While it did no harm, it did not transform the teacher’s ideas completely. It did, however, cause the teacher to reevaluate how he taught physics and concede that students who were taught the revised curriculum had a better understanding of the applications of physics in the real world. While the teacher stated that the revised curriculum had good aspects, he felt some of the inquiry activities took too much time away from traditional topics of instruction. The teacher was willing to concede that the time away did have value as the students were better able to see the social implications and ramifications of the
application of physics, but he felt that such curricula should only be reserved for the lower performing non-science career based students. We have seen that curriculum that stresses inquiry-based concept related topics (Barmby and Defty, 2006; Chang, 2002; Ebenezer and Zoller, 1993; George, 2006, Reid and Skryabina, 2002) can be effective in promoting positive attitudes in students and that this case study is no exception.

The second conclusion to draw is that the rift between students’ perceptions and teacher’s perceptions about what is important in learning physics are very wide. Hassler and Hoffman (2000) as well as others discussed this disconnect between that which the teacher thinks is important in a physics class and what students think is important in a physics classroom. This case study showed several disconnects between the students’ perceptions of the curriculum and the teacher’s.

The first was in the curriculum itself. All of the students interviewed noted some way in which the revised curriculum was different from the way the teacher had been teaching prior to its implementation. The teacher, upon his interview, noted no real difference, indicating that teachers may not be as self-reflective of their practices and their student’s perceptions of their practices as they might lead themselves to believe.

The majority of the students interviewed and the results from the CLASS survey showed that the students had positive changes in attitudes towards physics and were able to make better conceptual and real world connections with physics being taught in the revised manner. These positive changes, however, were not seen as important to the teacher who, in his interview, was unable to comment on whether he felt his students had a strong understanding of electricity and magnetism because he did not perform a
traditional assessment at the end of the unit. This disconnect between what the majority
of students interviewed saw as beneficial, learning physics in an inquiry-based concept
related way, and what the teacher sees as this type of curriculum being best suited for
students of lower ability, indicates that this disconnect is quite profound.

Another disconnect worth noting is the teacher’s paradoxical statements that the
inquiry activities provided deeper levels of understanding and application but that they
should be relegated to either a separate class or to classes of lower ability. These
statements were made after the teacher previously stated that he feels students learn
physics best when they have a physical (non-mathematical) component to their
instruction. That is, when they have something to relate the math and equations to in the
real world, he feels they learn better. To the teacher, the notion of redesigning the
curriculum so as to provide deeper understanding of fewer topics is not one he considers
viable. The teacher even concedes that while doing more inquiry-based, concept related
activities would be beneficial for his students, there is not enough time.

A third conclusion was that the perception that time was an enemy of the teacher
when teaching physics is rooted in the teacher’s own contradictions between what they
know to be the proper way to teach and the way they teach. When teachers are under
pressure to cover a lot of material within a limited time frame, teachers inevitably revert
to more traditional teaching practices, even when doing so goes against their personal
philosophy of teaching. In this case study, Mr. Taylor states that the way he would like
to teach physics, with both mathematical and real world applications side by side,
requires too much preparatory time and too much classroom time to implement correctly.
Doing so, he feels, would prevent him from being able to cover everything he feels that
should be covered over the course of the school year. This finding is right in line with that of Feldman and Kopf (1999) whose study looked at many physics teachers and how they taught physics. Despite stressing almost uniformly the importance of teaching physics in an inquiry-based concept related way, the teachers in their study, “…admitted to not having engaged their students in defining concepts, because it was difficult and time-consuming” (p. 532).

What is most distressing to the researcher about this finding is that, for this case study, nothing seems to have changed in the twelve years since the Feldman and Kopf study. This case study confirms on a small scale what Feldman and Kopf found on a larger scale, that physics teachers still seem to be stuck in trying to cover too many topics at the expense of what they know to be a different and better way to teach physics. It is not an issue of the teacher not knowing a better way, just not choosing to teach that way. There needs to be a more concerted effort to begin to teach physics in the ways teachers know will promote understanding. We know from this study and others that the students’ attitudes improve with such curricula. We also know that students will have better problem solving confidence and be able to relate what they learn and apply it in the real world with this type of curriculum.

Some students learn science much better in an inquiry-based concept related way. Based on observations of student engagement, student survey responses, and follow up interviews it is clear that some students responded very positively to curricula that is inquiry-based and concept related and that while some students respond very positively, others did not indicate that the curriculum hindered their understanding in any way. None of the student data indicated that a traditional approach was preferable or that the
curriculum promoted a negative attitude toward physics in particular and science in general.

**Implications for Research and Practice**

A single case study cannot alone make the case for a full reform of physics curriculum in secondary education in the United States. What this case study can do is continue to add to the ever increasing body of research that says that inquiry-based, concept related physics curriculum promotes more positive attitudes in students taking physics and also helps apply their physics knowledge to the real world. The students interviewed in the study surely felt that curriculum presented in this fashion helps their understanding of physics.

The students’ changes in attitudes and feelings about the curriculum confirm the findings of Murphy et al. (2006) that inquiry-based concept related curriculum can increase positive attitudes in physics students. Current high school physics classes still attempt to cover large amounts of material in a given school year. Teachers are still, as Sadler and Tai found in 2001, and Mr. Taylor stated in his interview, deferring to the tradition and the textbook for determining the scope and sequence of the physics curriculum. When the curriculum is altered to include more inquiry-based, concept related structure, the result is that some students tend to view physics in a more positive way. Further study needs to be done to see if this change can be harnessed to increase the number of students who pursue further study in physics and engineering, serving to help reestablish the United States’ key role as a leader in scientific and technological development.
Physics curriculum should move toward what Haussler and Hoffman (2000) found; which is that physics be taught in such a way that students have a chance to develop a positive physics-related self-concept and to link physics with situations they encounter outside the classroom.

As with their study, this case study can also conclude that a curriculum based on inquiry and concept relation seems to be superior to a traditional curriculum with regard to student attitude and learning. Students in this case study and in Haussler and Hoffman’s study were able to form stronger connections to the material. For the students in this study, it was the continuous use of inquiry activities and real world problems in the curriculum that spiked their interest. Haussler and Hoffman’s research is clear about the benefits of using a concept related, inquiry-based curriculum for secondary physics and this study comes to the same conclusions. This type of curriculum has the ability to promote positive student attitudes and better understanding. Duran et al. (2004) and George (2006) came to similar conclusions.

What is coming to light with this study, but needs further pursuit, is the sense of why these curricula and teaching practices have had only mild penetration within the U.S. secondary physics community. This study seems to confirm that the problem lies in teacher hesitations and concepts of how physics should be taught as seen in Davis (2003) and George (2006), as well as the time problems that can occur when implementing new curricula or practices (Davis 2003; Donahue, 1993; Feldman and Kropf, 1999; Goodnough, 2006; Haussler and Hoffmann, 2000; Neuschatz and McFarling ,1999).

What was clear from this study was that it was not only a question of time, but dedication and interest of the teacher as well.
The research supports better efforts be made to familiarize current and future secondary physics educators with the body of research that establishes the benefits of inquiry-based, concept related curriculum on physics students. What is needed at this time seems to be additional studies like the one from Feldman and Kopf (1999) that get at the heart of the issues that teachers have about adopting inquiry-based concept related physics curriculum. Feldman and Kopf noted that through interviews teachers stated that the felt that they had a duty to prepare students for college physics and thus expose them, mathematically, to the many concepts of physics and that not doing so would in some way harm their ability to succeed in college should they choose to pursue a scientific degree. Discovering the origins of this conception as well as addressing precisely how and why some secondary physics teachers continue to teach in a traditional manner even though their own self-concept of how students learn physics suggests a more inquiry-based concept related approach could serve to be beneficial for the reformation of secondary physics curriculum.

Concurrently with an addional study of teachers, a longitudinal study of students exposed to such curricula who pursue careers in science is also warranted. Data from this type of study would help to codify the critics of such inquiry-based, concept related reform movements who feel that such curricula infringes upon the successes students will achieve upon further study of physics in higher educational settings.

**Significance**

This case study is significant for several reasons. The research here supports the findings of various studies that have examined inquiry-based, concept related physics curriculum (Duran, 2004; George, 2005; Haussler and Hoffman, 2000; Murphy et al.,
2006). It supports the work of others that has determined that such curriculum promotes positive attitudes in physics students and allows them to better relate physics concepts to problems and real world applications. The study indicates that further research into the adoption of such curriculum and the hindrances to it be focused on the teachers of secondary physics and their construction of their philosophies of how students learn physics and their teaching practices. This study contributes to the expanding group of researchers looking at specific physics curricula implementations using a mixed-methodology in order to provide both the teacher and student perspective.
References


Enfield, M. *Content & pedagogy: Intersection in the NSTA standards for science teacher education.*


Minds on physics (2000).


State of New Jersey, State. *NJ school report card 2005-2006*


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Appendices


Introduction
Here are a number of statements that may or may not describe your beliefs about learning physics. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:
1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey Questions

1. A significant problem in learning physics is being able to memorize all the information I need to know.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

3. I think about the physics I experience in everyday life.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

4. It is useful for me to do lots and lots of problems when learning physics.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

6. Knowledge in physics consists of many disconnected topics.

   | Strongly Disagree | 1 2 3 4 5 | Strongly Agree |
7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

9. I find that reading the text in detail is a good way for me to learn physics.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

10. There is usually only one correct approach to solving a physics problem.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

11. I am not satisfied until I understand why something works the way it does.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

12. I cannot learn physics if the teacher does not explain things well in class.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

13. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

14. I study physics to learn knowledge that will be useful in my life outside of school.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

15. If I get stuck on a physics problem my first try, I usually try to figure out a different way that works.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

16. Nearly everyone is capable of understanding physics if they work at it.

    Strongly Disagree    1 2 3 4 5    Strongly Agree

17. Understanding physics basically means being able to recall something you've read or been shown.
18. There could be two different correct values to a physics problem if I use two different approaches.

19. To understand physics I discuss it with friends and other students.

20. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.

21. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

22. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

23. In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

24. In physics, it is important for me to make sense out of formulas before I can use them correctly.

25. I enjoy solving physics problems.

26. In physics, mathematical formulas express meaningful relationships among measurable quantities.
27. It is important for the government to approve new scientific ideas before they can be widely accepted.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

28. Learning physics changes my ideas about how the world works.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

29. To learn physics, I only need to memorize solutions to sample problems.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

30. Reasoning skills used to understand physics can be helpful to me in my everyday life.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

32. Spending a lot of time understanding where formulas come from is a waste of time.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

33. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

34. I can usually figure out a way to solve physics problems.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

35. The subject of physics has little relation to what I experience in the real world.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

36. There are times I solve a physics problem more than one way to help my understanding.

| Strongly Disagree | 1 2 3 4 5 | Strongly Agree |

37. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.
38. It is possible to explain physics ideas without mathematical formulas.

Strongly Disagree 1 2 3 4 5 Strongly Agree

39. When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.

Strongly Disagree 1 2 3 4 5 Strongly Agree

40. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

Strongly Disagree 1 2 3 4 5 Strongly Agree

41. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.

Strongly Disagree 1 2 3 4 5 Strongly Agree

42. When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

Strongly Disagree 1 2 3 4 5 Strongly Agree
Appendix B – The Interview Protocol

Interview Protocol Procedures:

1. The teacher and students interviewed will be given an “Informed Consent Form”. The research study participants will be on a voluntary basis through the parent permission (for students).

2. Parents will be given an opportunity to ask any questions via email or telephone to the researcher prior to the interview. Students selected for the interviews will be given information about the research.

3. The interviewer will set up interview times with the individual students selected and with the teacher. These interviews will take place at the end of the traditional school day.

4. The interview will be held in the physics classroom

5. Permission to record the interview via audio only or video with audio will be obtained via the “Informed Consent Form”.

6. The interviewer will start begin the interviews with informal greetings and demographic questions in order to put the subjects at ease. Students will be reminded that there is no right or wrong answers to the interview questions.

7. Student interview questions will be individually constructed based on their responses to the attitude survey. Students will be asked to expand upon their responses and provide more information at the prompting of the interviewer.

8. The following Interview Protocol was adapted from Creswell (1998, p. 127).
Appendix C: Student Interview Protocol

Interview Protocol
Project: Discussion of Attitude Survey responses
Time of Interview:
Date:
Place:
Interviewer:
Interviewee:
Position of Interviewee:
Length of Interview:

Interview Prompts-

1. A significant problem in learning physics is being able to memorize all the information you need to know, how did you’re feeling about this statement change over the course of the E&M unit?

2. Many students feel that physics consists of many disconnected topics. How do you feel? Did your opinion change over the course of the E&M unit?

3. Some students feel that there is only one correct way to solve physics problems. How do you feel? Did your opinion change over the course of the E&M unit?

4. Do you think the physics knowledge you gained will be useful in your life outside of school?

5. Is it important for the government to approve new scientific ideas before they can be widely accepted?

6. Did anything you learned in physics change your ideas about how the world work?
Appendix D- Interview Questions for Teacher

Interview Protocol
Project: Discussion of Teacher’s Perspective on Physics
Time of Interview:
Date:
Place:
Interviewer:
Interviewee:
Position of Interviewee:

Interview Prompts:

1. A friend’s daughter/son is choosing their subjects for their junior year in HS. Your friend is uncertain about what subjects their child should do and asks you “What is physics?” What would you say?

2. What do you consider to be the relationship between mathematics and physics?

3. How is physics knowledge produced?
   a. What were your initial impressions of the Energy Foresight Curriculum?
   b. Did it conform or go against your belief about how physics knowledge is produced?

4. You are a teacher. But why a teacher of physics?
   a. Why teach physics rather than mathematics?
   b. Why teach physics rather than other science(s)?
   c. How do you see physics and other sciences as differing?

5. What sort of teaching strategies do you value using most with your physics class? Why?
   a. What, if any, are the strengths of these strategies?
   b. You’ve mentioned the strengths, are there any weaknesses in these strategies?
   c. Are these strategies different from the way you were taught physics?

6. How do these strategies relate to those you were asked to teach in the Energy Foresight Curriculum?

7. What are your impressions about the other curriculum you teach throughout the year compared to the Energy Foresight Curriculum?
   a. Are you satisfied with it?
   b. Are your students generally satisfied with it?
   c. What would you change about it, if anything?
Appendix E – Letter from Principals

Dear Parent/Guardian:

As a part of your child’s Physics Class at the Eastern Regional School District, we would like to conduct a research study that would give your child an opportunity to enhance his/her learning of the topic of Electricity and Magnetism through the use of inquiry and problem based learning lessons. This particular topic is perceived by students as one of the hardest in physics to learn well. The Eastern Regional School District is committed to excellence and constantly searches for opportunities to create environments where your child may learn important concepts in new ways. The findings of this study will be used to provide insights into high school physics students and techniques for classroom instruction. This information may also be of interest to teachers and researchers in physics education.

Under the supervision of Education Professors, Dr. Elizabeth Haslam and Dr. Sheila Vaidya, Mr. Molotsky is conducting this research study in partial fulfillment of a doctorate in Education Leadership and Learning Technologies at Drexel University. Mr. Molotsky is currently a Science and Mathematics Teacher here in the Eastern Regional School District and has taught in the district for the past 14 years. The study will be conducted with [teacher’s name] Physics class during the fourth marking period. He will be observing the class periodically throughout the marking period. Dr. Patricia Denholm, Director of Curriculum, Mr. Robert Tull, Principal Senior High School, and Dr. James Talarico, Principal Intermediate High School, grant our permission and fully support for this research study.

The purpose of the research is to explore the impact of the revised electricity and magnetism curriculum on student’s attitudes toward Physics and their ability to connect the topics of electricity and magnetism to the world around them. Students will be given real world tasks and problems to solve along with learning the content using inquiry-based activities and laboratory experiments. The goal of this research is to provide teachers, administrators, policymakers, and communities with the ability to look more closely at how to better implement physics curriculum that improve students’ understanding and appreciation of science.

We are asking if you would like to have your child participate in this study. Mr. Molotsky will contact you by phone to provide you with more information. He will be happy to answer any questions and concerns you may have at that time. You may contact Mr. Molotsky via email at Molotsky_gregg@eastern.k12.nj.us or by cell phone 609-320-1078 with any questions.

Thank you very much for your interest in the research and in our effort to make your child’s education better.
Appendix F – Parental Consent Form

DREXEL UNIVERSITY
PERMISSION TO TAKE PART
IN A RESEARCH STUDY

1. SUBJECT NAME: ____________________________

2. TITLE OF RESEARCH: A Case Study Of The Impact Of A Reformed Science Curriculum On Student Attitudes And Learning In A Secondary Physics Classroom

3. INVESTIGATOR’S NAME: Dr. Elizabeth Haslam;
Co-Investigator: Mr. Gregg Molotsky

4. RESEARCH ENTITY: Drexel University, School of Education

5. CONSENTING FOR THE RESEARCH STUDY: This is a long and an important document. If you sign it, you will be authorizing Drexel University and its researchers to perform research studies on you. You should take your time and carefully read it. You can also take a copy of this consent form to discuss it with your family member, attorney or any one else you would like before you sign it. Do not sign it unless you are comfortable in participating in this study.

6. PURPOSE OF RESEARCH: Your child is being asked to participate in a research study. The proposed study seeks to gain insight into secondary physics classrooms by looking at the most direct practitioners of physics education, the secondary physics teachers and their students. By interviewing these individuals, the teachers and students, the researcher hopes to gain insight into teaching and learning that occurs.

Mr. Molotsky is a teacher at the Eastern Regional High Schools and is performing this research study as part of the requirements for his Doctorate Degree in the educational leadership and learning technologies program at Drexel University. The Research will be conducted during Mr. Christopher Miller’s 15th period Accelerated Physics class. Your child has been asked to participate in the research because they are as student in the class and are being taught a curriculum that includes more inquiry based activities and real-world problems than traditional physics classes. The size of the research group will be limited to the teacher, Mr. Miller, and the number of students currently enrolled in the class: 25 students with 11 being male and 14 female.

The Colorado Learning and Assessment Survey (CLASS) will be administered to all students in the class. Also, over the 4th Marking Period Mr. Molotsky will be observing the class two times a week. All students will take the survey and be in the room while Mr. Molotsky is observing the class. However, only students with parental consent and student assent will have their survey data analyzed and be directly observed by Mr. Molotsky.

APPROVED
Office of Regulatory Research Compliance
Protocol #: 19035-01
Approval Date: 06/20/10
Expiration Date: 06/19/11

Version 1
As part of these observations, Mr. Molotsky will videotape your son/daughter during the research study and possibly select them to be interviewed as well. The interviews will take place directly after school in the physics classroom and will be scheduled in advance. The interviews will also be recorded.

It is important to know that you or your student may choose to not be a part of the study and may withdraw at any time.

7. **PROCEDURES AND DURATION:** You and your child understand that the following things may be done during the research study.
   - Interviews - With four (4) selected students
   - CLASS Survey – Completed at the beginning and end of the curriculum unit
   - Observations – Will take place twice a week

8. **RISKS AND DISCOMFORTS/CONSTRAINTS:** All standards with regards to classroom safety and science department procedures will be followed as they have been during lab activities throughout the school year.

   Teacher supervision as well as safety instructions will be provided for all inquiry based lab activities that students in which students will partake.

9. **UNFORESEEN RISKS:** Participation in the study may involve unforeseen risks. If unforeseen risks occur, they will be reported to appropriate school officials and the Office of Regulatory Research Compliance at Drexel University.

10. **BENEFITS:** There may be no direct benefits from participating in this study.

11. **ALTERNATIVE PROCEDURES:** The alternative is not to participate in this study.

12. **REASONS FOR REMOVAL FROM STUDY:** Your child may be required to stop the study before the end for any of the following reasons:
    a) If all or part of the study is discontinued for any reason by the investigator, or university authorities.
    b) If your child's participation in the study is adversely affecting their academic performance.
    c) If your child fails to adhere to requirements for participation established by the researcher.

13. **VOLUNTARY PARTICIPATION:** Participation in this study is voluntary, and you or your child can refuse to be in the study or stop at any time. There will be no negative consequences if you decide not to participate or to stop.
14. **RESPONSIBILITY FOR COST:** Any costs for items required for use in the inquiry based lab activities will be provided by the researcher.

15. **IN CASE OF INJURY:** If you have any questions or believe your child has been injured in any way by being in this research study, you should contact Dr. Elizabeth Haslam at telephone number (215) 215-895-1277. However, neither the investigator nor Drexel University will make payment for injury, illness, or other loss resulting from your being in this research project. If you are injured by this research activity, medical care including hospitalization is available, but may result in costs to you or your insurance company because Drexel University does not agree to pay for such costs. If you are injured or have an adverse reaction, you should also contact the Office of Regulatory Research Compliance at 215-255-7857.

16. **CONFIDENTIALITY:** In any publication or presentation of research results, your child’s identity will be kept confidential; the only person who will see your name will be the researcher. You consent to such inspections and to the copying of excerpts of your records, if required by any of these representatives.

17. **OTHER CONSIDERATIONS:** If you wish further information regarding your rights as a research subject or if you have problems with a research-related injury, for medical problems please contact the Institution’s Office of Regulatory Research Compliance by telephoning 215-255-7857.

18. **CONSENT:**

- I have been informed of the reasons for this study.
- I have had the study explained to me.
- I have had all of my questions answered.
- I have carefully read this permission form, have initialed each page, and have received a signed copy.
- I give permission voluntarily.

DO NOT SIGN THIS INFORMED CONSENT AFTER THIS DATE [10/10/11]

---

Subject or Legally Authorized Representative ___________________________ Date ____________

Investigator or Individual Obtaining this Permission ___________________________ Date ____________

List of Individuals Authorized to Obtain Permission

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Day Phone #</th>
<th>24 Hr Phone #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregg Molotsky</td>
<td>Co-Investigator</td>
<td>856-784-4441</td>
<td>609-320-1078</td>
</tr>
</tbody>
</table>

APPROVED
Office of Regulatory Research Compliance
Protocol # 19035-01
Approval Date: 06/20/10
Expiration Date: 06/19/11

Version 1
Appendix G – Students Assent Form

DREXEL UNIVERSITY
CONSENT TO TAKE PART
IN A RESEARCH STUDY

1. SUBJECT NAME: _________________________________

2. TITLE OF RESEARCH: A Case Study Of The Impact Of A Reformed Science Curriculum On Student Attitudes And Learning In A Secondary Physics Classroom

3. INVESTIGATOR’S NAME: Dr. Elizabeth Haslam; Co-Investigator: Mr. Gregg Molotsky

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6. PURPOSE OF RESEARCH: You are being asked to participate in a research study. The proposed study seeks to gain insight into secondary physics classrooms by looking at the most direct practitioners of physics education, the secondary physics teachers and their students. By interviewing these individuals, the teachers and students, the researcher hopes to can gain insight into the teaching and learning that occurs.

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The Colorado Learning and Assessment Survey (CLASS) will be administered to all students in the class. Also, over the 4th Marking Period Mr. Molotsky will be observing the class two times a week. All students will take the survey and be in the room while Mr. Molotsky is observing the class. However, only students with parental consent will have their survey data analyzed and be directly observed by Mr. Molotsky.

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Version 1
As part of these observations, Mr. Molotsky will videotape you during the research study and possibly select you to be interviewed as well. The interviews will take place directly after school in the physics classroom and will be scheduled in advance. The interviews will also be recorded.

It is important to know that you may choose to not be a part of the study and may withdraw at any time.

7. **PROCEDURES AND DURATION:** You understand that the following things may be done during the research study.
   - Interviews- With four (4) selected students
   - CLASS Survey – Completed at the beginning and end of the curriculum unit
   - Observations – Will take place twice a week

8. **RISKS AND DISCOMFORTS/CONSTRAINTS:** All standards with regards to classroom safety and science department procedures will be followed as they have been during lab activities throughout the school year.

Teacher supervision as well as safety instructions will be provided for all inquiry based lab activities that students in which students will partake.

9. **UNFORESEEN RISKS:** Participation in the study may involve unforeseen risks. If unforeseen risks occur, they will be reported to appropriate school officials and the Office of Regulatory Research Compliance at Drexel University.

10. **BENEFITS:** There may be no direct benefits from participating in this study.

11. **ALTERNATIVE PROCEDURES:** The alternative is not to participate in this study.

12. **REASONS FOR REMOVAL FROM STUDY:** You may be required to stop the study before the end for any of the following reasons:
   a) If all or part of the study is discontinued for any reason by the investigator, or university authorities.
   b) If your participation in the study is adversely affecting their academic performance.
   c) If you fail to adhere to requirements for participation established by the researcher.

13. **VOLUNTARY PARTICIPATION:** Participation in this study is voluntary, and you can refuse to be in the study or stop at any time. There will be no negative consequences if you decide not to participate or to stop.

14. **RESPONSIBILITY FOR COST:** Any costs for items required for use in the inquiry based lab activities will be provided by the researcher.
15. IN CASE OF INJURY: If you have any questions or believe your child has been injured in any way by being in this research study, you should contact Dr. Elizabeth Haslam at telephone number (215) 215-895-1277. However, neither the investigator nor Drexel University will make payment for injury, illness, or other loss resulting from your being in this research project. If you are injured by this research activity, medical care including hospitalization is available, but may result in costs to you or your insurance company because Drexel University does not agree to pay for such costs. If you are injured or have an adverse reaction, you should also contact the Office of Regulatory Research Compliance at 215-255-7857.

16. CONFIDENTIALITY: In any publication or presentation of research results, your child’s identity will be kept confidential; the only person who will see your name will be the researcher. You consent to such inspections and to the copying of excerpts of your records, if required by any of these representatives.

17. OTHER CONSIDERATIONS: If you wish further information regarding your rights as a research subject or if you have problems with a research-related injury, for medical problems please contact the Institution’s Office of Regulatory Research Compliance by telephoning 215-255-7857.

18. CONSENT:

- I have been informed of the reasons for this study.
- I have had the study explained to me.
- I have had all of my questions answered.
- I have carefully read this consent form, have initialed each page, and have received a signed copy.
- I give consent voluntarily.

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Subject or Legally Authorized Representative       Date

Investigator or Individual Obtaining this Consent     Date

List of Individuals Authorized to Obtain Consent

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Day Phone #</th>
<th>24 Hr Phone #</th>
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</thead>
<tbody>
<tr>
<td>Gregg Molotsky</td>
<td>Co-Investigator</td>
<td>856-784-4441</td>
<td>609-320-1078</td>
</tr>
</tbody>
</table>
Appendix I – The Energy Foresight Curriculum compared to traditional curriculum

In a traditional course of study, physics topics related to electricity and magnetism are presented in chapter format with subsections of material. These items are presented as individual topics within the chapter and with examples may be provided that help students relate topics to the everyday world. In the physics text, Paul Hewitt’s’ *Conceptual Physics* (2009), the concepts of electricity and magnetism are presented in a series of chapters without relation to other topics or connections to real world problems. Here is the topic order from the Hewitt text.

V. ELECTRICITY AND MAGNETISM

- Electrostatics
- Electric Current
- Magnetism
- Electromagnetic Induction (Hewitt, 2009)

This list provides the roadmap to how students will learn about these topics and the order in which they are presented. Now the image below is taken from the CD-ROM that accompanies the Energy Foresight Curriculum (Energy Foresight, 2008). Not only does this menu serve as a table of contents for the topics at hand. Unlike traditional curriculum it discusses the same topics from the Hewitt text, however does so in context with the problem set forth within the curriculum. How do we as a society meet the
energy demands of the 21st century without contributing to the problem of global warming? (Energy Foresight, 2008). It is this type of concept relation in conjunction with inquiry related activities that will form the basis of the 8-10-week curriculum that will be the subject of the case study.
As an educator, parent, and global citizen my mission is to enrich the world of education by fostering the honesty, integrity and intelligence within all life-long learners. By leading with strength and compassion, I hope to achieve an environment of intellectual trust and prepare students for future experiences in higher learning education as well as the working world.

EDUCATION

**Drexel University**, School of Education- Philadelphia, PA  
*Ph.D. in Educational Leadership and Learning Technology* - June 2011

**University of Pennsylvania**, Graduate School of Education – Philadelphia, PA  
*Masters of Science in Education* - May 1993

**University of Virginia**, College of Arts and Sciences - Charlottesville, VA  
*Bachelor of Arts in Astronomy & Physics* - May 1992

CERTIFICATIONS

New Jersey Teacher Certifications  
– Mathematics & Physical Science

Pennsylvania Instructional I Certificate  
– Physics and Mathematics

Delaware Teacher Certification  
– Physics

PROFESSIONAL EXPERIENCE

**Drexel University**, Philadelphia, PA  
Adjunct Faculty, Spring 2007–current

- Curriculum writing and instruction of EDUC 803 & 810 – Educational Research Design I & II- Graduate Level Responsible for writing the curriculum and transposing the course into an online format suitable for students at the graduate level in the Drexel School of education.

**Eastern Camden County Regional School District**, Voorhees, NJ  
Teacher of Physics- Eastern Senior High School, 1995 – Present

- Designed and implemented multi-leveled instruction in physics for eleventh and twelfth grade students through the use of traditional and inquiry-based science instruction.
- Integrated the use of non-traditional student projects and assessments into the existing Honors physics curriculum to promote student directed learning.

PROFESSIONAL ORGANIZATIONS

New Jersey Science Teachers Association – Presenter 2008 Annual Conference
National Science Teachers Association
American Association of Physics Teachers
New Jersey Educational Association
National Education Association