ABSTRACT

MITCHELL, WILLYETTA ADELE. Physics Instructors Are Not Blank Slates Either: An Exploratory Study of Introductory Physics Instruction. (Under the direction of Len Annetta and John Penick).

The purpose of the study was to investigate the views of the nature of science and the classroom practices of instructors who teach introductory physics at a research intensive university. A study of this nature is necessary because calls to change how science is taught have been made since the 1800's, yet the methods of instruction have remained virtually unchanged. The conflict between how science is taught and how students learn science can be remedied by effective professional development at the university. However, training on the change process is virtually nonexistent in teacher education programs and in teacher professional development workshops at all levels.

The Views About Science Survey (*VASS*) was first administered to a sample of twenty-nine physics instructors and graduate assistants who have taught introductory physics courses within the last five years. To assess instructional practices in introductory physics at a research extensive university, a purposeful, stratified sample of 56 classes was observed. The interactions between the students and teachers were analyzed using the Flanders Interaction Analysis. The findings suggest that the physics instructors hold a mixed view of the nature of science. The instructors' views do not necessarily indicate how they teach physics. The results also showed that the professors reported that they use elements of effective teaching practices throughout their instruction. The results of the classroom observations revealed that non interactive lecture is the dominate instructional method used. The Flander's confirms that the majority of the class time is spent with the teacher talking and the student passively listening.

Physics Instructors Are Not Blank Slates Either: An Exploratory Study of Introductory Physics Instruction

by
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DEDICATION

To all the African-American children who don't know the value of a formal education yet

BIOGRAPHY

Willyetta was born March 23, 1970 in San Francisco, California. She attended college at Xavier University of Louisiana where she received a Bachelors of Art in Physics and a Masters of Arts in Curriculum and Instruction. It was at Xavier University, where she became increasingly interested in studying effective teaching methods in the sciences when she took three semesters of general physics taught using the inquiry-based science method.

Shortly, thereafter she enrolled in North Carolina State University and she began her career as a science educator under the direction of Dr. Michael Paesler, Dr. John Hubisz, and Dr. John Penick. Her experience in science education is rich and diverse. She has taught science courses both public and private schools at all levels. She has also trained pre-K through 8^{th} grade science teachers in both formal and informal science settings. Currently, she teaches physics and forensics science at the North Carolina School of Science and Mathematics in the Distance Learning Department. She is also on the national faculty of the National Science Resource Center's Leadership Assistance for Science Education Reform (LASER) Institute, where she educates policy makers nationwide on research-based methods used to develop a scientifically literate K–16 student population.

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ALL GLORY AND HONOR IS YOURS ALMIGHTY FATHER, FOREVER AND EVER!

I must give thanks to God who has never left me in throughout my journey in education. He has been everything to me I needed: a father, a mother, a listening ear, a comforter, and a friend…Thank you God.

I have realized that there is a time and a season for everything. In following my own path toward completion of the doctorate, I have learned many lessons. Not all the lessons were wanted or appreciated; however, they have served to make me wiser and to deepen my appreciation for time.

I must continue to thank God for placing the proper people in my life during the seasons when I need them the most. It would have been impossible for me to entertain this degree without the support, consideration, and sacrifice that was evidenced by my family. First, my Momma and Granny who have always supported me in my pursuit in education and for Mrs. Bettie who first told me that I would be a doctor one day. To all my extended family members: Dr. James Burnette, Mr. Curtis Burton, Rekia Morgan, Debra Evans, Newbern and Lucy Watkins, Maurice and Charlene Bridges, Willie and Paula Holley, Debra Bowick, Marilyn, Link, and Tomalei Vess, whose friendship, hospitality, knowledge and wisdom have supported, enlightened, and entertained me over the many years of our friendship. They have consistently helped me keep perspective on what is important in life and shown me how to deal with reality.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

STATEMENT OF THE PROBLEM

Numerous calls for change in the ways science is being taught in America offer beguiling challenges that are not new to the science education community. Most visions of promoting educational change focus on the societal need for a more scientifically literate nation. Such changes and literacy developed through the use of research-based instructional methods are predicted to increase recruitment into math, science and engineering careers that serve as America's economic engines (Center for Science, Mathematics and Engineering Education, Committee on Undergraduate Science Education, 1999; National Science Foundation, 1996; Project 2061/American Association for the Advancement of Science, 1989).

Along with science literacy, calls for change in instructional methods stress active learning through inquiry that models scientific processes. Research indicates that teachers who use collaborative or active teaching approaches achieve higher levels of student learning than those using more traditional and passive instructional techniques (Goodsell, Maher, & Tinto, 1992; Wankat, 2002; Weimer and Lenze, 1994). As a result, teachers from preschool through college are being challenged to move from the traditional didactic lecture models of teaching science to an inquiry-based instructional model where students construct knowledge from experiences, ideas, investigations and discussions.

But for teachers to embrace and use any new instructional method, teaching must change at all levels (Southerland, Gess-Newsome, and Johnston, 2003). As the university is

the formal training ground for teachers, further calls for change require university teachers to teach about the nature of science through inquiry, and the responsibility for much of the proposed reforms is ultimately placed on the university science professors, yet little is known about what they understand about the desired teacher roles or the nature of science and student inquiry.

At the undergraduate level, science courses are taught to students who will be the future leaders in science, education, and other fields. These courses set the tone for how science is taught at all levels and research suggests that teachers of any subject typically teach the same way they were taught (Britzman, 1986; Goodlad, 1990; and Lortie, 1975). Thus, science education is caught in what Hawkins (1990) describes as a loop in history by which some children are taught science little and poorly and grow up to be teachers who teach science little and poorly.

To further compound this situation; individuals who work in the scientific community often have little firsthand knowledge of the skills necessary to teach. When compared to most elementary and secondary teachers, scientists who teach in universities usually have had different experiences and success with science. As a result, they may well have different views than the elementary and secondary teachers as to what goals are important, even though scientists are often among the experts consulted during the creation of the goals for K-12 science education (Roth, 1989).

Teachers are educated at the university and work in the precollege world. The disconnection between these two environments creates confusion of goals, purposes and

actions. In an attempt to seek resolution to the problems created by this disconnect, this study explored the nature of science within the physics department at North Carolina State University (NCSU) as it pertains to the relationships between teaching introductory physics courses. Through a written questionnaire, classroom observations and selected interviews, this research study served as an initial starting point in investigating how physics faculty and graduate assistants view the nature of science and their use of innovative teaching practices and materials in introductory physics classes. A brief review of higher education practices in general and reform in physics education will demonstrate some of the problems and promises such reforms could offer teacher education.

Criticism of Higher Education

In 2000, The Boyer Commission published a report on the education of undergraduates in research universities entitled *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*. This report shows that the 125 research universities in the United States make up only three percent of the total number of institutions of higher learning, yet from 1991-1995 they conferred 32 percent of the bachelor's degrees. The report notes that graduates from research universities furnish the cultural, intellectual, economic, and political leadership of the nation (Boyer, 1998). Many of the graduates become science teachers.

Although the report provides an impressive set of data and comments, it also provides a critique of research universities, noting that research universities often fail their undergraduate populations. Tuition income from undergraduates is a major source of

university income, helping to support research programs and graduate education. But, in too many cases, the students paying tuition receive less than their money's worth. Recruitment materials proudly display world-famous professors, state-of-the-art facilities, and the ground-breaking research that goes on within the university. However, many students graduate without ever seeing the famous professors or experiencing genuine research or studying in state-of-the-art labs. Some university instructors are likely to be poorly trained or untrained teaching assistants or part-timers who are feeling their way towards effective teaching techniques. Some others may be "…tenured drones who deliver set lectures from notes on yellowed paper, making no effort to engage the bored minds of the students in front of them…"(Boyer, 1990, pg. 15).

While there may be some truth to these claims, the extent of the problem is not clear. The Boyer report makes over fifty recommendations for improving teaching at the research institutions but provides no evidence of their cost-effectiveness for society or learning effectiveness for students. While most of the recommendations address curriculum, few consider the effectiveness or education of the professors or the nature of instruction. It is clear, though, that the Boyer Commission is concerned with the quality of undergraduate teaching.

Some college and university faculty are responding to the criticisms and are not content with the quality of undergraduate education (National Research Council, 2003). These faculty apply their scholarly skills to seek out, experiment with, and assess how course revisions and new teaching practices can help students realize the objectives and expectations

of their courses (Center for Science, Mathematics, and Engineering Education, Committee on Undergraduate Science Education, 1999).

Many note that high quality undergraduate education requires higher education leaders and faculty who take student learning seriously. If learning is of such importance, then teaching must also be considered. In short, the critical thinking and scholarly skills used in research also can be used in teaching, studying and improving science. There is clear evidence of scholarship and research activity having a beneficial impact on teaching and learning (Carnegie Foundation for the Advancement of Teaching, 2005, p. 1)

The Carnegie Foundation's concern for teaching led to the establishment of the Carnegie Foundation for the Advancement of Teaching and the Carnegie Academy for the Scholarship of Teaching and Learning (CASTL). Designed to advance the development of a scholarship of teaching and learning, CASTL:

- fosters significant, long-lasting learning for all students;
- enhances the practice and the profession of teaching; and
- recognizes and rewards teaching in ways similar to other forms of scholarly work. (Carnegie Foundation for the Advancement of Teaching, 2005).

Much of the research and literature compares traditional lectures to other teaching strategies. These strategies include active learning, collaboration, inquiry, problem and project based learning, fieldwork, and others (Beichner and Abbott, 1999; Bernhard, 2000; Bloom, 1984; Crouch & Mazur, 2001; Dufresne, William, Leonard, Mestre and Wenk, 1996; Felder & Brent, 2001; Laws & Baxter-Hasting, 2002; van Heuvelen, 1991). All of the

proposed alternatives to lecturing involve students in an active fashion and most seek to have students play multiple roles and be more communicative in class.

Teaching and learning research highlight the efficacy of active learning (Bonwell & Eison, 1991; Johnson, Johnson & Smith, 1991) and suggest that learning involves an ongoing, reciprocal relationship between student and teacher. For this to happen, faculty must employ modes of teaching that require students to be active learners who take responsibility for their actions and learning. When both faculty and students actively participate in the teaching and learning process, the resulting synergy can produce powerful effects on student learning.

Undergraduate Dissatisfaction with Science

Current post-secondary teaching practices appear to lie at the heart of several problematic trends. The number of students majoring in science in the United States has dropped by half in the past thirty years (Kardash & Wallace, 2001; National Science Foundation, 1996; Seymour & Hewitt, 1997; Strenta, Elliott, Adiar, Matier & Scott, 1994). There are many claims as to the cause of this dramatic decline, which begins prior to the entrance to college (Pearson & Fechter, 1994; Powell, 1990). Seymour and Hewitt (1997), for example, found that 92% of students who switched from majors in science, mathematics, and engineering, and 74% of "nonswitchers," complained about poor teaching by science, technology, engineering and mathematics faculty. Seemingly, few students are satisfied, even those who enjoy science. Students complain that science instruction is primarily lecture, is

boring, has little relevance to daily life and is hard to relate to, especially for women and minorities (Rayman & Bret, 1995; Seymour, 1995; Seymour & Hewitt, 1997).

Kardash & Wallace (2001) reported that students cite many specific complaints about instruction in the science classroom: at the top of the list are unclear course goals, poor organization and inconsistency across materials, homework and evaluation. Students also complain of grading that is not reflective of achievement. There is an emphasis on competition over cooperative learning and a focus on memorization over understanding, a lack of linkage among concepts, too few examples and demonstrations, little classroom interaction, and faculty indifference to students. And, since science teachers are among these dissatisfied undergraduates, beginning teachers are not being prepared in an optimum manner. The decline in science majors and the poor performance of American high school students on standardized tests have caused many outside the academic community to be concerned about America's scientific future.

To reverse these trends, the National Science Foundation has funded projects to address systematic reforms to promote the use of research-based, student-centered science instruction at all levels (Ravitch, 1983). Higher education leaders and faculty have been charged by the business community (Daly, 1999) with placing more emphasis on the quality of teaching and its improvement so that the full potential of America's intellectual and creative capital will not be compromised. While Daly addressed higher education, the responsibility must be placed on teachers at all levels. But the role of higher education is critical, as elementary and secondary teachers must complete a college level certification

program where they learn the subject to be taught as well as how to plan, deliver, and assess instruction. Their role models are often science professors who rarely have formal education in developmental psychology, research related to teaching and learning, or in alternative teaching techniques (Schuler, personal communication, July 27, 2007).

Additionally, faculty members do not have much incentive to obtain this education and knowledge (McKeachie, 1999; National Science Foundation, 1996) or to demonstrate innovative teaching. Teaching is frequently viewed as an interference with research time, particularly at large research universities. Graduate assistants or part-time faculty are often assigned to teach introductory undergraduate courses and laboratory sections at many research institutions (McKeachie, 1999; Seymour & Hewitt, 1997). The hallmark of a truly valuable professor (or graduate student) is having almost no teaching responsibility except for graduate students in his or her specialty area. Faculty have set the wrong expectations for student learning where the focus in the college classroom continues to be transmitting information via lectures and readings and expecting memorization of content rather than students developing and cultivating "higher-order" learning (e.g., critical thinking) and affective dimensions (e.g., attitudes and values).

This traditional teaching strategy of lecturing about content has been the major impetus for critics to charge that what is known about teaching and student learning is not being applied in most university teaching practices. In many cases, faculty do not see teaching and learning as corollaries and certainly do not see teaching as a priority or even a major part of their roles. Reflecting this concern, Carnegie announced a new university

classification system (McCormick, 2000) which was completed in 2005 (Carnegie Foundation for the Advancement of Teaching, 2005). Additional criteria in this new classification include teaching and service activities. The new typology emphasizes teaching by focusing on the number and types of degrees offered rather than emphasizing research funding, selectivity in admissions or the total number of Ph.D.s awarded.

The Golden Age of Science Education and Physics Education Reform

During the 1950's, in response to the dissatisfaction with what was being taught in physics and the government's concern with the shortage of graduates in scientific and technological fields, the Physical Science Study Committee (PSSC), including professional physicists and both high school and college instructors, convened to address the need for changes in the physics curriculum (Shymansky, Kyle and Alport, 1983). The need for change became more urgent and visible when the Soviet Union launched the first man-made satellite, Sputnik, in 1957. The federal government responded by passing the National Defense Education Act that provided funds to support math, science, and technology education for students at all levels. Additional funding was provided by the National Science Foundation for curriculum development and teacher preparation. The resulting emphasis on science education accompanied by enhanced funding inaugurated a period lasting three decades considered to be the "Golden Age of Science Education" in the U.S.

During this period new ideas emerged to guide physics education reform in the U.S. Reforms promoted "less content, more depth," an emphasis on process and inquiry versus lecture and demonstration, the use of the laboratory as a means for investigation, and the

inclusion of multi-media material (Helgeson, Blosser & Howe, 1977). Next came the "misconceptions" movement where an awareness of our common presumptions about student learning became the main focus. One conclusion from this research was that students came to class with many naïve mental models for how the physical world works (Kuhn, 1970; Trowbridge and McDermott, 1980, Halloun and Hestenes, 1985; Redish, 1994). Then a renewed focus on the roles of students and teachers and the general atmosphere of the "classroom culture or climate" which is the foundation upon which all teaching and learning rests began. The "classroom culture or climate" addresses the norms established by the teacher for classroom interactions, for expectations of engagement and work output, for use of time, and for specific responsibilities of teacher and students. As part of these reform efforts, physics education instruction examined behaviors of instructors and students, ostracism of women students, excessive competitiveness over grades, and non-cooperation, among others (Tobias, 1992). Assessment has also been part of the "classroom culture and climate" reform as the focus shifted to in-class examinations and more authentic assessment (Tobias, 2005).

Hake (2002) identified fourteen lessons learned from the physics education reform effort. Six relate directly to teaching:

1. Faculty members overestimate the effectiveness of their teaching (Mazur, 1997; Hake, 2000).

2. Teachers must possess both content knowledge and pedagogical content knowledge in order to deliver effective instruction (Redish, 1999; Shulman, 1986; Bransford, Brown, Cocking, 1999).

3. High quality education research and development by disciplinary experts are needed to improve educational methods within the discipline (Redish, 1999; Hestenes, 1987; Arons, 1998; Hammer, 2000; McDermott, 1993).

4. Disciplinary experts should take advantage of the insights of cognitive scientists (Gardner, 2004; Mestre and Touger, 1989)

5. Development of effective instructional methods requires long-term classroom field testing, feedback, assessment, research analysis, and redesigning of non-traditional educational methods and curricula (Wilson and Davis, 1994; Sarason, 1996)

6. Cooperation of instructors, departments, institutions, and professional organizations is required for the synthesis, integration, and change of the entire chaotic educational system (Duderstadt, 2000; Hilborn, 1997; Tobias, 2005; Pister, 1996).

According to the Boyer Commission (1998), teaching is a scholarly operation and is performed best by those who study it. Teaching, like other forms of scholarship, is an investigation, complete with data collection, analysis, conclusions and revised understanding. But many physics education reformers at the college level focus narrowly on one or another topic in physics rather than on instruction, the role of the teacher, or classroom culture in general. Committed faculty members examine the purposes of courses and ask probing questions about themselves and their roles and the utility of particular teaching practices. In addition, students are assessed to discern whether desired learning and development are taking place, which can then help faculty make informed improvements in the classroom. Shulman (1998a) also argues that a course is an act of inquiry and invention just as much as any other activity that is considered to be research. If we agree with Boyer and Shulman, then conceptualization of the scholarship of teaching and learning (SOTL) can have important implications for faculty members who teach physics. Yet, little has been reported about

college science faculty understanding of teaching and learning and how they view science education. This dissertation study is an effort to add to the knowledge base in this area.

STATEMENT OF PURPOSE

This mixed methods study focused on the academic culture of a single physics department, especially as it related to teaching introductory physics classes at a research extensive university. In this study, a modified version of the Views About Sciences Survey (*VASS*) (Halloun, 2001) instrument (Appendix B), Classroom Observation Protocol (Appendix C), Flanders System of Interaction Analysis (Appendix D), and selected interviews (Appendix E) were used to explore physics faculty's and graduate assistants' views of science and the instructional strategies used in introductory physics classrooms. This research yielded information pertinent to many faculty and curriculum developers as they explore new ways to improve physics courses. Understanding how physics faculty members apply scholarship to their teaching furthers what is known about the scholarship of teaching physics at research extensive institutions of higher learning.

RESEARCH QUESTIONS

Much of the prior research into teachers' views of the nature of science has been conducted with elementary and secondary teachers, yielding little insight how university scientists' beliefs about the nature of science might be manifested in their teaching. Such investigations into faculty beliefs could support reform efforts in university science education practices that go beyond the dissemination of random goals and provide some insight into the degree to which post-secondary physics teachers' beliefs are consistent with inquiry-based

teaching. To provide supporting evidence, this research examined both quantitatively and qualitatively the teaching methods used and perceptions of science and teaching held by physics faculty and graduate assistants at North Carolina State University (NCSU). This research study explored three broad questions:

1. How do physics instructors view the nature of science?
2. What modes of instruction are used in the introductory physics classrooms at NCSU?
3. What relationships exist between the views of the nature of science and the classroom instructional practices in the university physics classroom?

SIGNIFICANCE OF THE STUDY

The physics community has been reluctant to assess or rank colleges and universities on the basis of the quality of physics teaching and its appropriateness to the students who might be attracted to the subject (Tobias, 2005). Yet, undergraduates and their parents select universities in the hope and promise of an excellent education and naively assume teaching to be a major emphasis in a university physics department. Going beyond physics, there is an unfortunate dearth of teacher education research at the college level (Kyle, 1994). Hutchings and Shulman (1999) noted that faculty in most fields are not in the habit of, nor do most have the training for, framing questions about their teaching, student learning, or designing the systematic inquiry that will open up those questions. Thus, there should be a sense of urgency to improve undergraduate teaching. This study should be viewed as a challenge for further research about scientists and their teaching, particularly at the undergraduate level.

LIMITATIONS OF THE STUDY

This study was confined to interviewing and observing 12 graduate students and 17 faculty in the physics department of North Carolina State University, a research extensive land grant university. This purposive sampling was used because it best served the purpose of this study. This sample was by no means intended to be representative of any larger population of physics teachers. Sources of error associated with teacher research further limit conclusions (Bogdan & Biklen, 1998). These include observer/experimenter drift, error of leniency, halo-effect, personal bias, reliability decay, contamination and error of central tendency (Borg and Gall, 1989). Exclusions and loss of subjects due to incomplete data surveys also limited generalizability.

In any research, bias is inherent. According to Lincoln and Guba (1985), while constructing holistic meanings, the analysis is influenced by the researcher's interactions with the subjects. Miles and Huberman (1994) suggested the following to check for researcher effects: (a) stay on-site as long as possible, (b) use unobtrusive measures where possible and (c) make sure the research intentions are unequivocal for informants. In addition, the research site can affect the researcher. To minimize these effects, Miles and Huberman (1994) suggest the following: (a) avoid "elite" bias by including lower-status informants, (b) spread out site visits, (c) triangulate data, and (d) keep research questions firmly in mind.

A specific limitation to this study is that there was no continuity of the researcher's presence in the classroom. The researcher was unable to visit all introductory physics classes

each day, leaving gaps in observation. According to Miles and Huberman (1994), the inclination is to make inferences (possibly erroneous) that connect any gaps.

Since this type of research is interpretive and value laden, the researcher's interpretations and biases will naturally play a major role in the analysis of this research. It is also logical, based on the researcher's history as a physics teacher and desire for quality physics education, that the researcher's perspective is immersed as a secondary instrument.

IMPORTANT TERMINOLOGY

One of the difficulties in studying education is that there is not a consistent vocabulary used by researchers in the field. It is important to clearly define the terms that are used in this study. Listed below are definitions of the terms used in this study. For the purpose of this research study, the terms graduate students and assistants are used interchangeably and refer to university teaching and research assistants. Views and beliefs are used interchangeably:

Beliefs (views): A set of personal cognitive constructs that drives a person's actions (Fang, 1996).

Culture: A set of shared philosophies, ideologies, values, assumptions, expectations, attitudes and norms within a community (Aikenhead, 1998).

Data analysis is a process of organizing and interpreting data (Creswell, 1994; Glesne and Peshkin, 1992; Goetz and Le Compte, 1984).

Inquiry: An active learning process in which students investigate scientific questions through data analysis (Bell, Smetana, and Binns, 2005).

Scholarship of teaching and learning: A faculty-driven initiative to improve learning by fostering faculty inquiry into learning and by building interdisciplinary communities that support and refine this inquiry. This innovative form of faculty development inspires and improves learning by engaging the scholarly talents and dedication of the faculty.

Teacher Practical Knowledge: The integration of knowledge, conceptions, beliefs and values developed by teachers based on their classroom experiences.

Structure: Specific views about the coherence of science and its relation to the real world.

Methodology: Subjects' views about certain processes and tools for developing and applying scientific knowledge.

Validity: Views about the verity and fidelity of scientific knowledge.

Learnability: Views about what it takes to learn science.

ORGANIZATION OF THE DISSERTATION

This dissertation is organized into five chapters. Chapter 1 includes the purpose, significance, research questions, limitations, and definitions of the study. A review of the literature is presented in Chapter 2. Chapter 3 outlines the research methods including the context of the study, participant research questions, and data collection procedures and justification. The findings of the study are described in Chapter 4. Chapter 5 provides a summary, conclusions, implications, and recommendations for further research.

CHAPTER TWO: LITERATURE REVIEW

INTRODUCTION

Education is at the forefront of the national agenda. States battle for education funding and there is a national teacher shortage in the STEM Fields. Questions concerning the adequacy of K-16 student learning, especially in the academic areas directly related to economic advancement center on science, math and engineering are not being addressed. Attention is focused in two areas: (1) teachers and teacher training and (2) various pedagogical techniques. To address these issues, this chapter reviews selected research and writings relevant to this investigation into teaching introductory physics at the university level. Organized into three sections, the first section examines research-based instructional methods promoted by physics education researchers. It opens with a look at the historical foundation of curricular change in American universities and the science education agenda. The section transitions into a holistic examination of the discipline of physics and the role that the culture of physics as a discipline plays in how science is taught, including research on the nature of science and its impact on instructional practice. This first section concludes with a discussion of elements identified in the literature that serve as barriers to changing teachers and teaching practices.

Section Two explores the demographics and the professional characteristics of scientists and how they developed as teachers. This section addresses the literature on the cultural milieu that describes how scientists and teachers learn to teach. It relies on the bountiful research on the effects of teachers' attitudes, beliefs, and behaviors on student

learning for further support and ends with a review of the conversations on how scientists view science and how those views affect what goes on in the classroom. Section Three supports the research design and the data collection methods that were used in this study.

SECTION I. A LOOK AT PHYSICS EDUCATION REFORM

Science education reform efforts from 1958-1988 are sometimes categorized as the "Golden Age" (Trowbridge, Bybee, and Powell, 2000). The early part of this era was characterized by the theory of behaviorism which focused in the idea that the desired behavior can be shaped through reinforcement and practice (Skinner, 1968; Gagne, Briggs and Wagner, 1992, Thorndike, 1913; Hull, 1943). The problem with behaviorism is that it neglected critical thinking, reasoning, and understanding (Bransford, Brown and Cocking, 1999). By 1968, most educators were seeking independent learning and looking to Piaget and his developmental stage theory for inspiration (Lawson and Staver, 1989).

The psychology of learning theories began a "cognitive revolution" that made room for new instructional techniques in education. It was during this period that science education moved from an epistemology of information processing to cognitive constructivism, where the learning theory was based on the search for truth and the external nature of knowledge (Doolittle and Hicks, 2003). Later, science education moved beyond radical constructivism where emphasis is placed on the nature of knowledge to von Glaserfield's (1989) primary assumption that knowledge is constructed from individual experience. The strategies adopted by radical constructivists include those that stimulate students to make their investigations and discoveries through the use of KWL (Know-Want-Learn) or KLEW (Know-Learning-

Evidence-Wonder) inquiry strategies (Hershberger, Zembal-Saul, and Starr, 2006). Social constructivism stresses that knowledge is filtered through sociological factors such as culture and language. A social constructivist instructor relies on cooperative learning techniques guiding the lesson based upon the input from the students. Few of these learning theories have influenced undergraduate teaching.

Early studies of college physics teaching revealed that the concern about college science teaching dates back to the earliest part of the twentieth century. The number of high school students enrolled in physics decreased dramatically in the 1900's from nineteen percent to about seven percent (U.S. Bureau of the Census, 1975). Monahan (1930, as cited in DeBoer, 1991) suggested that teachers could solve the enrollment problem by transforming physics courses to become more "vital, practical and interesting" by lecturing less and allowing students more time with laboratory activities. In the 1930's, a deeper analysis of physics instruction in America began when H. Emmett Brown, of Columbia University Teachers College, wrote a series of articles on the failure of physics educators to reflect on their own teaching practices (DeBoer, 1991).

Scholars within the community argued that physics teachers used an excessive amount of math to teach topics of no interest to students leading to little motivation for the continued study of physics. The apparent conflict between motivation and mathematics was viewed as an obstacle to be overcome. Yet, according to Brown (1940), the teacher has the responsibility to educate and motivate by making clear connections between quantitative relationships found in physics and the life experiences of students. Well-educated students

should be able to demonstrate a sound understanding of physics topics by thinking through quantitative problems and drawing conclusions from sets of data.

Professional organizations, with the support of the National Science Foundation (NSF), began to take the criticisms seriously and studied ways they could help school science programs. In the fall of 1956, the Physical Science Study Committee (PSSC) convened to develop a new high school physics course that provided depth in classical physics, added modern physics, and left out the usual technical and industrial applications. At the same time other conferences sponsored by the American Association of Physics Teachers (AAPT), American Institute of Physics (AIP), and the National Science Teachers Association (NSTA) investigated the need for revised courses at the high school level (NSF, 1962). Then in October of 1957, the Soviets launched the first man-made satellite. The U.S. government reacted by initiating the National Defense Education Act (NDEA) and enhancing the educational efforts of the National Science Foundation. The resulting mandate to cultivate a passion for math and science in America's youth yielded the most sweeping efforts in U.S. history to reform K-12 science instruction.

Additional arguments began to brew about how to motivate students to study physics. Many felt it was logical to start with teachers because they were at the heart of the academic profession (Boyer and Mitgang, 1996) and a powerful force for change. However, studies in physics that dealt with teaching were few and far between. Ogborn (1977) found that the best teaching practices in physics include a focus on motivation, individualized study, tutorial teaching (small group), and laboratory teaching (inquiry-based learning). Following Ogborn,

Prigo (1978) published the results from a lecture course he created that focused on the cognitive development of the students. This study found that the "objects" of physics should be emphasized because roughly 50% of college freshman perform at the concrete operational stage of development.

Unfortunately, PSSC and other efforts did not solve the problem of physics literacy and declining enrollment. Opposition to the early reform initiatives gained momentum as the number of students majoring in science and mathematics continued to drop (Kardash and Wallace, 2001; National Science Foundation, 1996; Seymour and Hewitt, 1997; Strenta, Elliott, Adair, Matier and Scott, 1994). Even those students who did well on the tests had difficulty integrating memorized facts and formulas into real life applications (Yager, 1991).

Noting that early reform efforts were aimed at producing scientists, education researchers began to look at student motivation and the broader goals of science literacy. Researchers examined teaching methods positioning the teacher as the sole information provider to passive students. Many curriculum projects began to promote innovative teaching and active student involvement (Shymanksy, Kyle, and Alport, 1983; Penick, 1994).

But, even in what were viewed as innovative curricula, students complained that physics classes were just boring lectures that meant nothing (Rayman and Brett, 1995; Seymour and Hewitt, 1997). Angelo (1991) studied undergraduate science lectures and found that after the lecture only 20% of the students remembered what the instructor discussed. He noted that students were too busy taking notes to internalize the information; eight minutes into the lecture, typically only 15% of the students were paying attention. Funding for

innovation continued, and eventually dozens of NSF-funded projects were offering laboratory-centered, inquiry driven curriculum projects. Unfortunately, only a few students benefited from the NSF-funded projects (The Subcommittee on Basic Research, 1998).

Project 2061 (1990) continued the work to identify problems in the science classrooms concluding that the present curricula in science and mathematics were overstuffed and undernourished. Science instruction emphasized the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, and reading in lieu of doing. Teachers failed to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their intellectual capabilities. (Project 2061, 1990, pg. xvii).

Obviously, the traditional teacher-as-information-giver and textbook-guided instruction did not bring about the desired outcomes, as students still could not think critically (Project 2061, 1990; Boyer, 1990; NRC, 1996, McNeal and D'Anzo, 1997) and just developing new curriculum was not sufficient. Some felt the most logical alternative was to change the focus of the classroom from teacher-dominated to student-centered using a constructivist approach to focus more on student thinking and ways that prior experiences, ideas and ways of thinking influence how students react to instruction (Bruner, 1966; Piaget, 1970; Schunk, 2000; Fosnet, 1996; Biehler and Snowman, 2003). Penick (personal communication, 2005) expressed this simply, "We will never have educational reform until we have instructional reform."

Many educators viewed constructivism as the vehicle to improve instruction. This learning philosophy extends back through many years and many philosophers, including Dewey (1938), Kant (1946), and even as early as Vico (2000). The guiding principle of this philosophy is that, "One only knows something if one can explain it." (Yager, 1991). Kant further elaborated this idea by asserting that human beings are not passive recipients of information. Learners actively make knowledge by connecting previously assimilated knowledge to new ideas, information, and experiences and make it theirs by constructing their own interpretations (Cheek, 1992). Costa and Liebmann (1998) explained that with knowledge doubling every five years - every 73 days by the year 2020 – one can no longer attempt to anticipate future information requirements. "If students are to keep pace with the rapid increase of knowledge, we cannot continue to organize curriculum in discrete compartments…the disciplines as we have known them, no longer exist. They are being replaced by human inquiry that draws upon generalized transdisciplinary bodies of knowledge and relationships." (p.23).

Embracing this method "requires a paradigm shift" that teachers be willing to abandon the perspectives and practices they are familiar with and adopt new ones (Brooks and Brooks, 1993). Since teachers are influenced by their university education, the reform effort must include university science courses. To help meet these expectations, several institutions established policies and practices to apply the norms of scholarly inquiry to build the capacity for research related to teaching and learning (D'Andrea and Gosling, 2000; O'Connell and Renfrew, 2000). This "scholarship of teaching and learning" allowed staff to

be recognized for researching their own teaching as well as for traditional scholarly activities (Healey, 2000; 2005; Yorke, 2000). Professional societies began to devote more serious attention to enhancing undergraduate teaching and learning in various disciplines (Doyle, 2000; McNeal and D'Avanzo, 1997; NRC, 1999, 2000; Rothman and Narum, 1999).

Even with all the talk and progress focused on high school physics reform, most undergraduate physics programs in the 1990's still closely resembled those of the 1960's. One exception was the Introductory University Physics Project, (Coleman, Holcomb, Ridgen, 1998) that was developed as a national attempt to develop new patterns of subject manner and new methods of instruction for the introductory college physics course. Guiding principles of the project called for total content to be reduced, course content coherence, topics making up the subject be linked together with a storyline, and include 20th century physics. Funding was provided by the NSF, AAPT, American Physical Society (APS), and the American Institute of Physics (AIP).

In the 1990's, physics departments all over the country were establishing research groups to study educational problems within the discipline (Heron and Meltzer, 2005). In 1994, the American Physical Society accepted physics education as a valid form of research. In the fall of 1996, the National Science Foundation released *Shaping the Future*, the results of a comprehensive analysis of undergraduate science, mathematics, engineering, and technology (SMET) education (George, 1996). The primary imperative of the report was that every student should have access to exemplary undergraduate education in STEM and these subjects should be learned through inquiry.

This report spoke of all students, including physics majors, engineering students, pre-medical students, pre-service teachers, women, minorities, and others underrepresented in the scientific community. *Shaping the Future* was intended to guide both the NSF and administrators in colleges and universities across the country examine undergraduate science education programs. A roundtable discussion, "Physics at the Crossroads," convened and led to a clear vision of the need for effective action for innovation and revitalization of undergraduate physics education. This vision asserted that the undergraduate physics education educates the next generation of research physicists, and consequently must provide effective science education for all students, including future K–12 teachers, posing a major responsibility that cannot be ignored by the physics community.

In 1999, the Strategic Programs for Innovations in Undergraduate Physics (SPIN-UP) project, a task force of eleven physicists from two-year colleges, four year colleges, and research universities compiled a list of characteristics of successful undergraduate programs at institutions such as Brigham Young, NCSU, and Harvard, to name a few. It was no secret that the preparation of many teachers in high school physics and middle school physical science is inadequate and in elementary school science nonexistent (Gollub and Spital, 2002; Lopez and Schultz, 2001). In 2002, another effort, The Physics Teacher Education Coalition (PhysTEC), was created to aid physics department's work with their schools of education to improve the science education of future K-12 teachers. Both groups focused on the entire program of an undergraduate physics department rather than solely on curriculum and pedagogy in introductory courses. Both projects recognized that "one size does not fit all" for

serious educational innovation and hoped to identify a set of principles common to successful physics departments. They found a wide diversity of approaches in applying those principles to the local situation and concluded that each physics department must identify its local mission and the resources needed to carry out that mission.

Several physics education researchers have conducted systematic studies on how instructors' beliefs about teaching and learning affect the adoption and use of research based curriculum and strategies (Henderson and Dancy, 2006; Van Sickle and Kubinec, 2003), students' conceptual understanding of physics (McDermott, 1984; Aguirre and Erickson, 1984; Thacker, 2003), and student views of the nature of science (AAAS, 1990). These studies further revealed that students already have deep-seated ideas about the physical world before entering physics classes (Halloun and Hestenes, 1998).

The use of research-based introductory curricula in small classes can significantly improve students' conceptual understanding (Hake, 2002; Redish, Saul and Steinberg, 1997; Laws, 1997; Heller, Keith, and Anderson, 1992). Although there is no universal best way to teach physics, research shows that some general principles apply (Project 2061, 1990; McDermott and Shaffer, 1994; Crouch and Mazur, 2001).

Most argue that effective teaching:

- promotes scientific ways of thinking;
- actively involves students in their own learning;
- helps students to develop a conceptual framework as well as problem-solving skills;
- promotes student discussion and group activities;

- helps students experience science in varied, interesting, and enjoyable ways, and
- assesses student understanding at frequent intervals throughout the learning process.

Along these lines cognitive scientists and educational researchers have developed general principles for improving teaching methods (delivery).

Recently, physics educators have created a number of new models for physics instruction using group activities and active student learning (Redish and Steinberg, 1999). Listed below are descriptions of a few recently developed materials for undergraduate physics:

- Student Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) (Beichner, Berhol, Burniston, Dail, Felder, Gastineau, Gjertsen, and Risley, 1999; Beichner, Saul, Allain, Deardoff, and Abbott, 2000).
  This approach requires redesigned classrooms equipped with round tables and laptop computers. Instructors use research-based pedagogies that include collaborative groups and Socratic dialogs through active engagement with their students.

- Investigative Science Learning Environment (ISLE) (Ektina and van Heuvelen, 2001). This approach uses the results of research on learning such as multiple representations of the processes of scientific investigation, active engagement, and multiple exposures to concepts to help students apply laws and models to real-world problems.

- Matter and Interactions, Electric and Magnetic Fields (Chabay and Sherwood, 1999). This approach attempts to make introductory physics reflect the contemporary physics enterprise. The students begin with a few fundamental principles and then proceed to learn introductory physics focusing on the atomic nature of matter with computer modeling.

- Teaching Physics Through Cooperative Problem Solving (Heller, Keith and Anderson, 1992; Heller and Hollbaugh, 1992).
  Through modeling, coaching and staging, instructors present a general problem-solving framework in the lecture. The students are then coached through the problem in discussions and given context-rich problems to solve in lab.

- Peer Instruction (Crouch and Mazur, 2001; Fagen, Crouch and Mazur, 2002; Mazur, 1997).
  This method consists of short lectures followed by a related conceptual question that probes student understanding of the ideas presented. The students discuss their answers in cooperative groups and then the instructor moves on to the next topic.

- Just-in-Time Teaching (JiTT) (Novak, Patterson, Gavrin, Christian, 1999; Novak and Middendorf, 2002; Novak and Patterson, 2000).
  This method connects outside of class preparation with what happens during the class. This teaching and learning strategy has students responding electronically to carefully constructed web-based assignments just before class and the instructor reads the student responses "just in time" to structure class discussions to meet the needs of the students.

Detailed empirical studies confirm that physics instruction at the university level generally has been ineffective (Hake, 2002; Hestenes, 1992). Research suggests that student understanding of the basic concepts in the first semester of a physics course should produce a score of 80% on the Force Concept Inventory (FCI) Test (Hestenes, 1992). The FCI is a qualitative, research-based, multiple-choice test that probes student understandings of fundamental concepts in Newtonian mechanics. A typical pre-test score in an introductory physics course in the university is between 40 and 50% when entering. Yet, students taught using the traditional lecture method only score 50-60% after they complete the course (Hake, 2002; Hestenes, 1992).

Research supports the notion that students can learn more physics in classes where they interact with faculty, collaborate with peers on interesting tasks, and are actively involved with the material they are learning (Hake, 2002; Mazur, 1997; McDermott,1993; Redish and Steinberg, 1999; van Heuvelen, 1991). Hake (1998) has shown instructional

methods using elements of "interactive engagement" to be extremely effective in helping students acquire conceptual knowledge.

Physics education researchers have developed a number of alternative instructional strategies that can be used in large lecture classes. These incorporate active learning into introductory physics classrooms by using hands-on materials in small recitation or lab sections that supplement lecture (Beichner, Berhold, Burniston, Felder, Gastineau, Gjertsen and Risley, 1999; McDermott, Shaffer, and Physics Education Group, 2003) or interactive lecture activities for large classes like Peer Instruction (Mazur, 1997; Fagen, Crouch, Mazur, 2002). Studio-style classes like Workshop Physics and SCALE-UP also allow students to work in teams observing and studying physics phenomena (Laws, 1997, Beichner and Saul, 2003).

Even with these advancements, NSF statistics show that from the mid-1990's to 2000, engineering and physics doctorates continued to decline by 15% and 22% respectively (Leath, 2005). There is still a "quiet crisis" as America is not producing enough scientists and engineers (Building Engineering and Science Talent, 2002). It is important to investigate why this crisis exists after all these calls for change.

Irvine (2002) argues "that teachers are systematic reformers and therefore need professional development in organizational theory, diagnosis, and change." Irvine's cultural synchronization theory is based on the premise that the language, non-verbal cues, actions, learning styles, and cognitive approaches between students and teachers must be mutually understood in order to create a culture of academic success. The university is where teachers

get their foundations to teach, both formally and informally. Ultimately, the university science professors must recognize that much of the onus to change the way science is taught is up to them.

Current researchers recognize the lack of professional development for teachers to develop leadership skills (Crowther, Kaagen, Ferguson, and Hann, L, 2002). Since most science teachers have not received training related to teaching, it stands to reason that they would not have full insight into their roles as leaders in the educational community. Through examining research and reflecting on personal experience, scientists must take on a leadership role in the educational community. Katzenmeyer and Moller's (2001) work provides a framework for looking at teacher leaders. The model operates on the premise that before teachers can understand their roles as leaders, they must know themselves.

The first step in the process that science professors need to make to understand their role as leaders is to examine how their views and beliefs inform their instructional practices. The next step in the process is to examine where they are in the change process. The last step of the process is for the science professors to understand themselves and their responsibility to the educational community. This study will focus on the first step of this process: an examination of the views and beliefs of introductory physics professors about the nature of science.

SECTION II: THE SOCIAL, CULTURAL AND INSTITUTIONAL CONTEXT OF UNIVERSITY PHYSICS INSTRUCTORS

Research suggests that science teachers can change their instructional methods; however, in order for this to happen, it is essential to examine the social, cultural, and

institutional context in which scientists operate (Cole and Engestrom, 1993; Littleton, 2000). This type of analysis validates certain knowledge and behaviors making the implementation of tasks and changes difficult for a scientist in the role of teacher (Littleton, 2000). Therefore it is necessary to analyze American faculty in the university. One critical area to look at is the promotion process.

Tenure and promotion are based more on research than on teaching. A recent study by the U.S. Department of Education, National Center of Educational Statistics (2006) found faculty with the least amount of student contact hours earn the highest salaries, and that the more refereed publications a faculty member produces, the higher their salary. Since research drives the tenure and promotion process, teaching is generally seen as secondary. Faculty members who are considered to be innovative and who adjust their teaching styles to accommodate students needs receive few rewards for their attempts (Becher, 1989 and Finkelstein, 1995).

The professoriate, in recent years, has been composed of individuals representing both genders and many ethnic backgrounds (Bowen and Schuster, 1986; Finkelstein, 1995). Studies of faculty confirm that the once popular stereotype of university professors as "pipe-smoking white males in rumpled tweed jackets" (Baldwin, 1987, pg. 106) or “lazy, elderly, over-privileged while males” (El-Khawas, 1992, pg. 323) has become outmoded in most academic institutions in every field. Bowen and Schuster (1986) and many others (NSF, 1996; Neuschatz and McFarling, 2003) confirm that women make up only a minute portion of the scientists working at the nation’s top universities (Wilson, 2004; Nelson and Rogers,

2004). Minorities are a rare find. The top fifty research institutions have a total of 19 Black women teaching math, science, or engineering; only two were in mathematics, one in chemistry, and none in computer science or physics. According to the a report entitled, *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities*, when minority and female professors are not hired, treated fairly, and retained, the female students perceive that they will be treated similarly, dissuading them from persisting in that discipline (Wilson, 2004).

The Culture of Physics

In the sciences, physics has been a popular area of study (Gaston, 1973; Pickering, 1984; and Traweek, 1992). According to Huber and Morreale (2002),

> Each discipline [including physics] has its own intellectual history, agreements, and disputes about subject matter and methods that influence what is taught, to whom, when, where, how, and why… . Each has a set of traditional pedagogies, such as lab instruction and problem sets in the sciences, and its own discourse of reflection and reform. Each has its own community of scholars interested in teaching and learning in that field, with one or more journals, associations, and face-to-face forums for pedagogical exchange (pg. 23).

Knowing the norms and practices of physics as a discipline provides a partial view of what physicists think and their roles related to effective science teaching practices (Fang 1996; Kelly and Berthelsen, 1995; Kuzmic, 1994). These norms and practices as well as the values, beliefs, and attitudes held by faculty, reflect their education and socialization experiences. All of these combined could be said to define the culture of a physics department.

Culture is variously defined through their shared philosophies, ideologies, values, assumptions, expectations, attitudes, and norms within the community (Kilmann, Saxton, and

Serpa, 1985; Peterson and Spencer, 1990). Understanding the physics faculty means understanding them in terms of their "beliefs, attitudes, technologies, languages, leadership and authority structures" (Maddock, 1981, p. 20), much of which is developed during their socialization as scientists.

Socialization is the process through which individuals acquire the norms, knowledge, and skills needed to exist in a given society (Merton, 1957). The process of socialization begins when a new faculty member enters the institution and typically takes place over a period of several years in three general stages (Hipps, 1980; Louis, 1980). First is the anticipatory stage, where the future faculty members participate in both undergraduate and graduate learning experiences. As physics students, they come to learn what are considered the "norms" of physics. Norms are the unwritten rules that determine acceptable and unacceptable patterns of behavior (Merton, 1957), along with an attached sense of punishments and rewards (Giddens, 1991).

During graduate school, prospective faculty members are directly exposed to the norms of the professoriate as they relate to teaching, research, and service. The norm for physics is large group lectures, supplemented by class laboratory sessions, and, in some cases, by fieldwork (Smeby, 1996; Hativa, 1996). Graduate students typically serve as research assistants working directly with faculty and faculty advisors encourage graduate students to present at professional meetings and conferences in order to become familiar with some of the other researchers in the community. Some graduate students serve as teaching assistants in undergraduate laboratory courses often grading lab reports and homework sets.

While many receive feedback on their teaching, it is usually related to correctness of content. The way students learn is rarely discussed (Gaff, 2002, Golde and Dore, 2001; Thomas, 2002). At the conclusion of the graduate experience, graduate students preparing to become prospective faculty have a solid understanding of what research and faculty life are like, but they rarely possess an informed vision of effective teaching or the skills to create or implement innovative teaching.

Once these post-grads find a job and are hired as new faculty, new professors enter the second stage of faculty socialization--the organizational stage. At the beginning of this stage, new faculty members are oriented to the university, usually just a few days before school starts. Subsequently, they are on their own to face a number of institutional challenges, most often by trial and error (van Maanen and Schein, 1979). Often, the first definitive deadline is to teach a class, leading to prodigious efforts at creating the class or presentation. But, few scientists at the university level have an understanding of learning or formal training in pedagogy or training (McKeachie, 1999; NSF, 1996). Much of what is known by science faculty about effective teaching practices is obtained during their apprenticeship or, at best, a review of the literature. A few participate in conference workshops on teaching and learning (Bloom, 1984; Anderson and Webb, 2000; Chickering and Gamson, 1987; and Osterlind, 1989); others discuss problems with colleagues or rely on their own experiences. As a result, many beginning university professors focus on ensuring their content, not their pedagogy, is state-of-the-art.

Although most universities have organized centers for faculty development, universities appear to value research over teaching (Bleak, Neiman, Sternman and Trower, 2000; Boyer Commission on Educating Undergraduates in Research University, 1998; Gray, Diamond and Adam, 1996; Rice, Sorcinelli, and Austin, 2002). University scientists understand research better than education or teaching and there is a perceived difference between good research and good teaching. Research is assessed when colleagues share ideas, offer critiques or modifications, and learn from each other. Evaluation takes place at every step of the process, at conferences and as research grants or articles are submitted to funding sources and professional journals. With research, the more positive the feedback, the higher the reward. Rewards come usually in the form of promotions, laboratory space, higher salaries, and often, fewer teaching responsibilities. A researcher who fails to gain respect in the scientific community can lose institutional support, be assigned fewer teaching assistants, and may be denied promotion and tenure while earning smaller salary increases.

Concurrently, discussing and evaluating teaching at the university level is not systematic, clearly understood or institutionalized. Few faculty will be found routinely analyzing and discussing teaching, and generally, teaching evaluations come at the end of a course through student evaluations. Unlike science research, this provides no opportunity for controls or manipulations of relevant variables. At the same time, few opportunities exist for developing norms or making comparisons.

Another interesting area of research summarized by Becher and Trowler (2001) addresses analyses by Biglan (1973), Kolb (1981) Becher, (1991). They found that scientists

in physics tend to prefer research to teaching but are open to collaboration with colleagues (Biglan, 1973). Like other scientists, operate in a cultural environment where they share a well-defined system of procedures, meaning, language, and symbols that influence worldview and social interactions. Physicists have particular need to create a good impression among as many key scientists as possible, either through personal contact or through published work (Reif, 1961). The professional language of a discipline, the "vocabularies and codes," plays a key role in establishing academic cultural identity (Becher and Trowler, 2001). This includes how diagrams are drawn on the chalkboard and in students' notebooks, how equations are written, ways graphs are interpreted, and how demonstrations are performed (Lemke, 1998).

Occasionally, scientific research may have significant implications for the outside world. Becher and Trowler (2001) suggested that an academic's professional life is affected by these implications and wider social environment in which he or she works. For example, physicists "may share a particular sense of responsibility" for the creation of nuclear weapons. Thus, academic culture includes perceived social and ethical responsibilities (Becher and Trowler, 2001; Taylor and Cobern, 1998).

Another characteristic of the university culture, including physics, is that almost everything and everyone is assessed and ranked in some way (Becher, 1989). Becher and Trowler (2001) maintain that in each pure science (physics, chemistry, astronomy, botany, biology, etc.) there are "gatekeepers" who determine who is allowed into a science community and is excluded. Cole (1983, as cited in Becher and Trowler, 2001) stated that

"the stars" of a particular discipline occupy the main gate-keeping roles. Gatekeepers have a significant role in terms of the development of knowledge and disciplinary practices. They determine which work is considered good and what is irrelevant or less important. Most departments also have someone functioning as an academic "thermostat," dealing with different and persistent pressures, conducting, controlling, and enlarging them in relation to their departmental expectations.

Even though research is primary and gatekeepers persist, some physicists have a long history of interest in student learning and many of the early science educators had physics backgrounds (Penick, personal communication). For example, the first large science curriculum project, PSSC, was organized by physicists. The Association of American Colleges and Universities, in a 2002 report, noted:

> The tradition in higher education is to award the [Ph.D.] degree and then turn the students loose to become teachers without training in teaching or, equally ridiculous, to send the students off without degrees, with unfinished research, incomplete dissertations, etc. hanging over their heads while the wrestle with the responsibilities of learning to teach…. During the long years of work toward a doctoral degree, the candidate is rarely, if ever, introduced to any of the ingredients that make up the art, the science and the special responsibilities of teaching. Yet, the major career option for most holders of the Ph.D. is full-time teaching in a college or university (p.35).

"The pedagogical skills of college faculty may be one of the most under developed resources in the country's institutions of higher learning." (Astin (1982), as cited in Ishler, 2003). Course planning in science is given minimal attention (Braxton and Bayer, 2004) with most effort going towards ensuring factual accuracy because much of the knowledge base is fixed. As a result, physicists spend little time on teaching preparation beyond focus on the

content. Marincovich, Prostko and Stout (2004) criticize science teachers for making dangerous assumptions in education. Many scientists believe that,

> …students are supposed to apply hard facts and reliable data to a problem solving situation, to consider possible outcomes, to hypothesize the most reasonable prediction, to perform a tightly controlled experiment to test the hypothesis, to measure the result meticulously, and to come to probable, carefully qualified conclusions based on the resulting evidence. Student opinion has little or no place in the process, and should establish the validity of the source when citing someone else's published opinion (Nelson and Rogers, 2004, p. 145).

Instructors teach as if their students have the same needs, interests and abilities as the scientists themselves had when they were students. Often, science professors forget that in many cases students take courses to fulfill a graduation requirement, to see if they are interested in the subject, or simply because the course may help to get a job (Angelo and Cross, 1993). Realizing the many facets of teaching and its importance to the university, many universities have embraced the idea of applying research skills and practices to the scholarship of teaching and learning.

Scholarship of Teaching and Learning

The Scholarship of Teaching and Learning (SOTL) is characterized as a systematic approach to inquiry about teaching and learning, the outcomes of which are shared with academic communities to enhance our collective knowledge of teaching and learning (Kreber, 2001; Martin, Prosser, Trigwell, Ramsden and Benjamin, 2001). Shulman describes the scholarship of teaching as an activity that "…will entail a public account of some or all of the full act of teaching – vision, redesign, enactment, outcomes and analysis in a manner

susceptible to critical review by teachers professional peers and amenable to productive employment in future work by members of that same community" (Shulman, 1999, pg. 6).

SOTL provides educators with a tool to evaluate their profession and their performance. Ernest Boyer's 1990 report, *Scholarship Reconsidered*, forcefully stated that it was time for institutions of higher education to move past the tired old 'teaching versus research' debate and to give the term 'scholarship' a more capacious meaning. This idea brought greater attention to teaching as a valid form of scholarship within the university. According to Boyer, the act of teaching is scholarly and can be compared to other forms of scholarship in that it is an experiment that is driven by an examination of the course objectives. Faculty members make informed improvements in the classroom and students are assessed to discern whether learning is taking place. This is not a one-time event, but takes place over an extended period of time in five stages: vision, design, enactment, outcomes, and analysis (Shulman, 1999).

With vision, the first element of SOTL, professors must transform the classroom to a place where meaningful learning can occur. Vision is usually presented in the form of the course syllabus with the course objectives. The syllabus outlines the course objectives, setting the stage for a comprehensive plan of class activities, teaching practices, and assessment methods.

The second SOTL element, design/redesign, leads physics education researchers to seek continuous improvement of existing introductory physics courses. This opens a door for the instructor to investigate whether the teaching practices are helping students meet the

objectives of the course (Shulman, 1998b). This is also a place where teachers can plan to incorporate research-based teaching methods. Once faculty have developed the course objectives and designed course activities, the next step is implementing the course, followed by analysis and redesign. The sequence can be compared to the processes of carrying out an experiment (Shulman, 1998).

Once design is accomplished, the class begins; enactment and strong assessment practices are implemented. Palomba and Banta (1999) defined assessment as a process that focuses on student learning, reviewing and reflecting on teaching in a more planned and careful way in order to see if the students are meeting the expectations and objectives of the course. Assessment is most effective when it reflects "an understanding of learning as multidimensional, integrated, and revealed in performance over time" (Banta, Lund, Black, and Oblander, 1996, p. 10). Multiple assessment methods should be used in order to create a comprehensive picture of what is actually occurring in the classroom (Palomba and Banta, 1998). Strong assessment practices are prerequisites to Shulman's last two elements of the scholarship of teaching and learning--outcomes and analysis. Once the redesigned course is implemented and assessed, instruction must produce tangible learning outcomes, i.e. changes in students' ideas about a topic. The results of assessment measures help faculty learn how the teaching practices and class activities affected student learning and development. Once this happens, the results can be disseminated across disciplines.

Teaching is highly complex and university teachers have "… scant opportunity to explore common problems and solutions or share new pedagogical approaches with their

colleagues" (Danielson and McGreal, 2000, p. 24). There are various factors that hinder the implementation of the SOTL, primarily the conflict between teaching and research that stems from the nature of academia. Research is to know and understand, while teaching is viewed as doing the right thing (Wong, Yung, Cheng, Lam, and Hodson, 2004). Other researchers argue that teaching is too complex to include a research component (Foster and Nixon, 1978). At the same time, research productivity is measurable (by the articles, citations or quarterly journals) while teaching success is less quantifiable.

Scholarship of teaching and learning is likely to require methods outside one's own disciplinary training (McKinney, 2004) and an additional time commitment. "Teaching is a profession in which it is extraordinarily difficult to find enough time to collect data…reflect, reread, or share with colleagues" (Cochran-Smith and Lytle, 1993, p. 91). However, teaching is limited to the awareness of current practice, student needs, and methods of SOTL.

The Nature of Science and Instructional Practices

Little recognition is given to the fact that many teachers often misunderstand the nature of science which can have an adverse effect on their teaching. Early curricular studies viewed science as a body of knowledge that students learn through direct instruction. John Dewey was among the first to describe science teaching as paying too much attention to the memorization of science facts and too little attention to thinking (Dewey, 1910).

Kimball (1968) studied science teachers who had the same educational background as practicing scientists and he investigated whether science teachers had an understanding of the nature of science similar to the understanding of practicing scientists. His research

uncovered that the science teachers thought science followed the scientific method but they did not understand experimental design. He concluded that American science teachers do not truly understand the nature of science and are not conveying it to their students.

The model of the nature of science that Kimball used to measure the views of professional scientists and science teachers was based on eight tenets based on Klopfer (1969)

1. Curiosity is the fundamental driving force in science.
2. Science is process oriented.
3. The goal of science education is to produce ever increasing comprehension in developing knowledge.
4. There is no single scientific method.
5. The methods of science are characterized by values rather than techniques.
6. The basic characteristics of science are based on faith in the physical universe.
7. Science has a unique attribute of openness of mind and investigation.
8. Science is tentative and revisionary.

Although, all of the tenets reflect how science should be taught, many science instructors promote the opposite, which is indicative of what is traditionally found in science classroom. Teachers have to become comfortable doing inquiry-based science so that classroom instruction resembles scientific research. This style of learning allows students to explore their own interests by formulating their own questions. Inquiry-based science focuses

on fewer scientific concepts but in greater depth with the ultimate goal to improve the quality of student understanding of science (NRC, 2000).

Although well-received and effective, use of these inquiry materials in K-16 science classrooms was not as widespread as anticipated (Abrams and Southerland, 2003; Keys and Bryan, 2000; Harms and Kahl, 1980; Harms and Yager, 1981; Shymansky, Kyle, and Alport, 1983; Woodbury and Gess-Newsome, 2002; and Anderson, 2003). But funding of major projects led to increased study and careful thinking about major issues in science education. Eventually, studies and issues regarding teaching the nature of science through inquiry instruction and process skills emerged. The research found that the role of the teacher was critical to inquiry teaching, instructional practice, and students learning the nature of science (Aguirere, Haggerty and Linder, 1990; Bloom, 1989; Yager and Wick, 1966; Shulman and Tamir, 1973; King, 1991).

Teaching strategies used by teachers reflect their own personal beliefs about learning. Brickhouse (1989) conducted a study which investigated three experienced secondary science teachers' views on the relationship between science and technology, the influence of such views on classroom practice, and the relationship between the same teachers' conceptions of the nature of science and classroom practice. Over a four-month period at least four hours of interviews and thirty-five hours of classroom observations were amassed for each of the teachers. Additional data were collected in the forms of tests, quizzes, and instructional materials. Two of the three teachers exhibited classroom practices that were

consistent with their personal views and philosophies. The novice teacher's classroom practices were not congruent with his beliefs.

Duschl and Wright (1989) conducted a comprehensive study involving both qualitative and quantitative techniques that observed and interviewed thirteen science teachers in a large urban high school. Their results suggested that the nature and role of scientific theories are not integral components that influence teachers' educational decisions. The nature of science was not being considered as a consequence of perceived students' needs, curriculum guide objectives, and accountability.

Abd-El-Khalick, Bell, and Lederman (1998) delineated "the factors that mediate the translation of preservice teachers' views of the nature of science into instructional planning and classroom practice." Fourteen preservice secondary science teachers completed a pre and post questionnaire to identify the factors or constraints that mediate the translation of their conceptions of the nature of science (NOS) into their classroom teaching. Participants were found to possess adequate understandings of several aspects of the NOS including the empirical and tentative nature of science, the distinction between observation and inference, and the role of subjectivity and creativity in science. Although the teacher reported that they taught the NOS through science-based activities, data analysis revealed that explicit references to the NOS were rare in their planning and instruction.

Similarly, Lederman (1999) performed a study of five high school biology teachers, with varied years of experience, investigating the relationship of teachers' understanding of the nature of science and classroom practice and to factors that facilitate or impede a

relationship. The results showed that the teachers' conceptions of science do not necessarily influence classroom practice. However, teachers' level of experience, intentions, and perceptions of students were of critical importance.

Direct and explicit approaches to teaching the nature of science also have proved to be effective (Abd-El-Khalick and Lederman, 2000; Akerson, Abd-El-Khalick and Lederman, 2000; Bell, Blair, Crawford and Lederman, 2003; Khishfe and Abd-El-Khalick, 2002; Moss, Abrams and Robb, 2001). These indicate that teachers must see the nature of science as an integral part of science instruction (Lederman, 1999; Schwartz and Lederman, 2002; Abd-El-Khalick, et al, 1998; Bell, Lederman and Abd-El-Khalick, 2000).

In an exhaustive review of the literature, Lederman examined the NOS, and divided the research into four distinct areas: (a) assessment of the student conception of the nature of science; (b) development, use, and assessment of curricula designed to improve student conceptions of the nature of science; (c) assessment of and attempts to improve, teachers conception of the nature of science; (d) identification of the relationship among teachers conception, classroom practice, and students conception. The identification of the relationship among teacher conceptions and classroom practice will be the focus of this research.

Lederman looked at the research over thirty years on the NOS and found four significant findings: (1) science teachers have inadequate beliefs about the nature of science; (2) efforts to improve teachers conceptions of the NOS have achieved some success; (3) academic background variables have not been significantly related to the NOS; (4) the

relationship between the NOS and classroom practice is not clear. Since the majority of science teachers are taught science by professors who have an expert view (positive philosophical perspective) as defined by Halloun (1996), Garrison (1986), and Brown, (1977) and leave the classroom with the perception that the goal of science or "science education" is to achieve an "isomorphic relationship between human knowledge and the natural world" (Glasson and Lalik, 1993, p. 187). Even though, in the university, the teachers are exposed to a positivistic perspective that maintains that only knowledge claims founded directly on experience are genuine, they use textbooks that present scientific knowledge as revealed truth (Gallagher, 1991).

Conventional introductory physics courses at university are not specifically designed for teacher preparation (McDermott, 1990). Since university professors usually have not received any systematic teacher preparation, it is reasonable to assume that they gain their knowledge about good teaching from colleagues, through trial-and-error, reflection and feedback from students and others or from reading and personal experience (Hativa, Barak, Simhi, 2001). According Hativa and Goodyear (2002), "this unplanned process may lead to fragmented pedagogical knowledge and unfounded beliefs of what is considered effective teaching." Brickhouse (1990), and Verloop (1992) all agree that a teacher's practical knowledge can be seen as the driving force behind teacher's instructional practices and almost all science (physics) teachers acquire views of the nature of science implicitly through their experiences of learning science content. Gallagher (1991) describes two teachers with strong formal backgrounds in the history and philosophy of science whose general views of

the nature of science and its links with the practice of school science were broadly similar to the views of other science teachers in his study who had not had that study of the history and philosophy of science. It appears that, as with the content of physics, knowing the content of history and philosophy of science by itself is not enough. Explicit study of the nature of science is not an automatic remedy. One also needs to understand how and why and for what purpose that knowledge interacts with pedagogy.

Brain research has also uncovered that meaningful learning in science involves established schemata within the brain (Anderson, 2002). These schemata are modified with incoming information making it more compatible with the learner's prior knowledge (Reynolds, Sinatra, and Jetton, 1996, p. 97). Using inquiry-based learning experiences coupled with cooperative group learning provides the necessary opportunities for the acquisition of knowledge as well as provide for the many social, intellectual, and student-generated sources of information that are experienced in group-oriented, laboratory-based exercises.

Lederman also looked at the relationship between the teacher's conceptions of NOS and classroom practice. The results of the research of Brickhouse (1989), Duschl and Wright (1989), and Zeilder and Lederman (1989) found that the presumed relationship between teacher beliefs and instructional practices were too simplistic with respect to the realities of what goes on in the class. Duschl and Wright (1989) found that there was no significant relationship between teacher understanding of the nature of science and classroom practice.

The study conducted by Hodson (1993) examined how teachers' reflective views of the nature of science influenced their design of learning experiences, especially laboratory procedures and practices. Inconsistencies were found between the instructors' expressed views about how scientific knowledge is constructed and validated within the scientific community and their views about the scientific knowledge implied by the activities chosen by the teacher.

These inconsistencies were manifested in several ways. Scientific knowledge was expressed to students in an authoritative manner that was in direct conflict with the teacher's own expressed views of the NOS. Mixed messages were sent to students by the other teachers in the study. Some material was presented through inquiry based learning while other material was presented as absolute truth. Hodson (1993) believes the reason there is a constant mismatch between the philosophical position of the classroom teacher and curriculum experiences is due to, "The failure to acknowledge the social construction of scientific knowledge in the design of laboratory activities" (p. 50).

SECTION III: THE STUDY

Research Design

This study used a mixed methods design more formally known as sequential methodological triangulation. This method applies both quantitative and qualitative methods to the same problem (Morse, 1994) with each method meeting the appropriate criteria for rigor as if the method stood alone (Tashakkori and Teddlie, 2003, Brewer and Hunter, 1989 and Morse, 1994). "Mixed method sequential triangulation studies produce complementary

findings that strengthen research results and contribute to theory and knowledge development" (Morse, 1994, pg. 145). In this case, the qualitative and quantitative data were collected simultaneously.

When qualitative and quantitative data are combined, a very powerful mix is produced (Miles and Huberman, 1994). Education policy makers value "numbers" that provide statistical evidence of the trends and instructors appreciate the "words" of the students interviewed about their educational needs. Qualitative research is recognized and appreciated widely and quantitative research is a long established approach making mixed method research a "legitimate research approach" (Brewer and Hunter, 1989, p. 28). Using traditional data collection methods, this study made use of electronic surveys, classroom observations, and semi-structured interviews to get physics instructors to reflect on their beliefs about the nature of science and a variety of teacher behaviors related to the teaching and learning of introductory physics.

Several authors (Greene and Carcelli, 1997; Way, Stauber, and Nakkula, 1994) cited that this design may be difficult to "sell" to those not familiar with it because it requires a more extensive data collection (Bryman, 1988). The cost and time needed may be difficult for a single researcher, therefore a team of researchers may be necessary. To overcome this, the researcher limited the size of this study.

Data analysis is one of the most difficult challenges for mixed methods research. Several authors (Caracelli and Greene, 1997; Tashakkori and Teddlie, 2003) offer some procedures to facilitate these challenges. In the triangulation design, qualitative data are

coded and the codes are assigned numbers while the number of times that the codes appear provides numerical data. Both the qualitative data and quantitative data are combined to form new variables (Caracelli and Greene, 1997).

DATA COLLECTION INSTRUMENTS

The primary goal of this portion of the study was to "… add to knowledge and not pass judgment on a setting" (Bogdan and Biklen, 1998, pg 46). Several strategies were used to ensure internal validity in this investigation. Triangulation was used to confirm the findings. The most common qualitative data collection methods are observations, interviews, and focus groups. For this study, a questionnaire classroom observations and selected interviews were used to gather data.

Questionnaires

Questionnaires are widely accepted as a tool for conducting and applying basic educational research methodology. According to Leary (1995), there are distinct advantages in using questionnaires as they are relatively inexpensive, easy to administer to groups, and confidentiality can be assured. Questionnaires provide researchers the opportunity to collect data from populations of any size. They come in a wide variety and can be distributed in a variety of ways and through various media. Electronic questionnaires have advantages over the traditional paper and pencil method, as they are cost effective and are transmitted faster and at a higher response rate (Frankfort-Nachmias and Nachmias, 1996). Technical problems associated with hardware and software are the major drawbacks of this method.

The *Views About Sciences Survey* (*VASS*), in its original form, is a pencil and paper assessment that measures personal beliefs about the nature of science and about science teaching (Halloun, 1996, 1997; Halloun and Hestenes, 1995). The *VASS* contains questions that address the two dimensions (see Table 2.1 for the details of each dimension) that make up the nature of science. The *VASS* includes the scientific and cognitive dimensions, the student learning styles, and attitudes toward science or science education. Each question was developed to reveal what an instructor knows about the nature of science within scientific and cognitive dimensions. Research has shown that most students and scientists have views that contradict the views often held by the lay community (Halloun 1996; Halloun and Hestenes, 1998; Halloun, 1997).

Table 2.1: *VASS* Taxonomy (Halloun and Hestenes, 1998)

Scientific Dimensions
Structure: Science is a coherent body of knowledge about patterns in nature revealed by careful investigation — rather than a loose collection of directly perceived facts.
Methodology: The methods of science are systematic and generic — rather than idiosyncratic and situation specific. Mathematics is a tool used by scientists for describing and analyzing ideas — rather than a source of factual knowledge. Mathematical modeling for problem solving involves more — than selecting mathematical formulas for number crunching.
Validity: Scientific knowledge is approximate, tentative, and refutable — rather than exact, absolute and final.

Table 2.2 (continued)

Cognitive Dimensions
Learnability: Science is learnable by anyone willing to make the effort — not just by a few talented people. Science achievement depends more on personal effort — than on the influence of teacher or textbook.
Reflective thinking: For meaningful understanding of science, one needs to: (a) concentrate more on the systematic use of principles — than on memorizing facts; (b) examine situations in many ways — instead of following a single approach from an authoritative source; (c) look for discrepancies in one's own knowledge — instead of just accumulating new information; (d) reconstruct new subject knowledge in one's own way — instead of memorizing it as given.
Personal relevance: Science is relevant to everyone's life. — It is not of exclusive concern to scientists. Science should be studied more for personal benefit — than for fulfilling curriculum requirements.

The way most undergraduate science courses are taught has not changed much since 1910. Professors in their classes focus on the products of science (theories, equations, etc.) rather than on the processes of science. A review of the literature has shown that what students know about physics topics discussed in their introductory physics courses often is situation-specific, concentrated on sensory features of physical objects such as atoms and Newtonian particles. Physics courses tend to be disjointed and weakly connected, and information is fragmented (Halloun and Hestenes, 1985; Hammer, 2000; McDermott 1993; Wandersee, Mintzes, and Novak, 1994; Reif and Allen, 1992).

The *VASS* methodology dimension focuses on how professors view the processes of science and how scientific knowledge is developed and applied. Students generally approach

physics problems by searching formula sheets for given recipes that will give them the solutions to problems (Arons, 1998; Hammer, 2000; McDermott 1993; Novak 1994; Reif, 1985; Van Heuvelen 1991;Viennot 1985).

The validity dimension of the questionnaire examines derivations and observations about scientific knowledge. Physics professors rarely provide students who take physics the opportunity to develop an appreciation for the contribution of science to the world. Therefore, when students work to complete a physics course, they do not analyze information presented to them in physics courses. Students attack problems and try to memorize problems instead of developing methods for checking their own physics solutions. Rarely are they able to appreciate error analysis in experimental design (Arons 1998; Gunstone 1991; Reif and Allen, 1992; Viennot 1985), which is probably the leading contribution to their lack of understanding of the depth of the subject.

These views also have an impact on the cognitive domain of science. The *VASS* questionnaire ranks beliefs about factors related to what teachers think students must do to learn physics, the amount students reflect on what the professors are trying to teach in their classes, and what is personally relevant to the students. Physics is among the least favored subject matter for students (AIP, 1996). Rarely does a college student take physics if not required to do so (Ivie and Nies, 2005). Halloun (2001) suggests that student views about what is necessary to learn in physics may contribute to these problems. Students rarely reflect on what they learned which may contribute to their failure to resolve incompatibilities between their initial knowledge and scientific theory.

The last section of the *VASS* attempts to measure the professors' commitments to teaching physics. Students become repeatedly frustrated if the information is presented as a collection of facts that have no relevance to their lives. College students often bring to their physics courses an array of misconceptions about the physical world that do not correlate with scientific theory (Arizona State University, 2001; McDermott, Schaffer, and Physics Education Group, 2003). These misconceptions are not affected when physics is taught by traditional lecture methods (Halloun and Hestenes 1985; van Heuvelen 1991).

The results from the *VASS* research show that students can be profiled by their views about the nature of science. Many passive learners lose interest in physics because of repeated frustration and failure. They generally do not believe physics is relevant to everyone because of the generic nature of its conceptual tools and the utility of the factual information it provides about the universe (Halloun and Hestenes, 1998). They tend to be the students who are motivated by grades and believe that teachers are the suppliers of knowledge rather than the students' intent on making a personal effort. Many have poor study skills, concentrating on isolated facts and memorizing the formulas without any prior knowledge. These students' concerns in their physics courses lie solely in satisfying course requirements and getting the highest grade by doing the least amount of work.

Active learners, on the other hand, are critical thinkers who take an active part in the learning process (Felder and Brent, 2001). These students tend to be more reflective and search for ways to resolve discrepancies between scientific knowledge and their own thoughts about a concept (Felder and Brent, 2001). Many active learners study physics for

their own personal benefit rather than merely to fulfill curriculum requirements. In an attempt to gather all of these views, Contrasting Alternatives Design (CAD), an assessment format devised by Professor Ibrahim Halloun at Arizona State University is used as the scale. It was developed to deal with the interpretation mismatch that is commonly found in Likert–rating scales.

The scientific and cognitive domains differ on ontological and epistemological perspective. Therefore, the number of items vary from one subscale to another, which prevent the two scales from having a split-half reliability assessment. The items within each individual dimension throughout the instrument vary. The Pearson's correlation coefficient has values of 0.64 and 0.92 when correlating the scientific and cognitive broad domains with the entire instrument.

Each domain and its impact on learning and achievement varies from one dimension to the next. The internal consistency of the *VASS* is measured and assessed indirectly and not with commonly used coefficients such as Cronbach's alpha or Kuder-Richardson's dichotomous items.

To establish content validity, drafts of the modification of the *VASS* were distributed to eight physics faculty members at NCSU, all of whom were interested in educational research related to physics. Feedback from the professors included clarifying jargon, ambiguous items, eradicating redundancy, and adding items to ensure a broad sampling of learner centered instruction. The modifications of the instrument were made and a final draft was then converted to a Web-based HTML format.

The *VASS* is an instrument that was developed by Halloun (1996, 1998) which is based on the philosophies of Kuhn (1970), Bachelard (1960), and Mortimer (1995). Unlike these philosophers, Halloun (1998) suggests that scientific thought in human mind can be represented by three views as shown in Table 2.2.

Table 2.2: Summary of Halloun's Paradigm

View	Type of scientific realism	Approach to Scientific Knowledge	Example
folk	naïve	Strict inductive	Regards mass as a observed or a measured quantity
mixed	classical	More deductive	Treats mass a ratio of force and acceleration
expert	modern	By insights of relativity and quantum theory	Mass depends on speed and other factors

One of the biggest criticisms of Halloun is how he defines a paradigm. Halloun is criticized of "inverting and de-quantizing" Kuhn's concept of paradigm. Halloun's, describes a paradigm as private and individual, like a fingerprint or DNA. This allows people to be grouped by similar characteristics; therefore Halloun describes the scientific community as being comprised of individuals who are 'virtually the same'.

> No two people can ever share exactly the same paradigm, whatever the nature of the paradigm or the profession that the two people might have in common, and this, because of biological and cultural differences in people's history. For paradigms of a particular nature, differences are significantly more pronounced within the lay community than within a professional community guided by such paradigms.... In fact, a scientific paradigm may be delimited in a specific field in such a way that we can practically ignore paradigmatic differences among scientists working in this field, and say that all those scientists share virtually the same paradigm (Halloun 2004, pp. 14–15).

This is vastly different from what Kuhn defines as a paradigm. According to Kuhn, a paradigm is considered a public entity, where scientific practice is shared and accepted by a community of scientists.

> I take [paradigms] to be universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners. (Kuhn, 1970 p. viii)…By choosing [paradigms], I mean to suggest that some accepted examples of scientific practice—examples which include law, theory, application, and instrumentation together—provide models from which spring particular coherent traditions of scientific research. (Kuhn, 1970 p. 10)

Halloun frequently references Kuhn in his work.

> [W]e believe that Kuhn's account of the development of scientific paradigms provides significant insights not only into those paradigms, but also into the natural paradigms of science students. In this respect, the cognitive implications of Kuhn's work bear for us a special value... (Halloun 2004, p. 16)

Halloun also assumes that there is a relationship between the historical development of science as a subject and the individual learning of science. The connection here is not clear.

This study, operates under the assumption that that teachers teach as they were taught (Britzman, 1991; Lortie, 1975). Because physics instructors have no formal teacher training, it is assumed that they were socialized by the physics community. Since Halloun is a respected member of the physics community, hopefully the use of the VASS would help increase the number of respondents.

Class Observation Instruments

Two instruments, The Classroom Observation Protocol (Tempel, 2003) and the Flanders System of Interaction Analysis (Flanders, 1970) were used. The Classroom Observation Protocol for Project Inquiry (Tempel, 2003) was used to gather information about instructional methods used in introductory physics courses. The Project Inquiry observation instrument gathers real-time information in the following five areas:

- introduction of the lesson,

- modes of instruction,
- use of questions,
- teacher behavior, and
- materials used.

The Flanders System of Interaction Analysis (Flanders, 1970) is an observational tool used to classify teacher-student interactions in the classroom. The system has been used and modified extensively in classroom observation studies since its development (Wragg, 1999). Research shows the analysis of the matrix is so dependable that the mental picture of the classroom interaction can be created so that accurate inferences about the verbal communications can be made without being present in the observation (Gay, 2000). Definitions and explanations of the instrument are found in Appendix C. The research suggests that, "teachers teach the way they were taught in the discipline. If they were lectured to, then they tend to become lecturers" (Stein, Haufman, and Sutherland, 2002). If this is true, then the information that can be uncovered by the Flanders can be extremely powerful.

Interviews

Interviews are one of the most widely used data collection techniques in qualitative research. Interviews are used to reveal how participants make sense of their world (Patton, 1990). The interviewees for this study were selected using snowball sampling. This method is used when it is difficult secure respondents. The sample relied on volunteers from the *VASS* questionnaires and referrals from initial interviewees to generate additional interviewees (Salganik and Heckathorn, 2004). It is also particularly useful because it

includes scheduling an interview, conducting the interview, and analyzing the data collected from the interview. Snowball sampling is also beneficial because it is used when the researcher has difficulty accessing the population of interest (Salganik and Heckathorn, 2004). This method of interviewing is limited, however, by researcher perspectives and perceptions.

LIMITATIONS AND DISADVANTAGES OF THE RESEARCH DESIGN

Mixed method research design combines both quantitative and qualitative approaches to collecting, analyzing, interpreting and reporting data. In this dissertation, a questionnaire was used to provide an overview of the university physics professors' beliefs about the nature of science and the classroom practices used introductory physics classes. Classroom observations and a few interviews with the professors and a content analysis of the *VASS* questionnaire and the classroom observations allowed the researcher to determine the factors that determine whether a scientist held an expert, mixed or folk view of the nature of science. This information was used to confirm support the conclusion drawn from the survey.

One of the advantages of mixed method research designs is that it provides a more comprehensive view of the relationship between classroom practices and the nature of science than any one research method. One of the perceived weaknesses of this type is that selective observation is limited to the observed behaviors exhibited by the participants. However, a combination of questionnaires, observations and interviews can balance the limitations of any one survey.

CHAPTER THREE: METHODOLOGY

INTRODUCTION

The information in this chapter serves to: (1) describe the research procedure, (2) explain the sample selection, (3) offer a statement of the research questions, and (4) provide an explanation of the data collection methods and statistical analysis procedures used to analyze the data. In this mixed methods study, a triangulation mixed method design analysis was used to explore relationships between teachers' beliefs and their practices.

The purpose of this design was to collect the qualitative and quantitative data, merge the data, and use the results to strengthen the weaknesses of each of the forms of data. This format was chosen because it is the most appropriate for triangulation and for adding both breadth and depth to examine the issues surrounding university physics professors and graduate assistants' views on the nature of science and their instructional practices. The weakness of this design is the amount of time involved in data collection if all phases are given equal priority (Creswell, 2003).

RESEARCH PROCEDURE

This study was conducted in the following sequence:

1. Permission was obtained to distribute the study from the Institutional Review Board for the Protection of Human Subjects in Research (Appendix B), Dean of the College of Physical and Mathematical Sciences and the head of the Physics department.

2. Following suggestions by the dissertation committee, several discussions took place with various members of the physics education research group to determine which questionnaire would be the best to obtain data about the nature of science from the physics faculty at NCSU.

3. The Views About Science Survey (*VASS*) was selected as a questionnaire because the physics education researchers recognized the authors Halloun and Hestenes as respected contributors to the physics education field and the only researchers within physics education who attempted to look at the scientists' views about science.

4. The members of the dissertation committee and physics education researchers completed the survey to determine if:
    - Each item was easily understood
    - Each item was interpreted in the way it was intended.
    - The intent was behind each item was clear to educational researchers knowledgeable about the subject.

    Modifications were suggested and acknowledged.

5. An electronic version of the modified *VASS* was made using Inform version 3, web-based software, to ensure the anonymity of the instructor completing the questionnaire. The researcher encountered several major problems in developing the web page.

6. Classroom observations were completed in the 2002/2003 and 2003/2004 academic years using the Project Inquiry Classroom Observation Protocol.

7. The electronic questionnaire was sent out in August 2004.

SAMPLE

The participants in the study were twenty-nine of the forty-six physics faculty members and graduate assistants who were teaching physics at North Carolina State University (NCSU), a public university in the piedmont of North Carolina.

The physics department at NCSU is a higher education anomaly. The funding for the research program ranks in the top three departments at NC State. Fifteen faculty members are part of NC State Academy of Outstanding Teachers. Fifteen others are members of the American Physical Society. The NCSU physics department seeks to become a national model among the public research universities in its approach to and innovations in education

and in its excellent and diverse faculty and graduates. The department has embedded in its mission a deeply held conviction to provide high quality physics instruction to the university community by: (1) improving teaching effectiveness through the use of innovative approaches and the implementation of new technologies, (2) seeking to raise the awareness of the science in K-12 education, and (3) recruiting and enrolling the best undergraduate and graduate students.

The sample selected to take the *VASS* questionnaire was both purposeful and stratified. The sample included ten full professors, two associate professors, four assistant professors, three instructors, four research assistants, and five teaching assistants. One respondent chose not to disclose academic rank. The majority of the respondents were full professors who described themselves as Caucasian males. Two were Caucasian females. One person did not respond to the question of gender.

The samples in the quantitative analysis (classroom observations/interviews) were the physics faculty members at North Carolina State University who were currently teaching introductory physics. The participants taught Physics 131, 205, 208, 211, and 212. These classes are introductory physics courses that meet general education science course requirements. All these courses cover the basic topics generally covered in introductory physics, emphasizing learning the fundamentals of physics topics related to mechanics, properties of matter, heat, sound, electricity, magnetism, light, and relativity. Each class only differs by the mathematical approach. The conceptual physics course (PY 131) covers the concepts of mechanics and electricity and magnetism in one semester. The algebra-based

physics (PY 211/212) and the calculus-based physics (PY 205/208) covers the content of PY 131 with a greater emphasis on problem-solving.

DATA COLLECTION INSTRUMENTS

VASS Questionnaire

The *Views About Sciences Survey* (*VASS*) was the questionnaire chosen for this study. A detailed description of the dimensions analyzed can be found in the review of literature. Unlike traditional questionnaires which use the Likert scale, some of the responses of the *VASS* used the Contrasting Alternatives Design Format developed by Halloun and Hestenes (1998). There were five response options on the *VASS* questionnaire. Responses to the option "*Only (a)*" were scored five, responses to the option "*more (a) than (b)*" were scored a four; responses to the option, "*equally (a) and (b)*" were scored three; responses to the option "*more (b) than (a)*" were scored two and responses to the option "*only (b)*" were scored one.

Figure 3.1 shows the scale of the responses with the extreme values indicating the extent of the view, with 5 being an expert and 1 being a novice. Unlike the Likert scale, the respondents are less likely to guess because the questions are alternated throughout the survey so that the responses do not follow any particular pattern.

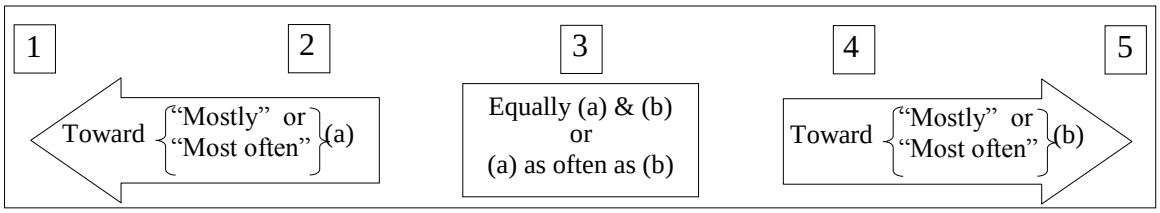


Figure 3.1: Contrasting Alternatives Design Scale

In order to categorize the respondent's views about the nature of science, each respondent had to be profiled to see whether they held an expert, high transitional, low transitional, or a folk view. The respondents were asked to respond to items that revealed insight into their views on the scientific and cognitive aspects of the nature of science. The responses of the physics instructors were expected to be polarized towards the expert end of the scale on almost every item.

As described in Table 3.1 a respondent with nineteen or more responses in the expert range was characterized as an "expert." If they had fifteen to eighteen responses in the expert range, the respondent was coded as "high transitional." If the respondent had at least fourteen but no more than eleven responses in the expert profile and an equal or smaller amount in the folk range, then the respondent was coded as "low transitional." The respondent received a label of "folk" if the responses express a view about the nature of science that is inappropriate.

Table 3.1: General Profile Characteristics (Halloun and Hestenes, 1998)

Profile Type	Code	Number of items out of 30
Expert	EP	19 items or more with expert views
High Transitional	HTP	15 to 18 with expert views
Low Transitional	LTP	11 and 14 with expert and an equal or smaller number of items with folk items
Folk	FP	11 and 14 with expert but larger number of items with folk items or less with expert views

The scientific and cognitive domains differ in ontological and epistemological perspective. Therefore, the number of items varies from one subscale to another, which prevents the two scales from having a split-half reliability assessment. The items within each individual dimensions vary throughout the instrument. The Pearson's correlation coefficient

has values of 0.64 and 0.92 when correlating the scientific and cognitive broad domains with the entire instrument.

Each domain and its impact on learning and achievement varies from one dimension to the next. The internal consistency of the *VASS* is measured and assessed indirectly and not with commonly used coefficients such as Cronbach's alpha or Kuder-Richardson's dichotomous items. To establish content validity, drafts of the modification of the *VASS* were distributed to eight physics faculty members at NCSU, all of whom were interested in educational research related to physics. Feedback from the professors included clarifying jargon, ambiguous items, eradicating redundancy, and adding items to ensure a broad sampling of learner centered instruction. The modifications of the instrument were made and a final draft was then converted to a Web-based HTML format.

The survey instrument was administered as a baseline measurement for assessment of physicists' beliefs about the nature of science at North Carolina State University. Based on a validated science questionnaire developed by Halloun and Hestenes (1998) of the Center for Research on Education in Science, Mathematics, Engineering, and Technology (CRESMEST), the survey was administered online to both teachers and graduate teaching assistants of physics at NCSU during the 2004-2005 academic year. All physics professors and the physics graduate students were sent emails containing instructions to participate, as well as a notice that their participation was voluntary and all identifiable information would be removed before release with any reports utilizing the data. The online survey was available from August 14 to November 30, 2004.

Data collection using the questionnaire began at the beginning of the Fall 2004 semester. One month later the department head sent out another email encouraging the professors and the graduate students to respond to the questionnaire. To ensure that responses to the *VASS* questionnaires were treated with complete confidentiality and anonymity, only the date and the time the questionnaire was completed were used to identify each respondent. Problems using the software arose when the university changed the version of inFORM, the software application that allows information to be collected and submitted to a web-based form, without notifying the campus faculty.

Classroom Observation Instruments

The purpose of classroom observations is to see the various interpersonal interactions that occur between the teacher and the students in the classroom. The emerging patterns of interaction are complex in nature and will assist the observer in accurately understanding classroom dynamics that exist. Effective inquiry-based science teaching and effective teaching of the nature of science have similar characteristics. Regardless of whether instruction is in a content course, methods course, or lab, the role of the instructor is paramount in determining whether or not effective teaching practices are being used. The teacher should be a guide on the side

> "... circulating, redirecting, disciplining, questioning, assessing, guiding, directing, fascinating, validating, facilitating, moving, monitoring, challenging, motivating, watching, moderating, diagnosing, trouble-shooting, observing, encouraging, suggesting, watching, modeling and clarifying (McKenzie, 1998) ".

It has also been suggested that the classroom arrangement is a tell-tale sign that inquiry-based instruction is occurring. Traditionally, college science classrooms are set as

lecture classes as shown in Figure 4.11. All factors including "… lighting, sound, temperature and desk arrangement—into account when they first design their classroom layout (Burke & Burke-Samide, 2004, p. 237)." There is no one "best" setup; but there are some best suited for certain class activities, and the diverse learners participating within them. It is important for teachers to make informed decisions about whether the lesson is conducive to rows, clusters, semicircles or some other arrangement (Wannarka & Ruhl, 2008, p. 89). Being mindful of this, the researcher was careful not to evaluate instruction or the setting but to record data that best reflected the types of interactions and the materials used in the classroom to see if these instructional practices lined up with the research.

The Classroom Observation Protocol for Project Inquiry (Tempel, 2003) and the Flanders System of Interaction Analysis (Flanders, 1970) were the instruments used to determine if the three elements essential to effective teaching were present in the undergraduate science classroom. Traditionally, it has been used to gather information about instructional methods used in K-12 science courses. The Project Inquiry observation instrument gathers real-time information in the following five areas:

- introduction of the lesson,
- modes of instruction,
- use of questions,
- teacher behavior, and
- materials used.

At least one class was observed on each day each course was offered in each of the spring and fall semesters using the *Classroom Observation Protocol for Project Inquiry (*Tempel 2003*)*, which generally was used to gather information about classroom inquiry activities at the K-12 level. The researcher was trained using the *Classroom Observation Protocol for Project Inquiry* at Xavier University of Louisiana as part of the course requirement for a masters degree in Curriculum and Instruction in the use of this observation instrument in order to gather real-time information in the following five areas: (1) introduction of the lesson, (2) modes of instruction, (3) questions, (4) teacher behavior, and (5) materials used. Percent agreement for the sum of the five areas was 93%, while the percent agreement for the overall rating was 100%. Appendix B contains a copy of the instrument, along with *Definitions and Explanations for Observers*.

The researcher also used the Flanders Interaction Analysis (1970) to measure classroom interaction patterns. The Flanders Interaction Analysis was used to analyze patterns of communication dynamics in the classroom. Seven categories describe professor talk patterns and two describe student talk patterns. Table 3.2 describes each of the categories analyzed. In this analysis, to initiate means to make the first move by leading, beginning or introducing an idea or concept for the first time. Respond means to take action after an initiation by countering, clarifying or reacting to ideas that have been expressed. In the traditional undergraduate physics classroom, the teacher will show more initiating behaviors than the students. In this study, it was hypothesized that in introductory physics classes where

the learning is student centered, there will be a balance between instructors talking to the students and students initiating conversation about the subject.

Research using the Flanders Interaction Analysis Categories (FIAC) suggests that the proportion of teacher statements that use student ideas and opinions is directly related to the average class scores on attitude scales and average achievement scores. If inquiry-based teaching does show greater measures of use of student ideas in class discussions, it could be argued that inquiry-based instruction works by forcing teachers to adopt teaching behaviors that are centered on student initiated discussions. However, a more sophisticated analysis of the data based on the coding of the individual tallies was performed in order to search for patterns of interaction.

According to the research on the FIAC, approximately 6,000 tallies collected from six to eight observations spaced according to a logical plan is necessary for a stable sample of teacher interaction patterns. If the data were collected as planned then a total of fifty-six classes were observed. This would provide a total of 201,600 tallies for the introductory physics classes (50,400 tallies in PY131; 46,800 tallies in PY 205; 43,200 tallies for PY 208; 36,000 for PY 211; and 25,200 tallies). It is not possible to code and analyze this amount of data within the time allotted for this project and it would appear unnecessary to do so. It is suggested that it is possible to collect less if the purpose of using the instrument is to investigate concerns with instructional methods.

Table 3.2: Flanders' Interaction Analysis Categories (Flanders, 1970)

Teacher Talk	Response	1. Accepts feeling. Accepts and clarifies an attitude or the feeling tone of a pupil in a non-threatening manner. Feelings may be positive or negative. Predicting and recalling feelings are included.
		2. Praises or encourages. Praises or encourages pupil action or behavior. Jokes that release tension, but not at the expense of another individual: nodding head, or saying 'Um hum?' or 'Go on' are included.
		3. Accepts or uses ideas of students. Clarifying, building or developing ideas suggested by a pupil. Teacher extensions of pupil ideas are included but as the teacher brings more of his own ideas into play, shift to category five.
		4. Asks questions. Asking a question about content or procedure, based on teacher ideas, with the intent that a pupil will answer.
	Initiation	5. Lecturing. Giving facts or opinions about content or procedures: expressing *his/her own* ideas, giving *his/her own* explanation or citing an authority other than a pupil.
		6. Giving directions. Directions, commands or orders to which a pupil is expected to comply.
		7. Criticizing or justifying authority. Statements intended to change pupil behavior from non-acceptable to acceptable pattern; bawling someone out; stating why the teacher is doing what he is doing; extreme self-defense.
Student Talk	Response	8. Student talk – response. Talk by students in response to teacher. Teacher initiates the contact or solicits pupil statement or structures the situation. Freedom to express own ideas is limited.
	Initiation	9. Student talk – initiation. Talk by students which they initiate. Expressing own ideas; initiating a new topic; freedom to develop opinions and a line of thought, like asking thoughtful questions: going beyond the existing structure.
Silence		10. Silence or confusion. Pauses, short periods of silence and periods of confusion in which communication cannot be understood by the observer.

In order to secure data, Flanders Interaction Analysis procedure was employed to observe classroom interaction patterns in introductory physics classrooms. The following observation procedure was used:

1. In each class period of 50 and 75 minutes, 15.0 minutes (900 seconds) were used as observation period.

2. In each class, 15 minutes (900 seconds) were divided in to nine time units. One time unit was 1.67 minutes (100 seconds).

3. In the first fifteen minutes of the class observation period, three time units were observed randomly, comprising 5.0 minutes (300 seconds).

4. In the second fifteen minutes of the class observation period, three time units were observed randomly, comprising 5.0 minutes (300 seconds).

5. In the third fifteen minutes of the class observation period, three time units were observed randomly, comprising 5.0 minutes (300 seconds).

6. Total time for observation in a single classroom comprised 15 minutes (900 seconds).

The coding process required that a tally, i.e. a category code, is made every three seconds, resulting in a total of 3,600 tallies from the fifteen minutes analyzed from each teaching session. These codes were analyzed using *SAS*. Although there was some variation in the patterns of interaction in each group from week to week, the distinctive patterns seen in these examples are consistent with the observations field notes for all the sessions observed.

In order to improve the validity of the classroom observations, a number of coding procedures are followed. The rules for coding procedures for this study are outlined in Table 3.3. The researcher used the simplest form of analysis to calculate the amount of time the students spent talking, the teacher spent talking and silence.

Table 3.3: Coding Procedures for FIAC

General	• Whenever there is an element of doubt code according to the prevailing balance of teacher initiation & response • Rare events should be coded wherever possible • Categories 1, 2, 3 & 9 are expected much less than 5, 6, 7 & 8 so use with caution.
Category 1	• This is a rare event. The teacher must actually label the feeling to obtain this code
Category 2	• Avoid using to code habitually routine superficial exclamations of praise. • Code more than once if extended praise is given.
Category 3	• Teacher can respond to student's ideas in a number of ways. Acknowledge – creating norms and logical connections Modify- rephrase Apply it to solve a problem or make inference Compare it with other ideas Summarize what is said • Code 3 more than once if extended response given. • Restrained use in coding 3 appears to enhance its diagnostic utility. • Beware of teacher making bigger abstraction from students statement (code 5) • Beware of teacher ignoring students suggestion and asking for another (code 4)
Category 4	• Teacher must act as if expects an answer (not rhetorical question) • If teacher talk is to bring others into discussion e.g. what do you think Joe? No need to code 4
Category 5	• Lecturing, expressing opinions, giving facts, interjecting thoughts and off handed comments included. • In traditional teaching approaches category 5 will be most common catchall category and incorrect tally for this category unlikely to distort teacher's profile.
Category 6 & 7	• Used to indicate close supervision and direction by the teacher • Used for statements intended to produce compliance. To recognize during coding ask whether compliance will be result of statement. • Avoid confusion with announcements (code 5) • Questions during teacher directed drill can be coded 6
Categories 8 & 9	• Making a choice between codes 8 & 9 should relate to the teachers preceding question. Student response to a closed teacher question e.g. Should we use draw a free-body diagram or not? = code 8 Student response to open teacher question e.g. what type of approach should we use = code 9 • Student response 8 can turn into 9 if the student embellishes or adds voluntary information or makes an independent judgment • Use 8 in all cases where there is silence • Category 9 also used for students making off target remarks (resistance to compliance is doubt about 9).

The pairs of codes used for analyzing the patterns of initiation and response are immediately above and below the line of code. The example in Table 3.4 shows a 60 second verbal interaction coded using the numbers in bold which showed the Flanders Interaction Analysis Categories. The numbers immediately above and below the line of code are coded pairs used for the purpose of analyzing the patterns of initiation and response.

Table 3.4: Coding Pairs Used For The Analysis

Pair #	1	3	5	7	9	11	13	15	17	19
Pair	[4-8]	[3-5]	[5-5]	[5-5]	[5,5]	[5-5]	[5-5]	[5-5]	[5-4]	[8,8]
Code	**4, 8**	**3, 5,**	**5, 5**	**5, 5**	**5, 5**	**5, 5**	**5, 5**	**5, 5**	**5, 4**	**8, 8** **8**
Pair	[8 - 3]	[5 - 5]	[5 - 5]	[5 - 5]	[5 - 5]	[5 - 5]	[5 - 5]	[5 - 5]	[4-8]	[8,8]
Pair #	2	4	6	8	10	12	14	16	18	20

The first pair represents the instructor initiating the conversation by asking a question followed by a student response (4-8). The second pair consists of the same student response followed by the instructor's reaction which is to use the student's idea (8-3). The third pair shows the initial response by the instructor that is followed by the instructor giving more information (3-5). Data on the number of pairs in each category can be entered in a 10x10 matrix as illustrated in Figure 3.2. The first number in the pair is found in the vertical column and the second is found in the horizontal column. The data entered into a cell is the frequency of interactions in that category. According to Flanders, the responses categorized as higher frequencies fall in cells (3-3), (3-9), (9-3) and (9-9). These responses are indicative of a more creative teaching pattern. Analysis of the pairs can be used to detect the pattern of a lesson. These codes will indicate to what degree the different classes used inquiry and traditional methods. If the inquiry based teaching is found to be the norm, it will be possible to give an

explanation on how the class was achieved. Inquiry based classes require that teaches put an emphasis on the classroom activities that incorporate creative patterns of inquiry.

Category	1	2	3	4	5	6	7	8	9	0
1										
2					1					
3										
4								2		
5				1	13					
6										
7										
8			1	2						
9										
0										

Figure 3.2: FIAC categories in 10x10 matrix completed with data

The different patterns of interaction can be shown using a 10 x 10 matrix. Figure 3.3 illustrates a typical pattern of interaction in the calculus and algebra based physics classes. The shaded squares are those which will contain the highest frequency of pairs in each pattern. The differences between classes will be presented visually using this method.

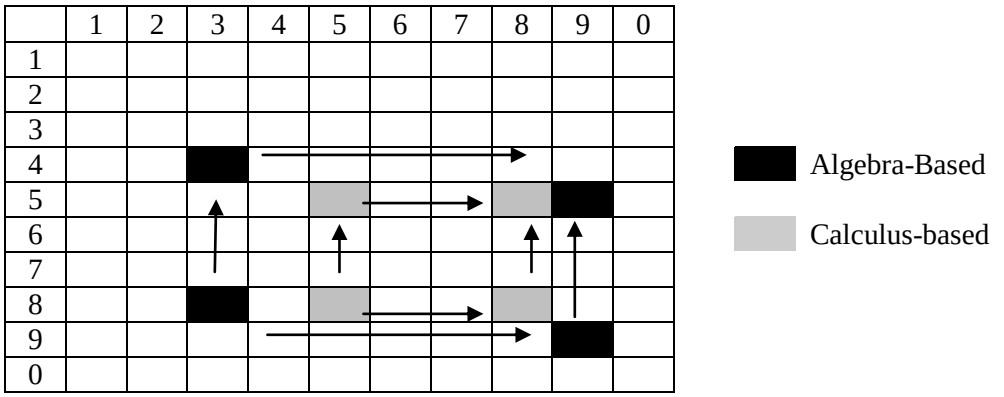


Figure 3.3: Typical pattern of interaction for calculus and algebra based physics.

To calculate teacher talk time, categories one through seven were added and converted into percentages by dividing the frequencies by total time. To calculate the professor's talk time, frequencies from category 5 through 7 were added and converted into percentages. The same procedure was used for each class. The interaction tallies for each class in the respective curricula were added together and then divided by the number of professors in the curriculum to give an estimated average pattern of interaction in each curriculum. The data generated were used to calculate a number of measures that can describe and analyze what happens in a particular classroom and to make comparisons between different classes.

During this study details describing the physical setting of the classroom were recorded in a field journal. The number of students in the room and the position of the teacher's table were recorded in writing. A rough sketch of the classroom was hand drawn. This included how the students were seated, patterns of interactions between the teacher and the students, any changes that occurred within these patterns, and specific teaching strategies (such as the use of hands-on activities, teacher demonstrations, small and large group activities, cooperative group work, open-ended inquiry and data collection, and/or manipulation exercises).

Interviews

Interviews are one of the most widely used data collection techniques in qualitative research. Interviews are used to reveal how participants make sense of their world (Patton, 1990). The interviewees for this study were selected using snowball sampling which relied

on volunteers from the *VASS* questionnaires and referrals from initial interviewees to generate additional interviewees (Salganik and Heckathorn, 2004). This method is also particularly useful because it includes scheduling an interview, conducting the interview, and analyzing the data collected from the interview. This method is beneficial because it is used when the researcher has difficulty accessing the population of interest (Salganik and Heckathorn, 2004). This method is limited by researcher perspectives and perceptions. One of the perceived weaknesses of this method is that selective observation is limited to the observed behaviors exhibited by the participants. However, a combination of questionnaires, observations, and interviews can balance the limitations of any one survey.

Following the observation, at a convenient time, one-to-one interviews were conducted with those who volunteered to participate. All interviews following an open-ended, semi-structured interview protocol. The professors were asked the questions contained in the Teacher Practice Index in the *VASS* followed by specific questions about the scientific community and its role in educating others about the nature of science. The questions are found in Appendix D.

In addition to the information provided, teachers were asked about the context in which they teach and how the context influences how and what they teach. Effective teachers were not predicted to list an algorithm of step-by-step procedures to engage undergraduates in the successful learning of physics. Therefore, an open-ended, semi-structured questioning technique was used. These interviews supported the results but were not used as a primary data source due to the fact that two of the three professors did not give their permission to be

audio taped. In an attempt to validate the interview data, each professor was emailed their portion of the data with the researcher's analysis and asked if the interpretation accurately reflected their thoughts. One of the two professors replied and any suggested corrections were made. According to Miles and Huberman (1984), using this model of analytical induction leads to further reliability of the validity of each interview because of the consistent formulation and reformulation of emerging explanations during the data analysis, which corroborates the accuracy of the profiles giving more credence to the validity.

Data Analysis

A triangulation mixed method design was undertaken to analyze the faculty and graduate assistant responses and the classroom observations. This design "is characterized by the collection and analysis of both the qualitative and quantitative data simultaneously and make an interpretation as to whether both data support or contradict each other" (Creswell, Plano, Guttman, and Hanson, 2003). In this study, the triangulation mixed method design consisted of two stages. Equal priority is given to the results of both the *VASS* and the observations of instructional practices of the introductory physics teachers (Abd-El-Khalick et al, 1998; Brickhouse, 1990). The goal of this analytical method was to understand the phenomena from the instructors' perspectives. In order for this to happen, the researcher inspected and examined the data for errors. The data were analyzed to identify the distribution of scores so that an appropriate statistic would be chosen.

When the data are not normally distributed, and the measurements contain rank order information, then computing the standard descriptive statistics (e.g. mean, standard

deviation) is not always the best way to analyze small data samples because they generally violate the Central Limit Theorem. Nonparametric distribution was used to compute a wide variety of measures of location (mean, median, mode, etc.) and dispersion (variance, average deviation, quartile range, etc) to provide a "complete picture" of the data.

The non-parametric Kruskal-Wallis test was used to test differences among respondents because of the small numbers of subjects in some of the comparisons. Differences were grouped according to the rank and were also compared as graduate students versus physics faculty. A p-value of 0.5 or less was taken to indicate significance in all tests. The Spearman R correlation coefficient was computed using the Chi-square test, the non-parametric equivalent to express a relationship between the two variables, (e.g. "expert" vs. "folk" by "faculty" vs. "graduate") which are categorical in nature.

RESEARCH QUESTIONS AND RATIONALE

This study investigated the views of the nature of science held by introductory physics instructors by addressing the following meta-question: How are introductory physics courses taught at the university level?

Research Questions

1. **How do physics instructors view the nature of science?**

   Sub-question: Do graduate assistants differ from physics faculty in their views of the nature of science?

   Rationale: Just as calls for change how science is taught have been made, so have changes to what is emphasized in science. In the 1900s, the nature of science

emphasized science. In the 1960s, the nature of science emphasized critical thinking for the purpose for "training the mental abilities of the students (Hurd, 1960). In 2000, the emphasis shifted again to science processes and emphasizing inquiry. The National Research Council added more to understanding the nature of science: This study will look at how scientists view the nature of science.

No single universal step-by-step scientific method captures the full complexity of doing science; creativity is a vital, yet personal, ingredient in the production of scientific knowledge; with new evidence and interpretation, old ideas are replaced or supplemented by newer ones; and while science and technology do impact each other, basic scientific research is not directly concerned with practical outcomes, but rather with gaining an understanding of the nature of the world for its own sake (Crowther, Lederman, and Lederman, 2005).

In the science education community, the nature of science is defined by its components:

- "Science is a way of knowing" and there are values and beliefs that critical to building a foundation of scientific knowledge (Lederman, 1998).
- The history, philosophy, sociology and psychology of science influences how science is taught and how science is learned (McComas, Clough, and Almazroa,1998).
- All people regardless of their age, race, sex or nationality engage in science consciously or unconsciously and is basically a human endeavor (Weinburgh, 2003).
- Science is rooted upon its evidence—not logic or faith (Weinburgh, 2003).

It is necessary to find out how the instructors of the introductory physics classes view the nature of science in order to understand how science is taught. This study will reveal how the introductory physics view the nature of science. To answer this question, the results for the *VASS* will be compiled to determine the view held by the physics instructors. Non-parametric data analysis will be used as well as interview quotes.

2. **What modes of instruction are used in the introductory physics classrooms at NCSU?**

   Subquestion: What amount of time does the introductory physics class instructor spend talking in class?

   Rationale: Horizon Research conducted The National Survey of Science and Mathematics Education: Trends from 1977 to 2000 (Smith, Banilower, McMahon, and Weiss, 2002), and the results from this survey indicate that instructional strategies used by science and math teachers have not changed much in the past ten years, but there is a very small trend toward more cooperative and hands-on type strategies. On the other hand, Lumpe, Haney, and Czierniak (1998) performed research that looked at the role of teacher beliefs regarding the implementation of cooperative learning strategies. In their study, cooperative learning strategies were not found to be compatible with the current educational policy efforts, because "a teacher, who does not share the same epistemology that surrounds the educational policy, may not implement that policy."

In order to explore the modes of instruction used in the introductory physics classrooms, this study was designed to gain insight into which instructional strategies are being used at the university level.

Methodology: Classroom observations will be made and the frequency will be determined by descriptive statistics and interview quotes.

3. **What relationships exist between the views of the nature of science and the classroom instructional practices in the university physics classroom?**

Rationale: A teacher's experience does not translate into an understanding of the components that make up the nature of science (Billeh, & Hasan, 1975; Carey and Strauss, 1970) and the relationship between teachers' conceptions of the NOS and classroom practice is not clear. According to Lederman's (1992) exhaustive review of research on the nature of science, K-12 science teachers' views of the NOS are not reflected in the classroom experiences that the teachers design or elect to use. In looking at the relationship between the nature of science and classroom practice, Lederman found that the presumed relationship was not significant. To explore this relationship, this study addresses the relationship between the views about the nature of science held by university physics professors and the instructional practices used by them in introductory physics classes.

Methodology: Interview quotes will be used to triangulate the data. Since the data only comes from two faculty members, it can only be used to give some insight to research questions one and two.

LIMITATIONS

Reported instructors' views are based on the responses to the *VASS* questionnaire, document analysis, classroom observations, and the comments from two professors who volunteered to be interviewed for this study. One of the subjects interviewed did not agree to be audio taped. In an attempt o make the participants in the interviews comfortable, the interviews took place in the office of the professor (Takahashi and Teddlie, 2003). The researcher took detailed notes and the subject reviewed the notes from the interview. Interview clarification is a recognized limitation in the study. To facilitate reader understanding of data analysis and interpretation, the results include not only representative quotes from the interview, but the researchers' discussion of their interpretations. "Student interviews would have been desirable to enhance the details of conceptions and learning factors (Lederman et al., 2002)", but unfortunately they were not part of the current study.

CHAPTER FOUR: RESULTS AND DISCUSSION

INTRODUCTION

This mixed method study examined the views about the nature of science and classroom observations of the introductory physics classes at NCSU. This was interested in determining the instructional methods used when teaching these introductory courses. The participants were the physics faculty and graduate students who had taught introductory physics within the last five years. Between 2003 and 2004 the participants views about the nature of science were measured by the Views About Sciences Survey (*VASS*) and the observations were coded by the Flanders Interaction Analysis and the Classroom Observation Protocol. The data collection followed the protocol as indicated in Figure 4.1 which outlines the triangulation mixed method design.

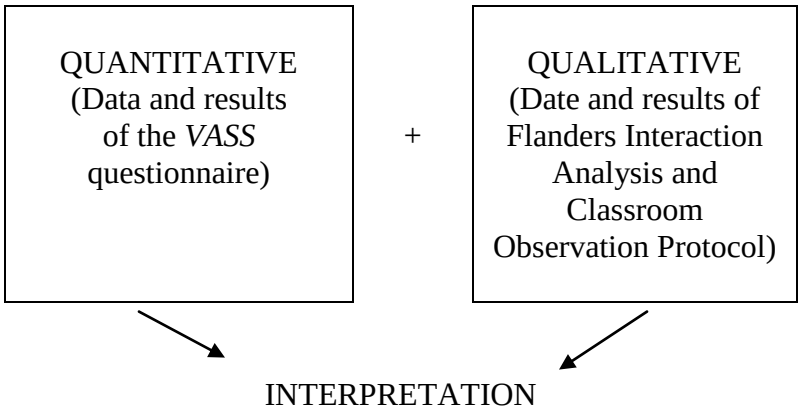


Figure 4.1: Triangulation Mixed Method Design

Legend:
Box = data collection and results
Uppercase letters/lowercase letters =major emphasis, minor emphasis
Arrow = sequence + = concurrent or simultaneous

This chapter is divided into two sections. The first section focuses on the results of the first and second research questions:

Research question 1: How do physics instructors' views of the nature of science? The first section categorizes the professors views of the nature of science derived from the *VASS* questionnaire and highlights data derived from their relationship to the overall results of the study.

The second section discusses the third research question. The chapter focuses on the classroom observations and interviews and the chapter ends with a discussion of the studies' research results.

Research question 2: What modes of instruction are used in the introductory physics classrooms at NCSU?

Research Question 3: What relationships exist between the views of the nature of science and the classroom instructional practices in the university physics classroom?

SECTION I: AN EXAMINATION OF THE PHYSICS PROFESSORS' VIEWS OF THE NATURE OF SCIENCE

Table 4.1 summarizes the results from Section C of the *VASS* questionnaire, which consists of seven questions to solicit demographic data (professor rank, gender, ethnicity, number of years teaching, area of research, number of courses taught, and grade distribution).

Item 1 asked for the rank of the respondent. Ten of the respondents were full professors, two were associate professors, four were assistant professors, three were instructors, four were research assistants, five were teaching assistants; one provided no

response. Item 2 asked for gender: twenty-six were male, two were female, and one did not respond. Item 3 asked for information on ethnicity; only 25 of the respondents answered this question. Twenty of the respondents were white, one Asian, one African-American, three Hispanics and three did not respond.

TABLE 4.1: Faculty Demographics Information

		Number of Respondents	Percent of Respondents
RANK	Full professor	10	34.4
	Associate professor	2	6.8
	Assistant professor	4	13.7
	Instructor	3	10.3
	Research assistant	4	13.7
	Teaching assistant	5	17.2
	No response	1	3.4
GENDER	Male	26	89.8
	Female	2	6.8
	No Response	1	3.4
ETHNICITY	Asian	1	3.4
	African American	1	3.4
	Hispanic	3	10.4
	White	20	68.2
	No Response	4	14.7
TEACHING EXPERIENCE	0-4 years	8	27.6
	5-10 years	6	20.6
	11-20 years	2	6.8
	>20 years	12	41.6
	No Response	1	3.4
AREAS OF RESEARCH	Astronomy	5	17.2
	Atomic	1	3.4
	Condensed Matter	2	6.8
	Material	3	10.4
	Molecular	1	3.4
	Nanoscale	3	10.4
	Nuclear	3	10.4
	Particle	3	10.4
	Physics Education	3	10.4
	Other	3	10.4
	No Response	2	6.8

TABLE 4.1 (continued)

NUMBER OF COURSES TAUGHT	One	25	86.2
	Two	2	6.9
	Three	2	6.9
GRADE DISTRIBUTION (% of class with C or better)	80-89%	9	31.0
	70-79	7	24.1
	60-69	12	41.4
	50-59	1	3.5

The data in the table indicates only 12 teachers had over twenty years of teaching experience; sixteen had less than twenty years of experience, so most had less. Item 5 asked the respondents to report their research interests. The research interests of faculty were equally distributed except in the area of astronomy, atomic, and molecular physics. Astronomy was listed most often as a research interest; atomic and molecular physics were each listed only once as research interests.

Responses to the *VASS* questions concerning the nature of science

The introductory physics courses in the study were considered to be common courses. Common courses are classes where all professors teaching the specific course cover the same topics in a given time frame. The enrolled students are given the same exam at the same time. Most of the faculty (86%) teach only one common course. The results provided information on the number students that received a grade of C or higher. About 41% of the respondents indicated that 60-69% of the students receive a grade of C or higher in their classes.

The methods used by a teacher to provide the most meaningful, equitable and efficient way to achieve the class objectives are important to how science should be taught. At the university level, the physics instructors also serve as scientists whose experiences in

science can be profiled. A person view about the physical realities are represented in the VASS by the scientific domain. The cognitive domain focuses on how scientists attempt to fulfill the course requirements.

According to the writers of the *VASS*, a paradigmatic profile, which consists of a many different paradigms can be constructed on each respondent. Although, these views are similar to those of Kuhn (1970). Halloun is careful to note

> …Our position regarding paradigms, and especially scientific paradigms, converges in part with Kuhn's position. We do not fully subscribe to Kuhn's work (1970), or any other work in the philosophy of science for that matter... (Halloun 2004, p. 16)

Therefore philosophical views about the nature of science as determined by the *VASS* can be categorized as expert (scientific realist), mixed (a combination of classical and modern scientific realist) or folk (naïve realist) views. Scientists are expected to hold expert views of the nature of science. This means that they recognize that most scientific knowledge is approximate and can change and can accept scientific laws at face value knowing they too are subject to change. For example, the scientists that contribute to the physics books used in undergraduate course have good reason to believe that the truths presented about Newton' laws of motion because of the scientific evidence that supports Newton's laws. It is also reasonable to look at Newton's laws independent of the theories in our textbook and conduct our own experiments (Halloun, 2007).

On the other hand, those that respond with a folk (naïve realist) views of the nature of science accept what the textbook says. They generally believe that the world is exactly what they see. They never reflect analyze or test any theory. They just accept that the world is

what it is. The average everyday person should have mixed views. This means that no one type of view is dominant. This generally describes the views of a typical person (Halloun, 2007).

Scientific Domain

Within the scientific domain, the questions are centered on how science is structured, the methods used in science, and the validity of scientific laws. In Section B, items 8 through 12, 14, 15, 26, 28, and 35 through 37 give insight into the views of the scientific domain. A summary of the responses to each domain and dimension follows. The expert view on the scientific domain would be a value close to 1. The mean value for the respondents was 2.5 for the scientific domain, which means that on average, the physics professors and graduate assistants at NC State have mixed views on the scientific domains of the nature of science.

Structure

The structural view of physics deals with the framework of physics as a subject. Items 9-12 delve into professors' views of the structure of physics. In theory, physics professors holding expert views believe that everything in the universe is connected. If a physics professor has a folk view on the nature of science, then that professor believes that physics consists of a large collection of unconnected facts. The mean value for the respondents was 3.0 for the structure of science, which means that on average, the physics professors at NC State have mixed views on the structure of science. Table 4.2 provides means and standard deviations of the results of items 9 through 12.

Table 4.2 provides information about how each respondent was ranked. To be considered an expert, the respondents' expressed views must be consistent with the appropriate view of the nature of science relative to the item.

Table 4.2: *VASS*-The Responses for the Structure Dimension of the Nature of Science (n=29)

STRUCTURE	**μ**	***SD***
ITEM 9. Different branches of physics, like mechanics and electricity: a) are related to each other by common principles. b) are separate and independent of each other.	2.0	1.2
ITEM10. Knowledge in chemistry is: a) related to knowledge in physics. b) independent of knowledge in physics.	3.8	0.61
ITEM 11. Physicists say that electrons and protons exist in an atom because: a) they have seen these particles in their actual form with some instruments. b) they have made observations that can be explained by such particles.	3.9	0.82
ITEM 12. Physicists' current ideas about particles that make up the atom apply to: a) physical objects that could be anywhere in the universe. b) some physical objects in the universe but not others.	2.3	0.97

Item 9 (μ= 2.02) shows that the professors perceive physics as being related by common principles. This means that there are common principles that connect the different branches of mechanics and electricity. Item 10 (μ=3.79) shows that the respondents' views varied on the importance of the knowledge of chemistry in learning physics. Item 11 (μ=3.9) asks for physicists' beliefs on how they know that electrons and protons exist. Most of the respondents answered by stating that observations have been made to explain these types of particles. Item 12 (μ=2.3) asks about the universality of the current ideas about particles that make up the atoms. Most of the respondents held a low transitional view.

Methodology

The view of the methodology of physics deals with how science is taught and practiced. Science is an open-ended process that is usually taught linearly, often following a single scientific method. Items 8, 26, 28, and 37 of this section of the *VASS* specifically explored some common myths about the methods of physics. The mean value for the respondents was 1.9 for the methods of science, which means that on average, the physics professors and graduate assistants at NC State have high transitional views on the methods of science. This means they are likely to have varied views which alternate between the mixed and the expert views about the methods of physics, but their responses are more inclined to align with the experts' view.

Table 4.3 summarizes the results of the methodology section of the *VASS*. The expert view would be polarized toward 1.0. Item 8 (μ=2.1) and 28 (μ=1.9) asked about methods of problem-solving. The respondents had a high transitional view regarding the methods of solving physics problems. Based on their scores, it is highly likely that the physicists would believe that each physics problem is unique. Items 26 (μ=1.9) and 37 (μ=1.7) probe at the role of mathematics in physics problem solving. Based on the scores, it is likely that physicists use mathematics as a tool to analyze, communicate and express meaningful relationships.

Table 4.3: *VASS*- Methodology Dimension of the Nature of Science Responses (n=29)

METHODOLOGY	**μ**	***SD***
ITEM 8. If we want to apply a method used for solving one physics problem to another problem, the objects involved in the two problems must be: a) identical in all respects. b) similar in some respects.	2.10	1.10
ITEM 26. In physics, mathematical formulas: a) express meaningful relationships among variables. b) provide ways to get numerical answers to problems.	1.9	0.82
ITEM 28. The first thing I do when solving a physics problem is: a) represent the situation with sketches and drawings. b) search for formulas that relate givens to unknowns.	1.9	0.82
ITEM 37. Physicists use mathematics as: a) a tool for analyzing and communicating their ideas. b) a source of factual knowledge about the natural world.	1.7	0.75

Validity

The validity dimension of the scientific domain examines the role of scientific laws in the organization of scientific knowledge. Items 14, 15, 35, and 36 on the *VASS* questionnaire delve into the professors' views about scientific laws. An expert would view the laws of physics as approximate while those with folk views believe that the laws of physics are exact. The mean value for the respondents was 4.0 for the methods of science, which means that on average the physics professors at NCSU have high transitional views of the validity of science. The results are provided in Table 4.4. Items 35 (μ=3.6) and Items 36 (μ=3.8) inquire specifically about the laws of physics and how they relate to the real world.

Table 4.4: *VASS*- Validity Dimension of the Nature of Science Responses (n=29)

VALIDITY	**μ**	***SD***
ITEM 14. Physicists' current ideas about particles that make up the atom a) will always be maintained as they are. b) may eventually be modified in some respects.	4.2	0.81
ITEM15. Newton's laws of motion: a) will always be used in their present form b) may eventually be modified in some respects.	4.4	0.86

Table 4.4 (continued)

ITEM 35.The laws of physics are:	3.6	1.6
a) inherent in the nature of things and independent of how humans think.		
b) invented by physicists to organize their knowledge about the natural world.		
ITEM 36. The laws of physics portray the real world:	3.8	1.3
a) exactly the way it is.		
b) by approximation.		

Cognitive Domain

The cognitive domain focuses on with how science is learned. Within the cognitive domain the areas of learnability, reflective thinking and personal relevance are assessed through items 6, 7, 16, 20- 25, 27, 29, 30-33. The mean value for the cognitive domain is 2.4, which means that on average the physics professors have a low transitional view of the nature of science.

Learnability

The *VASS* learnability dimension examines what it takes to learn science. Individuals with a folk view believe that learning in physics is dependent on the instructor, while the expert believes that learning is dependent on the learner. Table 4.5 summarizes the results for the learnability dimension of the nature of science. Items 16 (μ=2.8), 20 (μ=2.5) and 22 (μ=2.9) suggest that the instructors were torn between two options. The mean value for the respondents was 2.7 for the learnability of science, which means that on average, the physics professors have mixed views on how science is learned.

Table 4.5: Learnability Dimension of the Nature of Science Responses (n=29)

LEARNABILITY	μ	***SD***
ITEM 16. Learning physics requires:	2.8	0.79
a) a serious effort.		
b) a special talent.		

Table 4.5 (continued)

ITEM 20. For me, students doing well in physics courses depends on:	2.5	0.63
a) how much effort they put into studying.		
b) how well I explain things in class.		
ITEM 22. When a student experiences difficulty while studying physics:	2.9	0.79
a) they seek help, or give up trying.		
b) they try to figure it out on their own.		

Reflective Thinking

The reflective thinking dimension of the *VASS* examines the physics faculty members' beliefs about the importance of reflective thinking and how they may contribute to ideas about the physical world. Table 4.6 shows the means scores of the respondents. The expert answer on these questions should be oriented toward 5. Items 21, 23, 25, 27, and 29-33 ask questions pertaining to beliefs about teaching and assessment in physics courses. The mean value for the respondents was 2.8 for the reflective thinking dimension of the nature of science, which means that on average, the physics professors at NCSU have mixed views on the reflective thinking dimension of science. An expert would respond that physics cannot be understood by copying and memorizing facts from the professor or rote learning, but through taking an active role in his/her own learning.

Item 23 (μ=2.3), item 27 (μ=2.7), and item 30 (μ=2.3), had the lowest mean scores. Each is related to how students go about solving problems on their own. These responses show that the respondents have a low transitional view of how students solve problems.

Table 4.6: Reflective Thinking Dimension of the Nature of Science (n=29)

REFLECTIVE THINKING	μ	***SD***
ITEM 21. In my opinion, for any question asked in class, a good physics teacher should be able to: a) provide the correct answer. b) know how or where one may get the answer.	3.2	0.65
ITEM 23. When studying physics in a textbook or in course materials: a) students find the important information and memorize it the way it is presented. b) students organize the material in their own ways so that they can understand it.	2.3	0.99
ITEM 25. In physics, it is important for students to: a) memorize technical terms and mathematical formulas. b) learn ways to organize information and use it.	3.3	0.76
ITEM 27. After students go through a physics text or course materials and feel that they understand: a) they can solve related problems on their own. b) they have difficulty solving related problems.	2.5	0.87
ITEM 29. In order to solve a physics problem, students need to: a) have seen the solution to a similar problem before. b) know how to apply general problem solving techniques.	3.8	0.61
ITEM 30. For me, solving a physics problem in class more than one way: a) is a waste of time. b) helps develop the students' reasoning skills.	2.3	0.97
ITEM 31. After a student has answered all questions in a homework physics problem: a) They stop working on the problem. b) They check their answers and the way they obtained them.	3.1	1.08
ITEM 32. After the teacher solves a physics problem for which they got a wrong solution: a) The student discards their solution and learns the one presented by the teacher. b) The students try to figure out how the teacher's solution differs from theirs.	3.7	0.85
ITEM 33. How well students do on physics exams depends on how well they can: a) recall material in the way it was presented in class. b) solve problems that are somewhat different from ones they have seen before.	3.7	0.70

Personal Relevance

Items 6, 7, 24 and 25 assess the professors' beliefs about the perceived personal relevance of physics. The expert believes that physics is valuable to everyone. Table 4.7 shows the results. The expert answer on these questions should be oriented toward 1. Item 6 (μ=4.6) suggests that students find taking introductory physics a frustrating experience. Item 7 (μ=3.2) asks why students take physics. The responses indicate that the physics professors have mixed beliefs on the rationale students choose to take physics. Item 17 (μ=2.4) asks professors for the reasons students study physics. The mean value for the respondents was 3.4 for the reflective thinking dimension of the nature of science which means that on average, the physics professors have mixed views about the personal relevance dimension of science.

Table 4.7: Personal Relevance Dimension of the Nature of Science responses (n=29)

PERSONAL RELEVANCE	***μ***	***SD***
ITEM 6. For students, reading my physics textbook is often:	4.6	0.94
a) an enjoyable experience.		
b) a frustrating experience.		
ITEM 7. If students had a choice:	3.2	0.61
a) they would still take physics for their own benefit.		
b) they would never take any physics course.		
ITEM 17. Students study physics:	2.4	1.4
a) to learn useful knowledge.		
b) to satisfy course requirements.		
ITEM 24. For students, the relationship of physics courses to everyday life is:	1.8	0.3
a) hard to recognize.		
b) easy to recognize.		

ANALYSIS OF INSTRUCTORS VIEWS ABOUT SCIENCE

A one sample median test determined whether the sample median differs significantly from a hypothesized value of 5. According to Halloun (2001) scientists' scores on the *VASS*

should be a 5, indicating an "expert" view of the nature of science. The respondents' views of the nature of science are given in Table 4.8. The mean value of the scores for the sample are categorized according to the dimensions and domains of the nature of science. The results provided in the table indicate that the respondents' scores did not happen by chance (p=0.001), providing internal validity. The results showed that 55.1% of the respondents had a mixed view of the nature of science.

Table 4.8: Basic Statistics for the Views on the Nature of Science

	Mean	**Median**	**Mode**	***SD***
Scientific Domain	2.5	2.6	2.0	0.50
Structure	2.6	3.0	3.0	1.1
Methodology	1.9	1.6	1.6	0.47
Validity	3.2	3.0	3.0	1.29
Cognitive Domain	3.1	3.1	3.2	0.25
Learnability	2.5	2.3	2.3	0.45
Reflective thinking	3.2	3.2	2.9	0.26
Personal Relevance	3.3	3.3	3.6	0.57

The null hypothesis stated that the median score should fall at least in the high transitional profile (score at least a mean value of 4). The Wilcoxon Rank of Sums Test was used to test whether the respondents' scores differed significantly from the hypothesized value of 4 for those who respond as experts by virtue of their titles. The results show that the median response for the sample is less than 4, indicating that the faculty and graduate assistants' scores fell below the expected value of 4.

Table 4.9 shows the percentage of respondents' scores by view. Overall, 37.9% held either a high transitional or an expert view of the nature of science. About 53% of the faculty members held a folk view; 11.8% had a high transitional view and 17.6% had an expert view of the nature of science. On the other hand, 41.7% of the graduate assistants had a high

transitional view of the nature of science, and 33% of the graduate assistants had an expert view of the nature of science.

Table 4.9: Respondent Profiles and (Sample Size) on the Views of the Nature of Science

View Profile	**FOLK** FP		**MIXED** LTP		HTP		**EXPERT** EP	
	Freq	Percent	Freq	Percent	Freq	Percent	Freq	Percent
Overall	2 (29)	6.9	3	10.3	13	44.8	11	37.9
Faculty	9 (17)	52.9	5	17.2	2	6.9	3	17.6
Graduate	2 (12)	16.7	1	8.33	5	41.7	4	33.0

Profiles: * EP-Expert HTP=High Transitional LTP=Low

Another question that emerged through the research was "Do physics graduate assistants differ in their views of the nature of science?" The results reveal the mean score for the views on the nature of science and a comparison of means of the total score between faculty and graduate assistants are shown in Table 4.10. The research suggests that teachers teach the way they were taught (Committee on Undergraduate Science Education, 1997; Britzman, 1991; Lortie, 1975). The Wilcoxon Ranked Sums Test reveal that the difference between the mean values of the scores of the faculty and graduate students are statistically significant within their views of the scientific domain (p=0.05).

Within the scientific domain, faculty and graduate students' views differ statistically on the structure of science (p=0.002). Within the cognitive domain, there is no statistical difference in how the faculty and graduate students view science, yet there exists a statistical difference between their views on learnability (p=0.036) and personal relevance (p=0.024).

Table 4.10: Mean Score and Comparison of Means across the University Teaching Faculty and Graduate Students

Variable	FACULTY	GRADUATE	*p* – value
Scientific Domain	**12.78**	**19.2**	**0.05**
Structure	13.55	16.5	0.37
Methodology	11.84	21.0	0.002
Validity	14.55	15.85	0.69
Cognitive Domain	**12.45**	**16.34**	**0.23**
Learnability	16.10	13.10	0.37
Reflective thinking	16.0	13.10	0.38
Personal Relevance	15.87	13.35	0.44

** $p<0.05$*

Differences between the means of graduate assistants by rank (RA or TA) were also analyzed and a statistically significant difference exists between how the research assistants and the teacher assistants view the ability to learn science (χ^2 =5.07, p=0.024) and how the students reflect on what they learn in class.

The Spearman Rho was conducted to see if a linear relationship exists between the domains and the nature of science. Table 4.11 shows the results based on the Spearman Rho Coeffiecient. The results of the Spearman Rho Rank Order Coefficient suggest there is a strong positive relationship between structure and the professor's view toward the scientific dimension (R^2=0.748, p-value<0.0001). This means that the professors' view of the structure of science and the scientific domain increase together. There was also a strong positive relationship between the methodology scores and the scientific views (R^2=0.693, p<0.0001) among the physics faculty at NCSU. These relationships were expected because both the structural and methodology dimensions make up the scientific domain.

Table 4.11: Spearman Rho Coefficient

R values	Correlation
1	Perfect correlation
0 to 1	The two variables tend to increase or decrease together.
0	The two variables do not vary together at all
0 to -1	One variable increases as the other decreases
-1.0	Perfect negative or inverse correlation.

	Structure	Meth	Validity	learn	ref_think	per_rev	
Structure	1.0000	0.2429	-0.244	0.118	-0.0641	0.10268	R^2 ***coeffeicent***
		0.213	0.209	0.548	0.745	0.6031	***p-value***
	28	28	28	28	28	28	***frequency***
Meth		1.0000	0.0150	-0.08	-0.2066	0.01056	
			0.9382	0.650	0.282	0.9566	
		29	29	29	29	29	
Validity			1.0000	-0.22	0.08205	-0.29353	
				0.2458	0.672	0.1223	
			29	29	29	29	
Learn				1.0000	-0.162	0.56659	
					0.400	0.0014	
				29	29	29	
ref_think					1.00000	0.26639	
						0.1625	
					29	29	
per-rev						1.0000	
						29	

A strong positive relationship also exists between the cognitive view and reflective thinking (R^2=0.8980, p<0.0001) and between the professors' cognitive and personal relevance (R^2=0.5111, p<0.0046). This is also to be expected because reflective thinking and personal relevance are dimensions that make up the cognitive domain. This means that the more professors reflect on their teaching, the more likely they will understand how their students process the information taught in class.

TEACHER PRACTICE INDEX

An educator's philosophy of teaching serves as a guide to the actions and choices made to support the teaching and learning process. Walker-Tileston (2004) suggests an examination of the modalities that affect how teachers teach and how students learn. The teaching methods selected by a teacher are usually grounded in the teacher's philosophy of teaching.

The questions in Section B of the *VASS* questionnaire asked respondents' to rate their perceptions of their own teaching practices, by indicating the frequency they engage in various teaching activities that support active student learning. These activities include discussions on how to approach a particular topic, the role of mathematics, real-life physics applications, etc. Figures 4.1 through 4.9 detail the responses of the professors. The data were summarized by category using a Likert Scale, with 1 indicating more than once a week and 5 indicating never.

Figure 4.2 provides the results of Item 1 which focuses on how often discussions take place in physics classes about how students should study using their physics books. The majority of the respondents reported that they conduct class discussions on how to study using the physics book at least once a week. Less than 5% indicated that this discussion takes place more than once a week in their classes. Twenty-eight percent of the professors indicate that class discussions take place about once a month. Less than 10% indicate that this type of discussion never takes place. The mean score for this item was 2.93, which means that on average the professors discuss how to study using a physics textbook about once a month.

ITEM 1: How often do you discuss with your students how they should go about using their physics textbook for study?

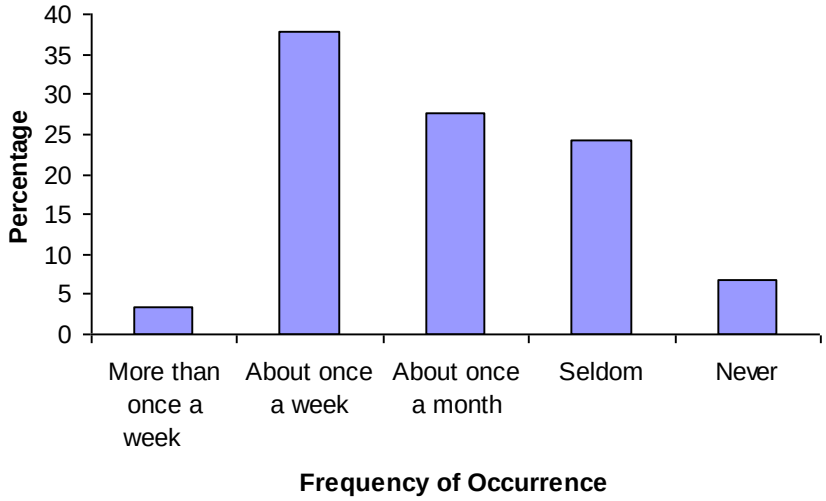


Figure 4.2: Frequency on how to study using the textbook

Figure 4.3 provides the results of Item 2, which asked respondents to indicate the frequency of class discussions on how to solve homework problems. Nearly 40% of the respondents stated that class discussions on how students should solve problems on their own occurred more than once a week. Thirty-three percent of the respondents stated that they conducted class discussion about once a week. Twelve percent of the respondents stated that they discuss how to solve problems about once a month. No one responded to never having discussed how to solve problems in his/her class. The mean response for this question was 3.6, which means that the physics professors and graduate assistants discuss problem-solving methods with their classes about once a week. It can be concluded that the instructor solving problems is the major emphasis within the lecture in undergraduate physics classes.

Item 2: How often do you discuss with your students how they should go about solving homework problems on their own?

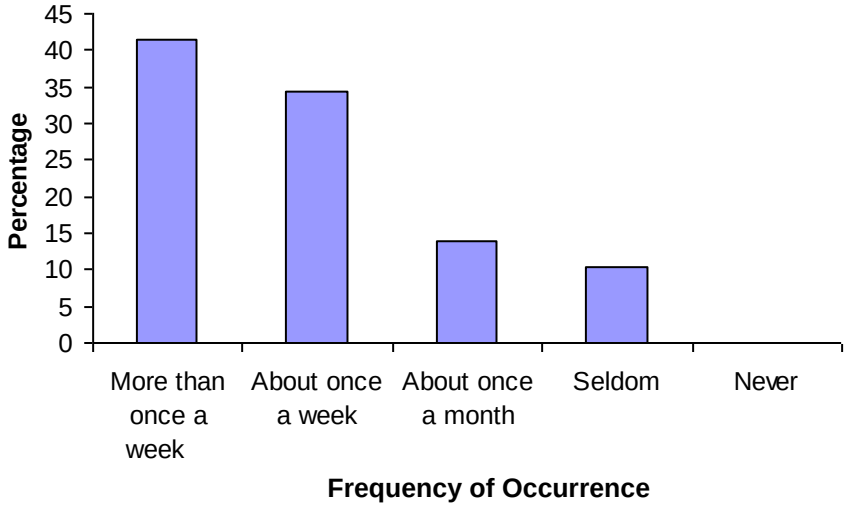


Figure 4.3: Frequency on how to solve homework problems

Figure 4.4 provides the results of Item 3 which focused on how often class discussions focused on the misconceptions about real world systems. The results for this question are skewed toward the left. No one held class discussions about misconceptions that students have about the real world phenomena more than once a week. Twelve percent of the respondents reported that they conduct class discussions on misconceptions about real world phenomena about once a week and 12% of the respondents reported having such discussions once a month. Forty-three percent of the respondents indicate that this conversation never occurs in their classrooms. About 35% also stated that misconceptions about real world systems and phenomena such as gravitational effects, forces of nature, etc are seldom discussed.

Item 3: How often do you discuss in class misconceptions that students typically have about real world systems and phenomena?

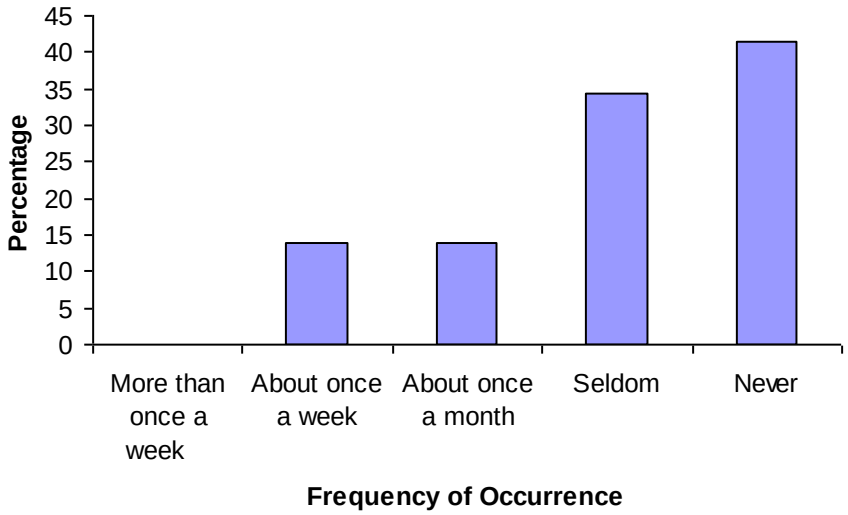
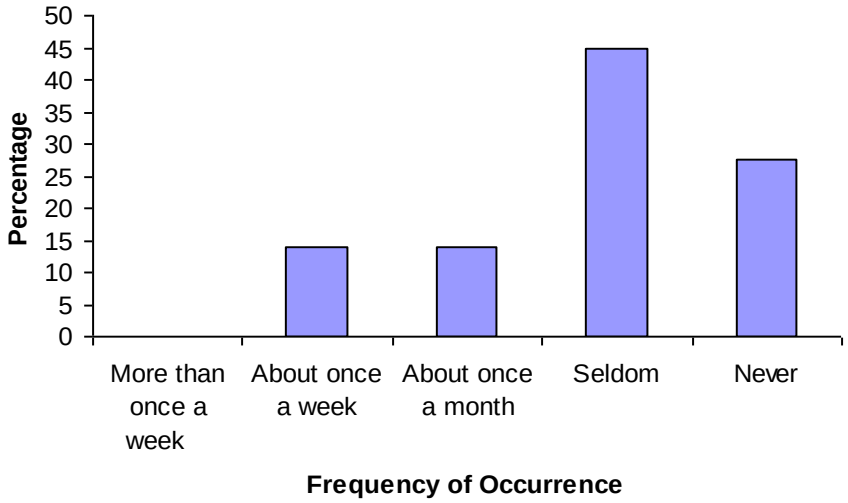


Figure 4.4: Frequency of the class discussions about misconceptions about real world systems and phenomena

Figure 4.5 provides the results for Items 4 and 5, which focus on how often physics instructors discuss mistakes on homework and exams. On Item 4, about 45% of the respondents reported that they seldom discuss the mistakes that students make on their homework. Thirty percent of the respondents responded they never discuss student mistakes in class. Mistakes students make in their homework are never discussed more than once a week in any introductory physics course. Item 5 focused on how often mistakes on exams are discussed. Nearly 10% of the professors and graduate assistants never discuss the mistakes the students make on their exams while over 55% indicate that they discuss the homework

mistakes the students make about once a month. If a higher percentage of the teaching faculty (faculty and graduate assistants) discuss how to solve homework problems weekly, then it would seem that they would look at the mistakes on the homework problems in class. It may be that they cover general information about a specific concept on the homework or the test instead of specific mistake. Most instructors speak to students on a one-on-one basis concerning specific mistakes made on home work or exams.

Item 4: How often do you discuss mistakes that students make on their homework in class?



Frequency of discussion about how physics relates to other science disciplines

Figure 4.5 (Continued)

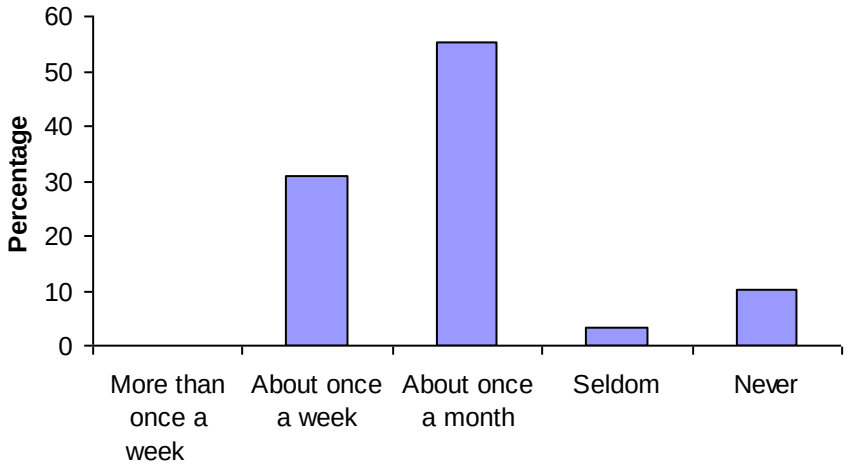
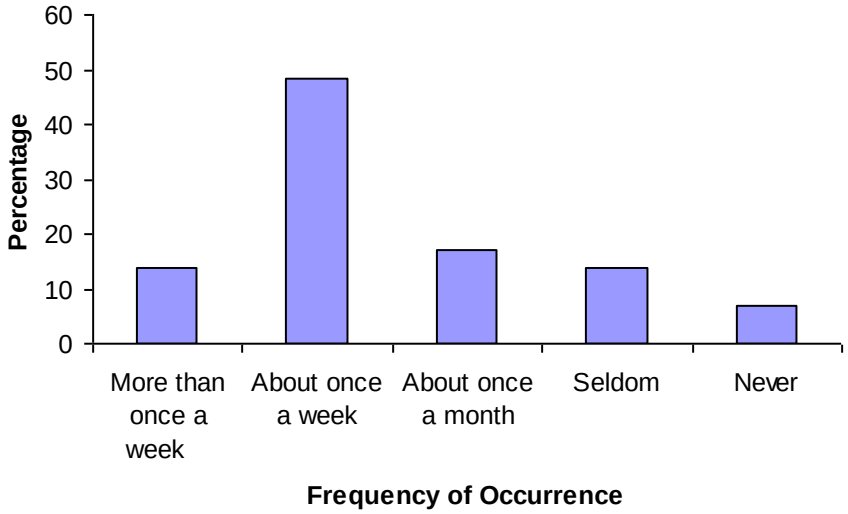


Figure 4.5: Frequency of discussion in class about homework and exam mistakes

Figure 4.6 summarizes the results of Item 6 and Item 7, which refers to how often students engage in hands-on activities at home and at school. Forty-six percent of the respondents indicate the students in their classes engage in laboratory activities about once a week. Sixteen percent of the respondents indicate students performed lab activities at school once a month. Five percent indicate that students never participate in lab activities. Item 7 asked the participants how often experiments or other practical activities were assigned for students to do at home. Most of the respondents seldom assign such activities. Less than 5% claim that they assign these types of activities once a week.

Item 6: How often do you get students engaged in laboratory activities at school?



Item 7: How often do you assign experiments or other practical activities for students to do at home?

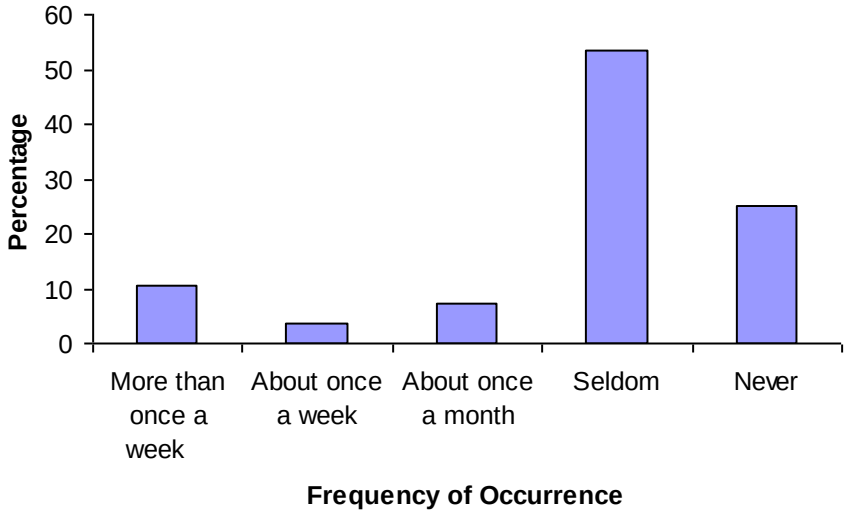


Figure 4.6: Frequency of student engagement in lab activities at home and at school

Figure 4.7 details the frequency of discussion of physics applications in real life.

Thirty-nine percent of those responding to the questionnaire indicate they discuss how

physics related to other scientific disciplines. Twenty-eight and half percent state that in class, they discuss the relationship between physics and technology about once a month. Fifteen percent never have this discussion.

Item 8: How often do you discuss the applications of physics in everyday life with your students?

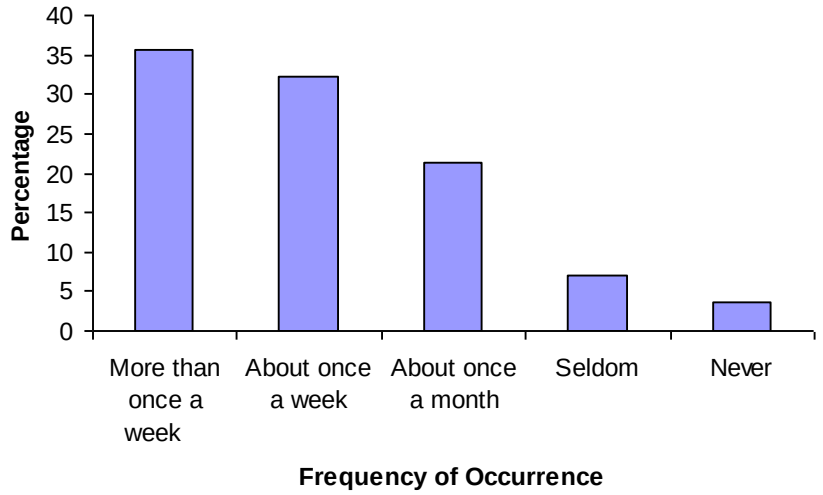
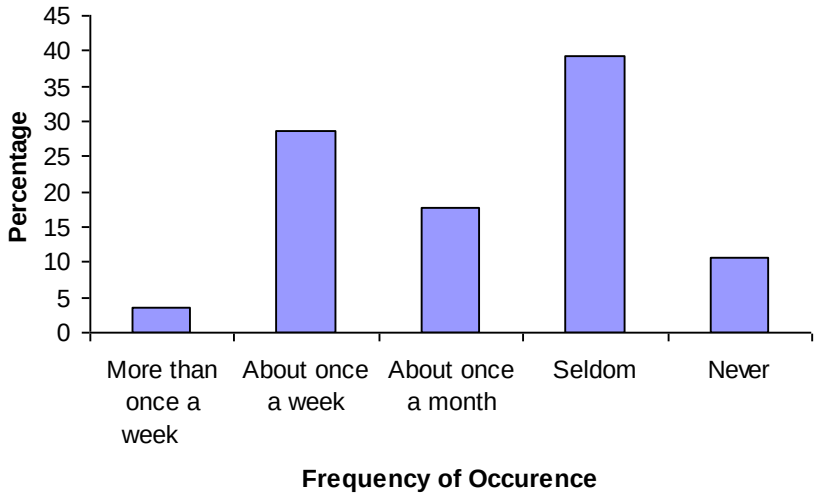


Figure 4.7: Frequency of discussion of physics applications in real life

Figure 4.8 summarizes the responses to Item 9, which asked how often physics is discussed as it relates to other scientific disciplines. Forty two percent of the respondents report that they rarely discuss physics in relation to other science subjects. About 25% feel that about once a week they discuss the relationship between physics and technology. This is problematic since the science community claims that physics is an everyday occurrence. Item 10 asks about the frequency of discussions about physics and technology. Most of the respondents indicate that they hold discussions about physics and technology.

Item 9: How often do you discuss with your students the relation of physics to other scientific disciplines?



Item 10: How often do you discuss with your students the relation of physics to technology?

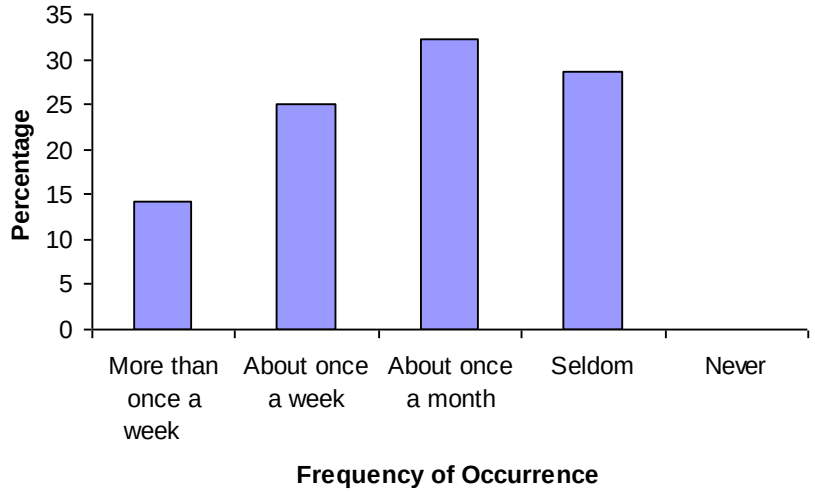
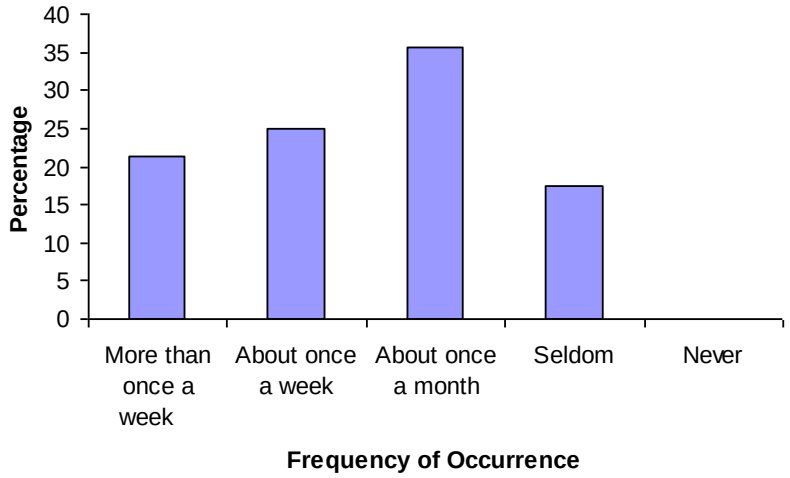


Figure 4.8: Frequency of discussion about how physics relates to other science disciplines and technology

Items 11 and 12 summarized in Figure 4.9, asked whether discussions of the nature of scientific laws, scientific thinking, and the role of mathematics in physics take place in introductory physics class.

Item 11: How often do you discuss with your students the nature of scientific laws?



Item 12: How often do you discuss with your students the nature of scientific thinking?

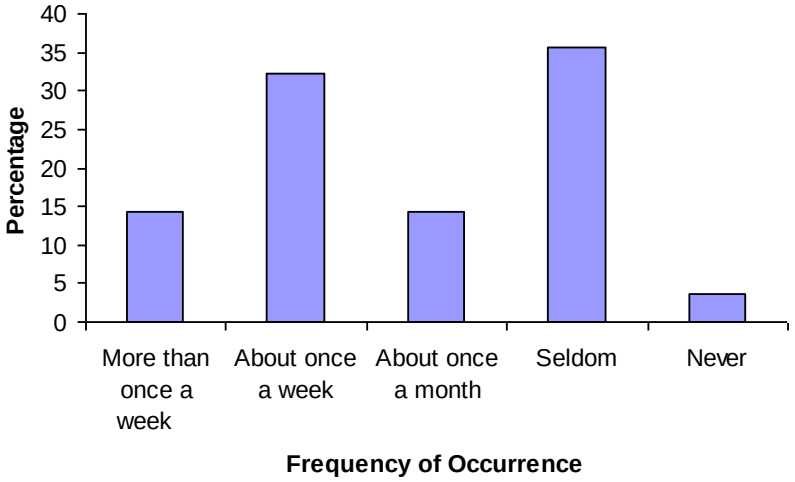


Figure 4.9: Frequency of discussion on the nature of scientific laws and scientific thinking

More than 15% of the respondents discussed the nature of scientific thinking in introductory physics courses more than once a week.

Figure 4.10 focuses on Item 13, which is how often discussion of the role of mathematics in physics is discussed. Less than 15% discussed the role of mathematics in physics more than once a week.

Item 13: How often do you discuss with your students the role of mathematics in physics?

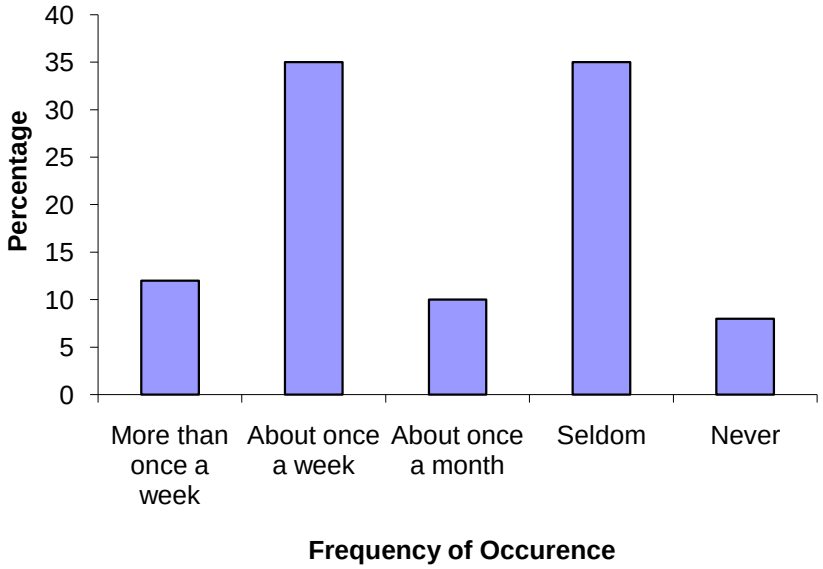


Figure 4.10: Frequency of discussion on the role of mathematics in physics

Summary of Research Question One

How do physics instructors view the nature of science?

The results provided evidence that overall the physic instructors have mixed views of the nature of science. Further analysis revealed that there is reason to suspect that physics instructors have a high transitional view on aspects of the nature of science, with the

exception of structural dimension, where the physics faculty has a low transitional view of the nature of science. The results of this study suggest that with 90% confidence that graduate assistants in this study held a higher view of the nature of science. The results of the teacher practice index showed that the instructors had responded by conducting behaviors in the classroom that were not consistent with the effective teaching practices ($p=0.34$).

SECTION II: CLASSROOM OBSERVATIONS

This section includes (a) detailed descriptions from classroom observations from the perspective of the researcher, (b) descriptions/analyses of the class sessions in terms of class introduction, modes of instruction, questions asked, teacher behavior and the materials used in class, and (c) description/analyses of the teacher-student interactions.

Instructional Context

Fifty-six classroom observations were used to describe the interactions between the students and the teacher. The classroom dynamics observed will help determine if the actions of the professor are consistent with those who hold expert views of the nature of science. Those who hold an expert view of the nature of science see science as a human endeavor and expect the students take an active part in their education. The researcher examined to see how the teachers introduced the lesson, the modes of instruction, the types of questions, the behavior of the teacher and the materials used.

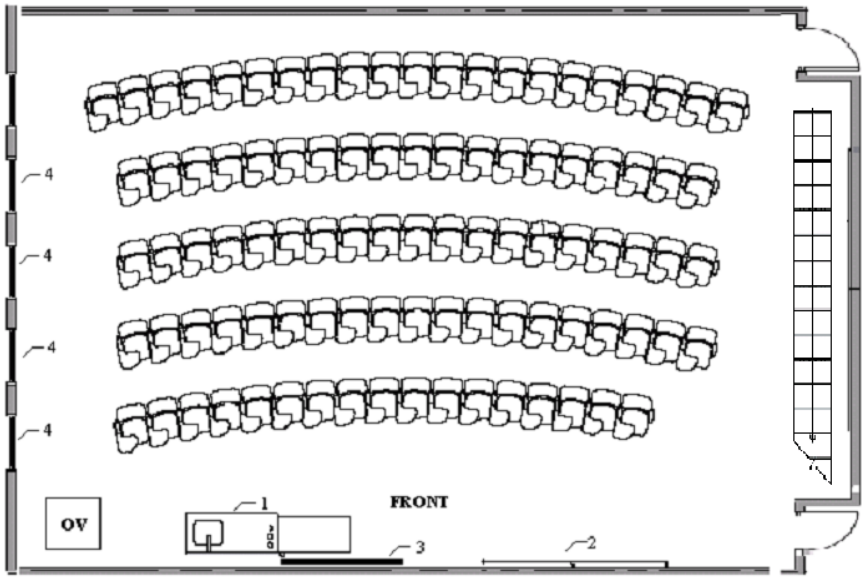
Three types of introductory physics classes were observed. Table 4.12 outlines the number of classes observed by type. All introductory physics courses cover basic kinematics and dynamics.

Table 4.12: Introductory Physics Classes Observed (n=56)

Course	Topics	#of Classes Observed
Conceptual Physics		
PY 131	Mechanics, Electricity, Magnetism	14
Calculus Based Physics		
PY 205	Mechanics	13
PY 208	Electricity and Magnetism	12
Algebra-Based Physics		
PY 211	Mechanics	10
PY 212	Electricity and Magnetism	7

Most of the lectures took place in the same room, which Figure 4.11 depicts. An old wooden demonstration table is permanently positioned in the front of the room, contains a sink with both hot and cold running water and three electrical outlets. On the wall closest to the door, 100 numbered personal response systems or "clickers" are hung. When a class demonstration is planned, the manager of the "Demo Room" and a work study student assemble the materials in room 214.

The students came into class quietly or conducted conversations with friends. When seated, some of the students opened their textbooks while other students read the newspaper. The professors usually arrived with the students, three to five minutes before class officially began, placing their book on the table and looking at the class in silence and without warning, began to talk, usually facing the board while writing. The professors and teaching assistants generally did not greet the students before classes, but conducted small talk with any student who initiated conversation.



(1-Fixed bench with water and electrical hook-ups; 2-whiteboard/chalkboard; 3-AV screen; 4-window; OV-overhead projector)

Figure 4.11: Floor Plan of the Lecture Classroom

Most of the classroom activities were the same from everyday, only varying by the use of a teacher demonstration in the classroom. In general, the professors started the lessons standing in front of the class, and stayed there to address the class during the entire instructional period. Only two professors used a computer on a cart, which contained the software necessary to operate the personal response system. There were always between five to ten students who were "off-task." They were observed passing notes, reading the newspaper, doing work for other classes, etc. For the most part, students remained in their desks. Occasionally, students left the class early. The classes ended with the students beginning to pack-up.

Instructional Practices

The Classroom Observation Protocol and the Flanders Interaction Analysis were used to analyze which teaching methods were used in the classroom. When analyzing the instructional methods used in the different classes with the Classroom Interaction Protocol, each class session was analyzed in terms of (1) introduction and emphasis, (2) modes of instruction, (3) questions, (4) teacher behavior, and (5) materials used. The following scale was used to determine the score:

0 Never occurred
1 Rarely
2 Sometimes
3 Frequently

The data were analyzed using Wilcoxon-Mann-Whitney and Kruskal-Wallis calculations to determine whether any significant differences existed between the faculty members and the graduate assistants in terms of how the lesson was introduced to the class, modes of instruction, types of questions asked during class, and teacher behavior (what behaviors professors employed to help students learn). Group differences were calculated by course (PY 131, 205, 208, 211, 212); type of course (Conceptual, Algebra-Based, or Calculus-Based) and term (Fall or Spring).

Modes of Instruction

The various modes of instruction were analyzed during each class observed. A checklist was used to measure the frequency teachers engaged in various practices. Table

4.13 provides the results of the percentage of time instructors used various modes of instruction in introductory physics during each class.

Table 4.13: Percentage of Modes of Instruction Utilized By Physics Professors

Modes of Instruction		3=Frequently	2=Sometimes	1=Rarely	0=Never
(a)	Whole class instruction	100	0	0	0
(b)	Hands-on activities	0	8.6	48.2	63.2
(c)	Lecture or recitation	96.6	3.4	0	0
(d)	Drill and practice	1.8	0	19.6	78.6
(e)	Reading textbook	0	0	14.3	85.7
(f)	Teacher demonstration	50	38.0	3.6	8.4
(g)	Small group discussion	7.1	17.9	39.3	35.7
(h)	Cooperative group work	5.4	16.0	48.2	30.4
(i)	Individual seat work	1.8	7.1	16.1	75.0
(j)	Open-ended inquiry	0	1.8	50.0	48.2
(k)	Data collection and/or manipulation	14.3	50	23.2	12.5
(l)	Note-taking	78.9	21.1	0	0
(m)	Homework/classwork review/correction	14.3	28.6	33.9	23.2
(n)	Group presentation	5.3	3.6	10.7	80.4
(o)	Notebook entry or log	1.4	1.8	3.6	95

All of the physics instructors employed whole class instruction and discussed topics or concepts without checking for understanding. Manipulatives were rarely used to explore, observe or collect data about a concept. The majority of instructors (96.6%) lectured. During each observation, the instructor talked, and students listened and took notes. Occasionally, students answered questions posed by the professor. In a few classes, more than one instructional method was employed.

The conceptual physics course employed more instructional methods than any of the other courses. On three occasions in the Physics 205/208 and two occasions in the Physics 211/212 course demonstrations, data collection or manipulatives were used. The results of the Kruskal Wallis indicate a statistically significant difference among the three types of

introductory physics courses (χ^2 with two degrees of freedom=18.621, p=0.0001). The results of the Fisher Exact Test also suggest a significant relationship between modes of instruction and course type (p=0.0001).

Introduction Emphasis

In this section, the observer looked to see if the instructor provided any type of introduction. The research suggests that students benefit when told what main points will be covered in the lecture. One of the common complaints of students in physics is that the professor comes into class and just starts talking (Tobias, 2002). Table 4.14 provides the percentage of instructors who performed the various tasks related to effective lesson introductions in introductory physics classes.

Table 4.14: Results by Percentage of Instructional Emphasis

Introduction Emphasis	3=Frequently	2=Sometimes	1=Rarely	0=Never
a) Provides Overview	25.0	44.6	30.4	0
b) Relates to Previous Lesson	23.2	8.9	21.4	46.4
c) Assesses prior knowledge	23.2	2.1	26.4	48.6

Nearly 25% of the professors provided clear and complete overviews of the lesson. In PY131 and PY 211/212, most professors provided a brief outline of the material to be covered in class on the blackboard. Two professors used personal response systems when reviewing material covered in the previous classes during each observation.

The results of the Kruskal-Wallis ANOVA indicate that there was a statistically significant difference in how the class began among the three type of introductory courses (χ^2 with two degrees of freedom = 23.8045, p = <0.0001) and by class type (p = <0.0001).

A Wilcoxon Rank Sums Test indicated that when analyzed by term, a statistically significant difference (p=0.0294) was found among the professors using the introduction to connect to previous lessons. The Kruskal-Wallis ANOVA test indicated that when analyzed by course number, there exists a significant difference in whether or not the instructor introduced each lesson (p=0.0037). Statistically significant differences were found in how the professors provided an overview of the lesson (p=0.0003) and assessed prior knowledge (p=0.0266).

The Use of Questions

Higher-order questioning is extremely important when looking at effective teaching strategies. In general, teachers asked very few questions during the classes. When questions were asked, professors rarely waited for a response. The few questions that were asked were rhetorical or directly related to problem-solving, and generally fell into the knowledge and comprehension range on Bloom's Taxonomy (Bloom, 1956). See Appendix D for a detailed description of the categories of the types of questions found in Bloom's Taxonomy. These included questions such as, "Do you all know what you are supposed to be doing?" or, "Can anyone recite Newton's Three Laws?" Questions in the affective domain like, "How do you feel about what you just learned?" were not asked during the observations.

In the PY 211 and 212 classes, personal response system (PRS) technology was utilized by the students. The observer noticed that the professors appeared to use a question cycle as described by Beatty, Gerace, Leonard, & Dufresne, (2006) and shown in Figure 4.12. When using the PRS, each student was given an infrared transmitter, similar to a

television remote control. The professor presented a question and provided students a few minutes to work through the problem to report their answers. The PRS transmitter enabled student to communicate their answers anonymously via an infrared detector in the front the lecture hall. After submitting responses, the students paired up to discuss the question among themselves in small groups. Students decided on a response and signaled their responses on the PRS, while a bar graph displayed the results of the entire class. The instructor and the students could see the distribution of student answers on a histogram displayed in front of lecture hall.

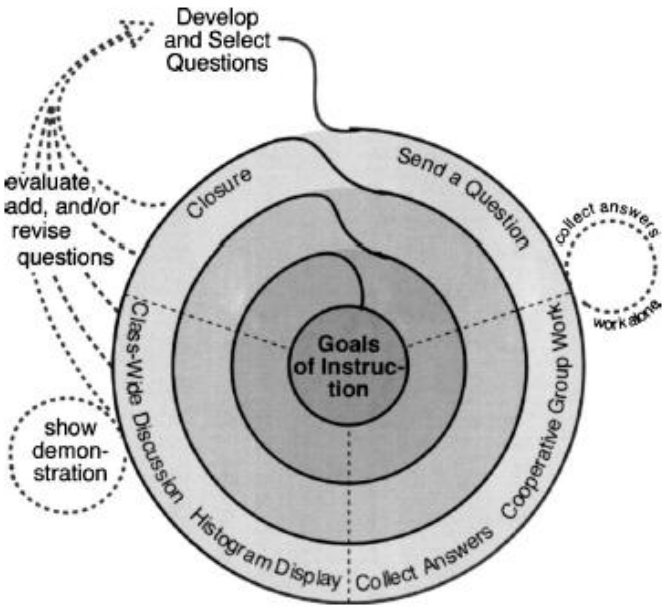


Figure 4.12: The *question cycle* used with a classroom response system (Beatty et. al, 2006).

During this process, students appeared to be actively participating in the class. The questions were clearly worded multiple choice questions that focused on one concept

followed by a think-pair-share activity (Lyman, 1981), similar to the Conceptest questions were developed by Mazur (1997). Unfortunately, many students (n=37) just randomly chose an answer, which was evident by the erroneous choices. Only two professors used the PRS during every class observation.

Table 4.15 shows the percentage of professors who used the three types of questions. No statistically significant differences were found in the use of questions. The sample size limited the reported non-significant difference in the types of questions asked. The researcher failed to reject the null hypothesis.

Table 4.15: Types of Questions Used by Physics Professors by Percentage

Questions	3=Frequently	2=Sometimes	1=Rarely	0=Never
a) Knowledge, Comprehension (procedural , rhetorical, recall, recognition, factual)	17.9	10.7	30.4	41.0
b) Application, Synthesis, Analysis, Evaluation (compare, contrast, associate, evaluate, apply, expand, consider-what if)	7.1	23.3	0	69.6
c) Feeling (affective)	0	0	1.9	98.1

Scale: *3-=many questions 2=evident-some questions 1=evident-few questions 0=no questions*

The Kruskal-Wallis ANOVA results revealed that no there was no significant differences in how the professors asked the questions or the types of questions asked. Most of the questions asked in the class were knowledge or appreciation type of questions according to Bloom's Taxonomy. The Wilcoxon Ranked Sums Test also confirmed that significant difference existed in the types of questions asked when the groups were analyzed by rank (p=0.0387), course number (p=0.0007), or by type of course (p=0.0015).

Teacher Behavior

When analyzing teacher behavior, the observer looked at whether the professor provided opportunities for the students to become actively involved in lectures/discussions as evidence of the professor promoting more active participation in class. While in many of the physics courses the students appeared to be intellectually engaged with the physics topics presented, evidence of student confusion and off-task behavior were apparent in forty-nine out of the fifty-four observed classes. Students were observed sleeping, reading the newspaper, playing video games on cell phones, walking out of class to talk on a cell phone, and doing other assignments during class. The data and observations agree with research studies that suggest in many undergraduate physics courses, instructors did little to make physics class interesting to students or to connect physics to other disciplines or real-world contexts (Hake, 1998; Tobias, 1997). Table 4.16 provides the results on the various behaviors professors displayed during class.

Table 4.16: Teacher Behavior by Percentage

Teacher Behavior	3=Frequently	2=Sometimes	1=Rarely	0=Never
a) Explains activity-Gives concise, sequential directions to guide activity		NOT APPLICABLE		
b) Circulates among students/student groups asking question	3.6	0	0	96.4
c) Emphasizes relations to real life	17.9	8.9	32.1	41.1
d) Uses ongoing embedded assessment	0	8.8	19.5	71.6
e) Uses appropriate classroom management techniques		NOT APPLICABLE		

One of the noted effective teaching strategies in undergraduate education is to walk around making sure students are on task, and frequently assessing student understanding. The

observer noted that professors rarely circulated among the students..

Significant differences in teacher behaviors (p=<0.0001) were noted by class. Significant differences were noted in the promotion of active participation by term (p=0.0009), type of class (p=0.0457), and rank (p=0.0037). Highly significant differences were found by course (p=<0.0001). According to the research, effective teaching practices (Chickering and Gamson, 1991) emphasize making connections to activities or providing a context for learning.

No significant differences among groups were found in how professors encouraged students to generate ideas and/or questions or how professors showed respect for students' ideas, questions, and contributions. Significant differences were found in intellectual rigor, constructive criticism, and challenging ideas by type (p=0.0159) and course (p=0.0001).

A Spearman Rho correlation was also conducted to compare the relationship between lesson introduction, modes of instruction, questions, and teacher behaviors. A relationship between the types of questions asked and teacher behavior while teaching introductory courses resulted in statistically significant differences (R^2=-0.03209, p=0.0097). No correlations were detected, although inconsistent correlations occurred with some of the sub-categories. Weak to mild negative correlations were found between two of the domains of the nature of science measure and those of the classroom observations. No differences emerged among groups when analyzed between classes.

The Use of Materials

At NCSU there is a physics demonstration room, known by all those who use it as the 'demo room.' This room houses the equipment for over 500 physics demonstrations and the equipment to assemble more. The demo room is staffed by a manager and two to three work study students who set-up demonstrations for all the courses offered in the department. Overhead transparencies for all current introductory level textbooks used by the physics department are located in the demo room. Computer equipment is also available to the physics instructors. Materials are updated as often as the budget allows so that the professors have the latest instructional materials available. Table 4.17 lists the percentage of time the instructional materials were present in the courses.

Table 4.17: Material Used in Introductory Physics Courses

Material Used	Percentage of the time present
a. Printed reading materials (books, articles, stories, etc.)	22
b. Computer or computer technology	44
c. Overhead projector, LCD projector	37
d. Chalkboard, white board, chart tablet	97
e. Videos, films, music	17
f. Demonstration Models	35
g. Manipulatives, (hands-on materials or equipment)	21
h. Worksheets	13

The summary of the scores provides information describing what one can expect when observing an introductory physics class in Table 4.18. An average score of 2, "evident sometimes" is expected (Tempel, 2002) in a class that employs some of the methods suggested by the results of the literature review. The analysis of data suggests that the introductory physics instruction observed was less than average quality when compared to the characteristics for reformed science teaching in an undergraduate course.

Table 4.18: Summary Score Rating for Introductory Physics Classes (n=54 classes)

Summary Score Category	PY 131 Conceptual (n=12)	PY 205 Calculus (n=13)	PY 208 Calculus (n=12)	PY 211 Algebra (n=10)	PY 212 Algebra (n=7)	TOTAL (n=54)
Introduction Emphasis	1.46	1.42	1.63	1.89	1.42	1.56
Modes of Instruction	1.45	1.24	1.24	1.02	1.16	1.22
Questions	0.92	0.92	1.13	0.83	1.19	0.99
Teacher behavior	1.36	0.90	0.42	1.42	1.20	1.06
TOTAL SCORE	1.30	1.12	1.11	1.29	1.24	1.21

Scale: *3-=Evident-frequent 2=Evident-more than once 1=Evident-rarely at least once 0=Not evident*

Flanders Interaction Analysis

This portion of the study reports the results of the following interactions: balance between teacher and student talk and silence; balance between teacher and student initiation and response; professors' reactions when students stop talking; professor-directed emphasis on content and sustained expression, and analysis of the transition from teacher to student centered patterns of interaction. To triangulate the findings from the *VASS* questionnaire and the classroom observations, the Flanders Interaction Categories (FIAC) along with the Kruskal Wallis Analysis of Variance were used. FIAC consists of ten communication categories which include all possibilities.

Figure 4.13 illustrates the patterns of interaction for each class type in terms of the proportion of the total observed time spent on each for interaction. Each category has been summed by finding the mean and standard deviation of ten categories for fifty-six introductory classes. Frequencies from categories one to nine were added and converted into percentages by dividing the frequencies by the total time interactions.

Observational data from the classes suggest that while the professors are trying to use effective instructional strategies, they are doing so by different methods and with varying

degrees of success. The measures that indicate student centered instructions include the behaviors reported by the professors in the *VASS* questionnaire and the Classroom Interaction Protocol. The FIAC indicates to what degree this is achieved in the classrooms. It could be the instructors try to focus on the transition to and sustaining of inquiry patterns in their classes. There was some variation in the patterns of interaction in each class type from week to week, but the distinctive patterns seen in the examples in Figure 4.13 are consistent with the observation field notes for all sessions observed. On average, the physics instructors in the calculus based physics class spent 45% of the class time lecturing and 29% of the remaining time was spent in silence. It was noted in the observation notes that the teacher was talking and most of the students were taking notes.

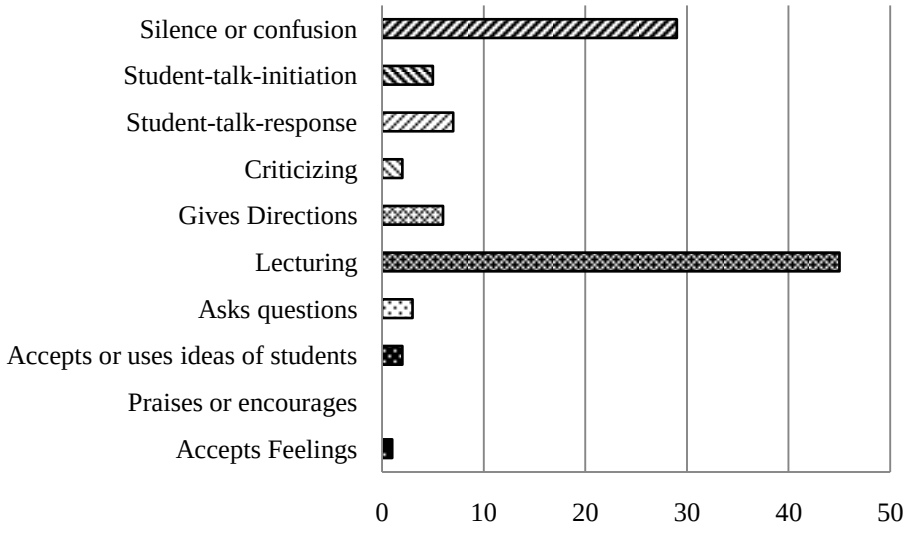


Figure 4.13: Average Talk Time in Calculus Based Physics

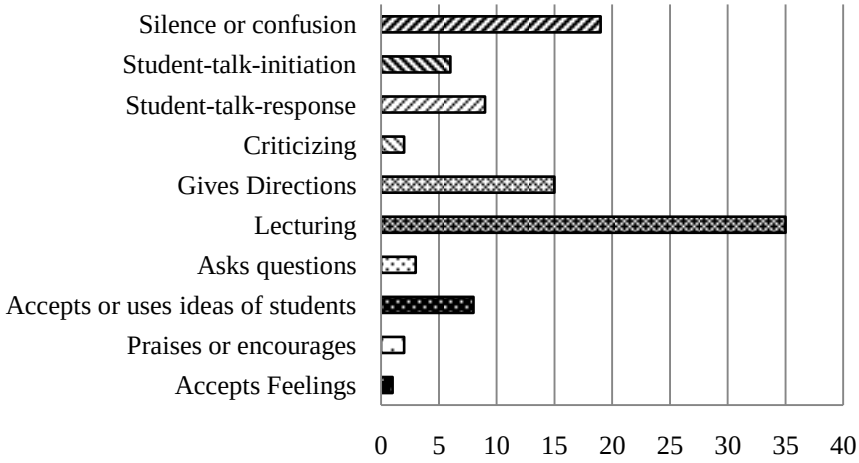


Figure 4.14: Average Total Talk Time in Algebra-Based Physics

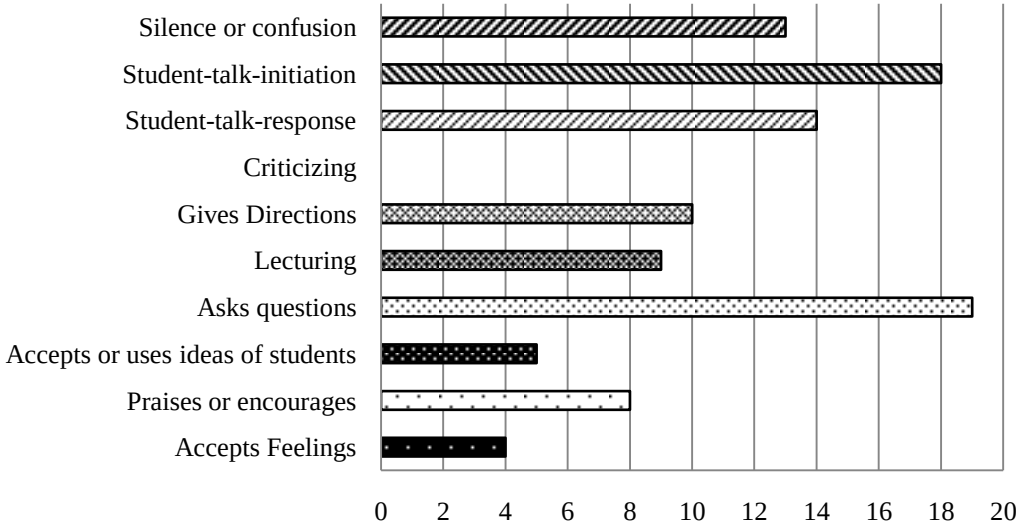


Figure 4.15: Average Talk Time in Conceptual Physics

On the days of observation, the students in the calculus-based courses appeared generally quieter and less likely to initiate discussion with each other than the students in

conceptual and algebra-based physics who appeared to be more ready to voice their views and opinions. In one of the conceptual physics courses, student initiated talk comprised a larger portion of interaction than in the other two conceptual physics courses. This was not consistent across all the classes observed. According to Flanders, the established norms for science classes are 80% teacher talk, 10% student talk, with 10% of the student time spent in silence (Flanders, 1970). The observational data found that calculus-based physics has more teacher talk time on average, i.e. 90% teacher talk, 2% student talk, and 8% silence.

In the algebra-based classes, approximately 65% of the interactions were teacher-centered interaction compared to the calculus-based physics classes where approximately 90% of the interactions were teacher centered. Approximately 30% of the interactions were student-initiated (algebra-based classes), compared with approximately 10% in the calculus based classes. Based on these data, it appears that the interactions in the conceptual physics class were the closest to the norm of what is expected in inquiry-based classes.

It is also important to note the greater proportion of time spent in silence in the algebra based classes, as this suggests that the silence may be tolerated by the teacher because the students might be thinking (Rowe, 1976; Black and William, 1998). Part of this silence is commonly referred to as wait time. While these measures of talk are useful, a high percentage of student talk alone is not necessarily an indicator of a creative, student-centered learning environment.

The balance between teacher and student-initiated talk was also analyzed, where the researcher focused on the nature of the talk. It was hypothesized that the percentage of

student and teacher talk may not be significantly different in any of the introductory physics courses.

Ratios were calculated that analyze the data in terms of the teacher talk, student initiation and teacher response. The teacher talk ratio measures the amount of teacher talk relative to student talk. A high teacher talk ratio indicates that the amount of time a teacher spends talking is high and the amount of time students spent talking is low. It was hypothesized that calculus-based physics students would have a higher student talk ratio because these students generally have had more exposure to science and should be capable of asking and answering higher order questions. The student initiation ratio (SIR) measures the portion of talk that is actually initiated by students. Flanders maintains that an average SIR =34. A high SIR indicates that students show initiative in introducing their own ideas in class discussions. It was hypothesized that the calculus-based physics course would have the highest ratio over the other classes. The SIR for the calculus-based class equaled 9, for algebra-based SIR=19, and for conceptual based SIR=33. Therefore, the conceptual physics course had the highest ratio indicating that it was a more student centered course.

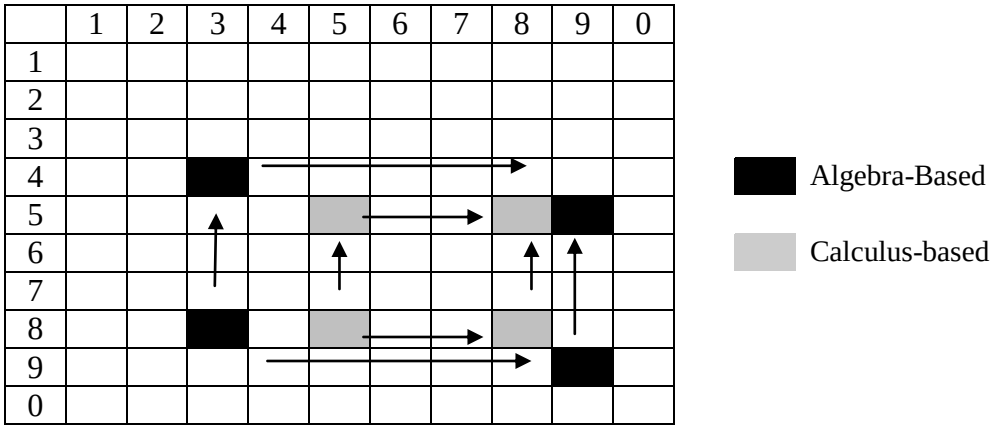
It is also possible to analyze how the professor manages the transition from teacher centered to student centered (i.e. creative inquiry) patterns of interaction. By examining the course syllabi, the design of the introductory physics classes can be described as traditional fashion. The lessons did not include roles and interaction that are consistent with inquiry-based or student-centered physics. Almost all the lessons in the algebra and calculus-based introductory physics course are “traditional” in nature, including lectures. The algebra-based

incorporated the use of technology (PRS) in order to get students actively involved. In all classes where lecture is the form of instruction, the majority of the lessons were far lower in quality than expected. Out of the fourteen observations of the conceptual physics class, there were ten observations wherein almost every student in the classroom was fully engaged in deepening his/her physics conceptual knowledge and involved in open inquiries.

The patterns of interaction in each group from week to week were the same. On average, the physics instructors talked about 94.5% of the time. The students were not praised (0.1%) nor were they provided much feedback (1.3%) on their work. The instructors did not ask the students many questions (4.1%). On the few occasions when the instructors asked questions, most were rhetorical or on the lower end of Bloom's taxonomy. A three second period of silence followed an instructor's question a total 72 times, while the instructor started to talk without a period of silence 227 times.

Figure 4.16 shows the typical patterns of interaction for the various introductory physics classes. Flanders argues that the most common transition in teacher and student talk is via an 8-3 transition, where the professor makes use of ideas expressed by students, because this transition remains in control of the professor. A 4-9 transition is most likely to occur when the professor asks very broad questions or when the students ignore the professor's questions to instigate their own discussion. This requires professors to have the ability to ask the type of question that provokes student talk. The students instigate an 8-9 transition as they shift from responding to the professor's ideas and begin to express their own without interruption from the professor. These types of interactions were found to be

most prevalent in the conceptual physics classes.



Typical pattern of interaction for conceptual and algebra based physics.

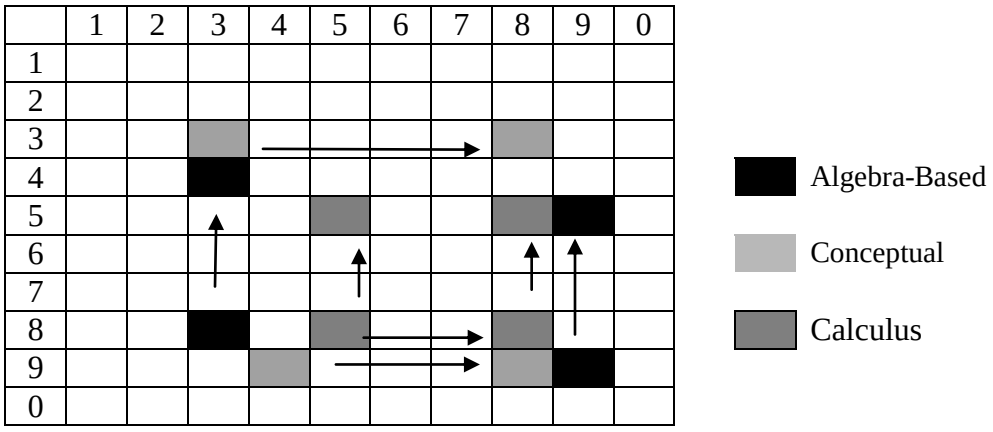


Figure 4.16: Typical pattern of interaction for calculus and algebra based physics.

The results of Figure 4.16 reveal that the Conceptual Physics courses had the most student centered interactions. These results are not consistent with those found in the *VASS*, where many of the professors claim to use student centered approaches in their classes. The observational data suggests that that some instructors in the various introductory physics

classes make more of an effort than others. Many of the activities in the list of the modes of instruction were relevant to the K-12 science classroom, so the modes of instruction were re-grouped into the modes most relevant to the university science classroom.

Table 4.19 shows the modes of instruction relevant to the undergraduate classroom and reveals the results of the post-hoc analysis using the Cumulative Link (Logit) Model, a generalized linear model.

Table 4.19: Comparison of Instructional Methods using a Cumulative Link Model

Modes of Instruction	Effect	p-value	a-level=0.05
Hands on Activities	Rank	0.8831	NS
	Class Type	0.2687	NS
	View	0.072	NS
Teacher Demonstration	Rank	0.3760	NS
	Class Type	0.2894	NS
	View	0.109	NS
Small Group Discussion	Rank	0.2475	NS
	Class Type	0.4112	NS
	View	0.0481	S
Cooperative Group Work	Rank	0.1311	NS
	Class Type	0.0428	S
	View	0.0974	NS
Open Ended Inquiry	Rank	0.8789	NS
	Class Type	0.1502	NS
	View	0.0381	S
Data Collection and/or Manipulation	Tenure	0.5722	NS
	Class Type	0.0292	S
	View	0.0322	S
Group Presentation	Tenure	0.5907	NS
	Class Type	0.8095	NS
	View	0.921	NS

**__Rank:__ faculty or graduate assistant __Class Type:__ Conceptual, Calculus, or Algebra*

A significant difference that was found when looking an instructors' view of the nature of science there appears to be a correlation between an instructors views on the nature of science and collaborative group work, open- inquiry, and data collection/manipulation. An unexpected result was found in this analysis. It was also found that that a correlation was found on the type of class in cooperative group work, data collection and manipulation. This is interesting because the emphasis in any of the classes.

INTERVIEW QUOTES

According to research about beliefs about teaching and learning, much of what teachers do within the classroom is either influenced by (1) beliefs and experiences (Brand and Glasson, 2004; Keys and Bryan, 2001; Pajares, 1992) or (2) by what their own instructors did. The results of the classroom observations and the *VASS* questionnaire can be supported this research. These interviews were conducted to triangulate their findings. These were conversations captured during the interviews that are important to mention in this study. The two professors interviewed volunteered to add insight. Both professors had earned emeritus status and were interested in changing how science is taught.

At the beginning of the conversation, the researcher explained to that the questions were only being asked to provide insight to the data that was already collected. It is interesting to note that both professors answered the questions similarly and exactly how they answered on the *VASS*. When asked about the teaching environment in the department they both indicated how the leadership in the department promotes inquiry-based learning and

were proud of being a part of a "progressive" university. Each noted that they attempt to incorporate "inquiry" as much as possible in lecture.

The interview questions probed at the professors' views of the nature of science and their instructional practices. Neither professor indicated the physical environment (i.e. the lecture classroom) as a hindrance to the use of effective teaching strategies. One professor cited that scheduling had some influence on his/her instructional decisions and discussed how teaching a Tuesday/Thursday class as compared to a Monday/Wednesday/Friday allowed him/her to slow the pace of their lessons and provided the opportunity to implement a variety of instructional strategies during the extended class period. Neither professor mentioned any particular policies that had any impact on his/her selection of instructional strategies. Both mentioned that the physics department leaders encouraged the use of the materials in the demo room.

Interviewees Views on the Nature of Science

Analysis of the teacher interviews and the questionnaires indicated that the professors held mixed views on the nature of science. The professors both agreed that scientific knowledge is tentative and that many of the ideas and concepts are observable. When asked to define science, both professors responded:

> I like Richard Feyman's definition…'Science is a dangerous belief in the ignorance of experts' [laughing]. (Professor UB2)

> Science is an intellectual activity that helps humans to collect facts about the world around them. The goal is to collect facts and learn the skills to distinguish between fact and opinion. (Professor UB4)

A follow-up question was asked to get a clearer and better understanding of how the physics professors defined science. The interviewees were asked why students should study and learn physics. The following comments were provided:

> Whenever students ask that question, I say to them that physics is my starting point. [Studying physics is] necessary to make sense of the world we live in…even though we don't know where to start and it does not make a difference to start anywhere else but with physics (Professor UB2)

> …Science is a funny thing. We base our lives on something that is continuously changing. Even though we don't like change…We can't claim to know the truth about anything, but we can search out continuous patterns in nature. (Professor UB4)

Interviewees Conceptions of Physics and Pedagogy

Both physics professors appeared to have difficulty distinguishing between the subject of physics and teaching the subject of physics. Both professors referenced classes (Scale-Up, Matter and Interactions, and First Year Inquiry Courses) within the university that focused specifically on alternative methodologies for approaching physics.

Their views about active learning teaching methods were most intriguing. Active learning pedagogies are often identified by physics professors as effective strategies because they actively involve students in the lesson. Both professors noted many times that they did not believe it was their responsibility to provide those types of experiences.

> I have been discussing this idea with a colleague…as children we were actively responsible for our own learning. The teacher taught the topic …we went home and thought of ways to experiment with it and take our learning to the next level. Most children know this, but you have to ask the right questions, take what they know and …get them thinking and actively involved, then they'll remember next time…that was how I learned and once I began thinking and expressing out loud I could not be stopped. But kids nowadays don't play…they are like addicts to technology. (Professor UB2)

> I believe that hands-on is probably beneficial for students, but it is difficult to think of good activities…and time-consuming, getting all the materials is easy here, if you have time to do it in advance… . The longer I teach, the more I realize there is something's wrong with the system…It is not our responsibility to do this… . It should have been done before they got here... but I don't know…if this stuff gets [the students] more interested, keeps them busy, helps them learn more …at least they won't be sleeping… (Professor UB4).

Instructional Practices and the Physics Professors' Views

The physics professors taught using two different instructional methods. The professor that taught conceptual physics used methods consistent with his expressed views about the nature of science. One professor included many inquiry oriented activities in his course. These included classroom demonstrations and in-class/at-home activities that require students to collect data and discuss the results based on evidence found in the data. Neither professor indicated that the students' understanding of the nature of science was instructional goal. When the researcher asked them about the purpose/goal of the activities in the class that was observed, the following comments were given:

> The purpose of that demonstration was to excite the students and get them excited about physics. Too many students have heard and believe that physics is hard and complain about it before even trying it…I want them to feel good about learning physics… (Professor UB2)

> I want students to develop skills to make physics connections to the real world. (Professor UB4)

The Culture of Physics

The researcher described to both professors the research of Becher (1991) and Becher and Trowler (2001) which analyzes the unique cultures of academic disciplines. Both

professors agreed that there is a well defined system of procedures and processes that includes language and symbols. The professors disagreed on the concept of "gatekeepers" and "academic thermostats." They both denied their existence yet they described behaviors of their colleagues that fit the description.

> Professor UB4: …I agree that there are some people who believe that physicists are born and not made but if we put lousy physicists to teach we will yield lousy physicists…which will make science worse so we have to "weed" out students that don't have the capacity to learn the subject…
>
> Researcher: Who determines who should be weeded out?
>
> Professor UB4: You can tell by a lot of things: the questions they ask, the arguments they make about the grades they receive, their ability to learn from lectures, their ability to accept things the way they are…
>
> Researcher: That sounds as if it has the potential to be problematic. Have you ever looked at brain research and how students learn physics? One of the guiding principles is that learning is developmental. Is that taken in consideration?
>
> Professor UB4: We can't wait on a person to develop. They have been in school for at least 18 years before trying to get a job as a physics professor. They should have learned and developed by that time. That is why we try to do them a favor by guiding them into a different career path in undergraduate when they don't make the cut.

The researcher shared an experience with the language of physics.

> Researcher: Let's look more into the culture of physics and discuss the language. One thing I have discovered in working with students is that many don't understand the language so much of what I do is assisting those who are just learning physics is to "translate" the meaning of teams. For example, One student did not know what a professor meant whey described the function as "*blowing up* as it approached infinity". The student was relieved when they found out that it only meant that the particle was growing very big very fast and stated that the professor got angry when asked about it. Do think this type of experience could turn introductory physics students off? How do you think this could be avoided in the future?

Professor UB2 responded with the following statement.

> Many students don't take the time to listen and study what the professor is presenting to them. I am sure that term could have easily been figured out if the student would open a book and study.

Professor UP4 offered the same answer but when about it in a different way.

> Of course, the faculty is responsible for presenting the material in a manner that is clear and easy to follow. However, the students also have a responsibility to study and know what the professor is talking about in class.

An interesting conversation came up when questioned about diversity of knowledge within the scientific community.

> Researcher: Teaching physics will become even more complex and challenging in the next ten years when the current minority students change to be the majority in the classrooms. Issues centering on teachers' lack of awareness of best practices, high poverty level, and the ethnic and linguistic barriers between students and teachers (Settlage, 2004; Tobin, Roth, & Zimmerman, 2002) will emerge. Do you think the physics department is ready to address these issues?

The interviewees seemed comfortable discussing gender diversity within the physics community.

> Professor UB2: Let me just be frank. I never thought I would see the number of women would be enrolled in the program…Minorities now that is a different story. Many come unprepared so we have a lot of work to do.

However, it appeared that one of the professors was not as comfortable when discussing the lack of minority students and professors in the field. The professor began to fidget, tapping his fingers rapidly on the desk, then immediately began arranging items on his desk before jumping up and pacing, and running his fingers quickly through his hair.

> Professor UB4: ... I don't understand multicultural science. There is no black or white physics. When I teach my classes, I don't see color, I just see students.
> Researcher: In your classes, do you see male and female students?
> Professor UB4: Yes, I generally have more male students than female students. There are a lot more female students in the introductory physics classes than when I went to

> college. I could count the number of students on one hand when I was a student. As a professor, I can now count them on two hands. There is evidence of some progress (laughing).
>
> Researcher: Do you modify your instruction to accommodate the different experiential interpretations of females or ethnic groups?
>
> Professor UB4: I don't really care what the ethnic make-up of the students is, only the physics topic matters. Anyway, all the history of science lies in the heart of Europe and the field is open to anyone who wants to commit themselves to the study of the field….

Summary of Research Question Two

What modes of instruction are used in the introductory physics classrooms at NCSU?

The evidence shows that all the respondents indicated that they were using effective teaching methods in their classes on a regular basis. However, the results from the study showed that they were pretty much teacher-centered. On average, 97% of the time the teacher used a chalk or white board which means that there is evidence to suggest that the instructor lectured and wrote on the board a lot. This finding is supported by the Flanders Analysis which suggests that about 95% of class time is spent with the teach talking.

The elements for effective teaching practices (i.e. introduction emphasis, modes of instruction, questions and teacher behaviors) were rarely found and again the teacher did not spend time emphasizing or clarifying what the student learned. Conceptual physics had the highest student interaction ratio (SIR=33) which meant that it is most like to be student centered.

Summary of Research Question Three

What relationships exist between the nature of science and classroom instructional practices in the introductory physics courses?

It was very clear in the research that the physics instructors had a different definition of effective teaching practices than the research literature. As a whole, the instructors held a mixed view of the nature of science which fell in the high transitional realm, which means that their views could be classified as a more modern scientific realist. According to Halloun,

> [S]tudent conceptions about physical realities consist more of mixed beliefs and knowledge of vague correspondence to the real world than of viable knowledge about physical realities. (Halloun 2004, p. 89, emphasis added)

The results of this questions indicated that teachers' views of the nature of science do not necessarily influence classroom practice because the definition of effective teacher practice is not clear to all involved. The results of the Cumulative Link Model shows a relationship between an instructors views on the nature of science and collaborative group work, open-ended inquiry, and data collection/manipulation. This was not show in any of the other analyses.

CHAPTER FIVE: DISCUSSIONS AND RECOMMENDATIONS

INTRODUCTION

The final chapter of this dissertation examines the physics professors' views on the nature of science and their instructional methods in introductory physics courses. The chapter begins with a summary of the significant findings related to the research questions. This summary does not give a detailed analysis of each question but discusses the findings deemed most important to the study. The implications of the study are discussed in the context of changing teaching behavior in the university physics classrooms. The concluding section of this chapter includes closing remarks in light of analyses and recommendations for further research.

The theory that drives the work of this dissertation is grounded in constructivism guided by culturally responsive pedagogy. According to Gay (2000), culturally responsive teaching uses the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective for them. Irvine's (1990) model of cultural synchronization which is outlined in Figure 5.1 describes how learning is maximized and instruction becomes more effective when teachers have a connection with the students they teach. If they are out of sync, then it results in student failure.

This model has been traditionally used to describe the interaction of White teachers who teach Black students at the elementary and secondary levels, but it easily applies to any instructor. It is especially applicable to the university, where the students who are interested in studying science are turned away because of the way it is taught.

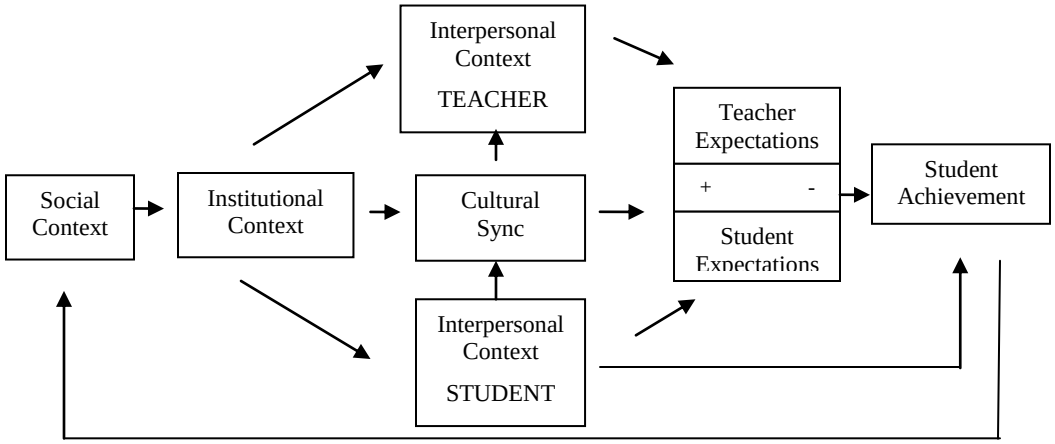


Figure 5.1 Cultural Synchronization Model

Many physics instructors are not trained in pedagogical content knowledge with adult learners where students have different experiences. While physics teachers can bring their knowledge of physics to the classrooms because they have earned a doctorate in a subject, it is important that they be encouraged to look at education through another lens.

In chapter one, the problem is presented and highlights the issue of higher education, business community, the educational research community, and undergraduates are dissatisfied with how science is taught at all levels. Despite of all the attempts to make learning a dynamic process, the university physics classroom remains as an "spectator sport" (Nunn, 1996). In order to explore this problem, this study examined the views held by instructors, the materials used in the classroom along with the amount of time spent was analyzed in order to see if the instructors views in the nature of science influenced the methods that they use in their classes. This study addressed this issue by analyzing the following research questions:

1. How do physics instructors view the nature of science?

2. What modes of instruction are used in the introductory physics classrooms at NCSU?
3. What relationships exist between the views of the nature of science and the classroom instructional practices in the university physics classroom?

Discussion of Findings

Research Question One: How do physics instructors view the nature of science?

In designing this study, the researcher was able to draw upon the physics instructors at NCSU. In order to better understand the population within the sample, the demographic characteristics of the physics instructors were analyzed first. The results of the study showed that the sample chosen reflects the make-up of the current teaching population of the physics department at the university level. The instructors are primarily Caucasian males (Van Hook, 2002).

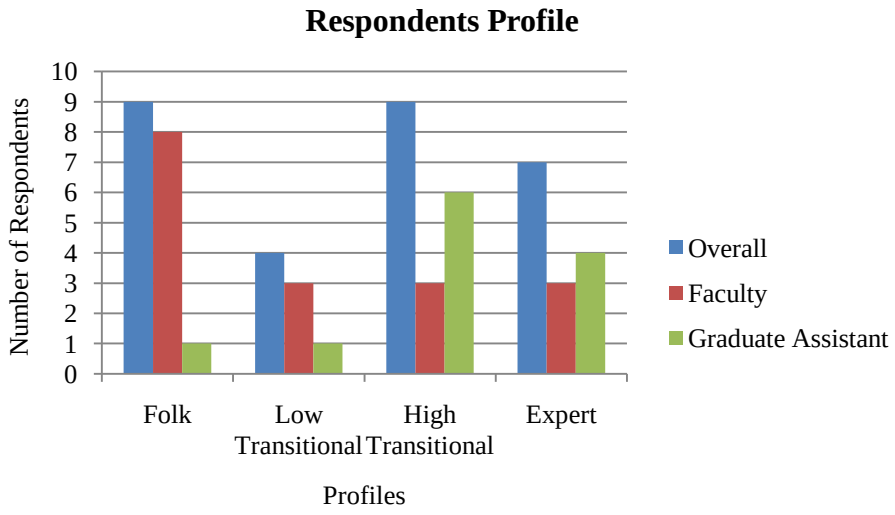


Figure 5.2: Respondent Profiles

Figure 5.2 shows a summary of the respondents' profiles which clearly indicate that the physics instructors did not have a uniform view of the nature of science. It was expected that the majority of the physics faculty members would hold an expert view of the nature of science. The graduate assistants held higher views of the nature of science than the physics faculty. The reason for this was not revealed in this study.

Further exploration by domains revealed that faculty and graduate assistants' views differed statistically on their beliefs on the methods of science. Research suggests that there is dissatisfaction in the way the nature of science is taught in conventional physics courses (National Research Council, 2005). When physics is practiced in the lab, it involves making models, so science instruction should engage students in using and making models. The reason for the difference could be that faculty know that many students think that there is only one scientific method. Arons (1990), and Coble and Koballa (1996) points out in their research that college science professors, especially those who teach introductory courses, teach science as a body of facts, rather than a way of knowing the natural world through inquiry. Traditional physics courses generally emphasize problem-solving. As a result, students taking physics generally approach physics problems by searching formula sheets for equations that will give them the solutions to problems (Arons, 1998; Hammer, 2000; McDermott 1993; Novak 1994; Reif, 1985; Van Heuvelen 1991; Viennot 1985). This finding may shed light on the reason some of the scientists have mixed views about how science is taught.

A Spearman Analysis was conducted in an attempt to explore the relationship between the domains. A problem was found in the analysis of each domain. Both structure and the methodology are components of the scientific domain likewise the learnability and reflective thinking are components of the cognitive domain so it would be expected that their growth would occur simultaneously. This means that there could be problems with the development of *VASS* which was based on the responses of forty-eight high school and twenty-six college physics professors, especially if it were based on the college professors alone. It could not be generalized to the general population because it would have violated the Central Limit Theorem.

On the other hand, in the initial development of the *VASS*, the responses in the areas of knowing and learning science studies also showed that the faculty instructors did not hold expert views on the nature of science. Although, the categories have been reclassified, it appears to be resurfacing. It could also be hypothesized that there could be a possible error in the translation of the instrument. It could also be that physics professors usually have been teaching long than graduate assistants, their experiences could have led them to a more developed, more realistic view on attitudes of the students long enough to know that it is rare for a student to take physics if it were not required for their major (Ivie and Neis, 2005).

It is unclear if the *VASS* had been changed. An area of future research would be to check to see if it is an anomaly or if it is something different. It is important to note, however, that Halloun describes a scientific paradigm using language that is different from Kuhn's in defining scientific paradigm.

> "Kuhn writes of the paradigm shift as a revolutionary, vision-altering conversion experience, Halloun writes of a gradual evolution from one way of thinking to another and an easy back and forth switch between paradigms" (Wendel, 2008).

This may not be the most appropriate way to represent the views of the nature of science.

Research Question Two: What modes of instruction are used in the introductory physics classrooms at NCSU?

The responses the Teacher Practice Index were analyzed and yielded some interesting results. The responses as a whole indicate that the professors in the physics department believe they use instructional methods in class that promote student achievement using research-based effective teaching methods but a closer analysis reveals something much different.

The introductory physics classes were observed to see if what was being taught in-class matched the responses to the teacher practice index. The sample included all introductory physics classes taught at NC State with the exception of the non-traditional classes, i.e. Conceptual Optics, Scale-Up, Matters and Interactions and those taken by physics majors. The classes were visited equally with the exception of PY 212 which was observed the fewest number of times (n=7). The PY 131 classes have a slight over-representation of females in the classes. Otherwise, the classes studied were comparable to introductory physics classes across the U.S. including race, ethnicity and gender.

The responses to the Teacher Practice Index in the VASS indicated that both the graduate assistants and the physics professors had high levels of general self-efficacy and

indicated that they performed the activities conducive to student centered learning. There was little evidence found during the classroom observations to support this finding.

In general, the pattern was the same daily, the teachers explained, the students sit in rows facing the chalkboard and their understanding was checked with quizzes and tests. The premise was simple. The instructor knew the correct processes and answers, so the benchmark of student success in the introductory physics course is the final exam.

There were several times when the Conceptual Physics and one of the Algebra-Based physics courses varied instruction in the classrooms. The instructors encouraged students' creative thinking by inviting them to solve problems using the peer instruction model. The instructor lectured for 10-15 minutes, then gave the students a "conceptest", an in-class quiz consisting of a single multiple-choice question displayed on an overhead projector. The students were first asked to answer the question individually then recorded their answer using the personal response system. Then the instructor asked the students to discuss it among themselves for 1-2 minutes. The students were encourages to share ideas and possible solutions. A histogram appeared with the various answers giving the class immediate feedback on their responses. If the results were positive then the instructor moved on to another topic, if not, the topic would be revisited. Some of the problems were open-ended with no one "correct" answer. The "solution is usually the consensus for the students working together. The students were also encouraged to make their own improvements to the work in progress.

On several occasions the Conceptual Physics students were usually seated in several small groups sharing ideas equally. As the students work progressed the instructor began to probe the students to make them think a little deeper about their problem by asking them questions related to the topic. In one lesson observed the instructor loss focus and direction and seemed to flounder, but never loss control of the class. The teacher was able to continue teaching and the students were not aware of the change from the outline.

Classroom observations, lesson outlines and interviews indicate clear differences between classroom practices of the instructors of conceptual and calculus-based physics. Those classes that were required by science majors were expected to employ more inquiry-based methods. However, the Conceptual Physics course included many inquiry-based demonstrations and activities that required students to collect and analyze data, make inferences about the data they collected. These inferences were discussed, tested, and revised. However, when questioned informally, journal entry analyzed, and analysis of lesson outline indicated that this was an unintentional result.

This finding is constant with the research findings of Abd-El-Khalick et al. (1998); Duschl and Wright (1989); Gess-Newsome and Lederman (1993) and Gess-Newsome and Latz (1994) which determined that teachers rarely consider the nature of science when planning their lesson or deciding how instructional methods used. It appears that teacher's beliefs about the nature of science don't necessarily influence instructional methods of an instructor.

Research Question Three: What relationships exist between the views of the nature of science and the classroom instructional practices in the university physics classroom?

A cumulative link analysis was run to see if there could be a possibility of a relationship between the classroom practices and rank, views and class type. In chapter 4 in Table 4.19 found a significant difference that was found between the instructors' view of the nature of science and collaborative group work, open- inquiry, and data collection and/or manipulation. An unexpected correlation was found when analyzed by class type in the areas of cooperative group work, data collection and manipulation. This is interesting because the purpose of physics is to teach the concepts but many professors disagree on the purpose of the course.

There is some evidence, however, that some physics instructors have beliefs about the nature of science that influence their classroom practice. Since the majority of the respondents to the *VASS* have mixed views about the nature of science, it could be possible that their views of the nature of science and scientific processes are all correlated with their views of teaching and with their teaching actions. Clark and Peterson (1986) research supports this finding shows that a reciprocal relationship exists between a teacher's belief about the nature of science and classroom practice. Since the research concludes that the teachers have high self-efficacy, many [instructors] expect their students to learn by accumulating bits of information" (p. 57). Others, however, believed that science progress occurs through new interpretations of old observations, and so students learn science through the interplay between thinking about old information and assimilating new information.

The results of this research suggests that the physics instructors have many different contextual variables that they refer to when talking about their teaching which often serve as reasons to reject the calls to change how teaching is done at the college level and lead to the continuation of current teaching methods. Table 5.1 outlines some of the factors that affect how they teach and how students learn.

Table 5.1: Factors That Affect How Physics Instructors Teach And How Students Learn

	Response by Professor	
Issues related for student learning	**UB2**	**UB4**
Students not retaining lecture materials/learning basic concepts	x	x
Students lack problem-solving skills/can't critically think	x	x
Students only interested in grades	x	x
Issues related to teacher instruction		
Student enrollment in courses like Scale-Up, Matter and Interactions, etc	x	x
Active learning technologies		x
Differentiating Instruction		
Amount of time in class	x	x

The result of this study is consistent with previous research, which indicates that teachers' conceptions of the nature of science do not necessarily influence classroom practice (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 1998; Brickhouse, 1990; Lederman, 1992; Lederman & Zeidler, 1987). Unfortunately, this question could not be answer within the scope of this dissertation but the results from the questionnaire lays the necessary foundation for future research.

RECOMMENDATIONS

The research is filled with arguments about how science should be taught which gets us no further than the argument "Which comes first, the chicken or the egg?" Physics education researchers take one approach and science educators take another and again, the argument just boils down to semantics. Physics education research has several examples of case studies on barriers to change but very few reference studies on what it takes to change. In the mist of these arguments, we have researchers designing adult experiences based on knowledge about how children think and learn when the learners in the university are adults. Information on how university physics faculty view the nature of science, the influence their beliefs about the nature of science have on their instructional methods serve as a necessary foundation to begin the discuss on what needs to be done in introductory physics classes. It was hoped that this study would provide a knowledge base that would shed some light on a few aspects of university instruction and the lack of change in how science is taught to adults as learners.

This study revealed that even though the physics instructors are aware of the innovations in physics education, many of the instructors have had difficulty changing to a more inquiry-based model. These findings suggest several implications for practice beneficial to those teaching introductory physics in order to provide a common view of inquiry-based science. Physics education researchers have done well in describing this in the literature. However, much more is needed before we can even address such a drastic instructional change. Studies like this one help to shed light on the instructional practices of

those who teach introductory physics at the university level, so that departments and institutions for higher education can decide where to start.

Dreyfus and Dreyfus (1986b) explains it best, "when things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works" (p. 30). Although, additional research is need to explicate the relationship among teachers' beliefs, classroom practices, and student achievement is needed, some preliminary recommendations can be gleaned from the results of the current investigation.

Trigwell and Prosser (1997) suggested that teachers' choice of a particular teaching approach is dependent on both their prior experience with such an approach and their perceptions of whether such an approach is compatible with the teaching situation. It appears to be important that physics instructors become educated in areas beyond their content knowledge which include topics in science education and directly address teachers' abilities to translate their understandings of the nature of science into classroom practice (Abd-El-Khalick & Lederman, 1998; Lederman, 1986, 1992). A systematic and concerted effort to help physics instructors develop their classroom skills and abilities that will enable them to transform their understandings of physics into classroom practice should be pursued and systematically evaluated.

One way to approach this is to follow the agenda for the National Science Resource Center (NSRC), which was established in response to the report, A Nation At Risk. The goal of the organization is to improve the teaching and learning of science throughout the world (NSRC, 2008). Figure 5.2 shows the model of the action theory designed to assist school

districts in developing a research-based science education programs in grades K-8. The need for a strategic plan for a professional development based on a systems thinking approach is quite evident. It is likely that both the university and the science faculty will benefit. This implies that the professional development activities at the university level need to go beyond what the university's Faculty Center of Teaching and Learning offers.

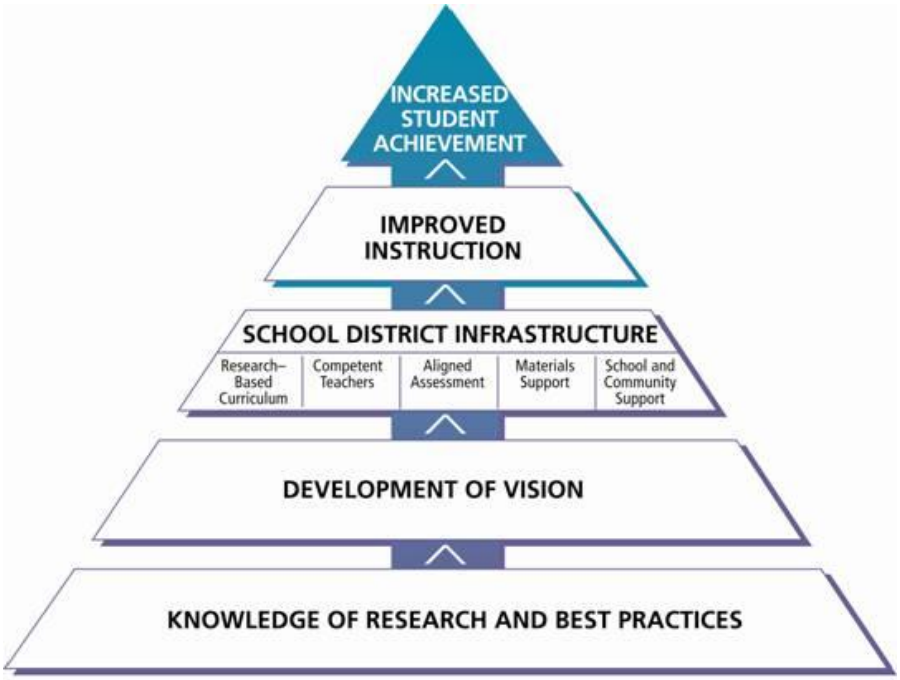


Figure 5.3: NSRC Theory of Action (NSRC, 2008)

This same theory of action could be beneficial to the university community by the changing the level of titled 'School District Infrastructure" to the "Infrastructure of University Change" whose subcomponents include

- Educating University Faculty on Models of Change
- Scholarship of Teaching and Learning
    - Lesson Study
    - Effective Teaching Practices
        - The Adult Learner
        - Textbooks as a Tool for Learning
        - Motivating the Adult Learner
    - Instructional Innovations in physics
- Improving Graduate Student Teaching Programs
- Establishment of Centers of Pedagogy
- Establishment of Professional Learning Communities

Educating University Faculty on the Models For Educational Change

There is a growing consensus that education reform efforts are doomed to fail if the teacher's beliefs, intentions, and attitudes are not taken into account (Haney, Lumpe, Czerniak, & Egan, 2002; Haney, Czernick and Lumpe, 1996; Loughran, Mulhall, Berry, 2004). There are many reasons why instructional changes are not easily applied to teaching practice. First teachers do not risk changing their own practices; especially if their practices work for them.

It is evident from this study that there is a need for professional development on interactive engagement in the introductory physics classroom. It is clear that there is need for professional development to help the instructors understand their role in the educational process. There is no 'ideal' way to organize staff development in the context of calls for change. However, staff development should be a permanent feature in the career of a

university professor. The staff development is needed that focuses on systems thinking, teacher knowledge and beliefs throughout all stages of change, peer coaching, and allows sufficient time for changes to occur. Professional development in the traditional sense does not work. Instructors tend to change their practices in a tinkering manner, picking up new materials and techniques here and there and incorporating these in their practices (Thompson and Zeuli, 1999). This is referred to in education as knowledge concentration; people get comfortable in a set routine (Bereiter and Scadamalia, 1993). As a result, it becomes more difficult to move into an unfamiliar area.

Fullan (1991) and Hall and Hord (2006) suggest that the change process traditionally followed these steps:

- the curriculum developers or policy makers define the core elements of the reform;
- a description is made of the expected change in behavior or the skills the instructors should acquire;
- a series of training sessions or supervised activities focuses on the desired change generally in the form of one shot interventions such as teacher workshops or conference presentations;
- usually the change is not adopted by the instructors in the manner intended or the teacher tries to implement change initially but reverts back to what is comfortable;
- the steps above are repeated in a modified manner after the innovation has been refined.

Not every design for change follows this pattern, but it is clear that the role of the instructor is critical in the execution of innovation.. It is imperative that university professors understand the educational change frameworks which are rich and solidly grounded in empirical studies and practical applications. Figure 5.4 shows a concept map which features seven educational change models determined by Ellsworth (2000) to be the epitome of a perspective shared by a group of models.

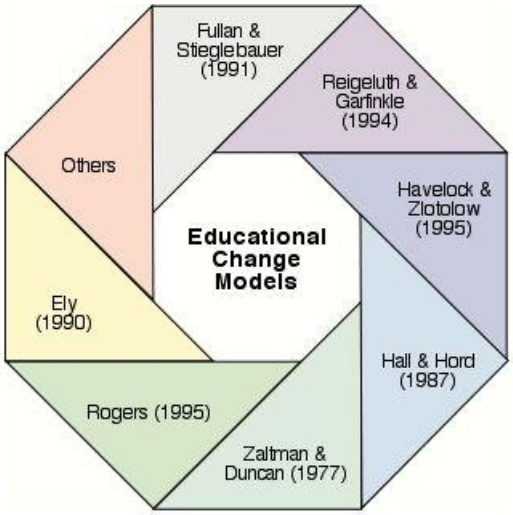


Figure 5.4: 360^{o} View of the Change Process (Ellsworth, 2000)

The "others" category represents a small group of studies from disciplines outside educational change. The 360-degree view yields combined perspectives of the change process. There is no single starting point, so one may start anywhere and skip around to different models depending on interest. While these change models are identified in this graphic as independent, they are interrelated. For example, one may start at the bottom and look at *Strategies for Planned Change* (Zaltman and Duncan, 1977) to help isolate the causes

of resistance. One method for handling obstacles, such as resistance, is to modify or adapt the innovation's attributes, or perhaps, the perceptions of the innovation among stakeholders. *Diffusion of Innovations* (Rogers, 1995) identifies the influential stakeholders and helps readers to select an approach.

Conditions for change and deficiencies in the environment are explained in Ely (1990). The *New Meaning of Educational Change* by Fullan and Stiegelbauer (1991), can help individuals decide where to start (or stop a bad change) if they are interested in trying to improve schools. From there, one may wish to consider the system being changed as described by Reigeluth and Garfinkle (1994) in *Systemic Change in Education*. The *Change Agent's Guide* (Havelock and Zlotolow, 1995) facilitates future efforts by serving as a checklist to ensure that the right resources are used at the appropriate time.

Table 5.2 outlines the stages Concerns Based Adoption Model (CBAM) (Hall and Hord, 1987) that can be used as a tool to monitor the intricacies of the change process and to collect information from the professor involved in the professional development process as needed.

Table 5.2: The Concerns-Based Adoption Model (CBAM) (taken from Rudd, 2006)

Stages of Concern	Expression of Concern
6. Refocusing	I have some ideas about something that would work even better.
5. Collaboration	How can I relate what I am doing to what others are doing?
4. Consequence	How is my use affecting learners? How can I refine it to have more impact?
3. Management	I seem to be spending all my time getting materials ready.
2. Personal	How will using it affect me?
1. Informational	I would like to know more about it.
0. Awareness	I am not concerned about it.

These stages have major implications for professional development. Often professional development workshops focus on the how-to-do-it and rarely address self-concerns. The CBAM model follows the change of an individual and points out the importance of reaching people where they are and addressing the questions the instructors are asking when the instructors are asking them. Focus is almost always on student learning before teachers are comfortable with the materials and strategies.

What currently happens to professors is that once their practice becomes routine, they never have the time and space to focus on whether and how their students are learning. Therefore, some organizational time must be set aside to stimulate interest and focus on specific student learning outcomes. Realizing everyone has concerns including administrators, parents, policy makers, professional developers, and acknowledging the concerns and addressing them are critical to progress in a reform effort. Learning experiences evolve over time, take place in different settings, rely on varying degrees of external expertise, and change with participant needs. The strength of the concerns based model is the embedded reminder to pay attention to individuals and their various needs for information, assistance, and moral support.

It takes at least three years for early concerns to be resolved and later ones to emerge. To implement change, teachers need to have their self-concerns addressed before they are ready to attend hands-on workshops. Administrative concerns can last at least a year, especially when teachers are implementing a school year's worth of new curricula (Hall and Hord, 1987). New approaches to teaching require practice, and each topic brings new

surprises; therefore, the instructors need support over time, which is necessary to work the problem areas and then to reinforce good teaching. The implementation of this type of faculty development activity presupposes that the institution considers teaching important. Evidence of this commitment is demonstrated when the university provides financial support to the organization of special events, initiates pilot programs, opens workshops, and provides certification at the end of the program.

Scholarship of Teaching and Learning

Findings from this study suggest that rather than advocate one type of pedagogy over another, the vision of high quality instruction must emphasize the need for a science literate society, instructional activities that engage students with the physics content, a learning environment that is simultaneously supportive and challenging to all students, and, vitally, attention to appropriate questioning to help students make sense of the physics concepts they are studying.

Implementing the methods of the scholarship of teaching and learning supported by the Carnegie Foundation (Shulman, 1998 and Boyer, 1998) is a logical second phase for the physics professors because scholarship of teaching and learning is likely to require methods outside the professors' training as physicists (McKinney, 2004) and will require an additional time commitment. The early interventions mentioned in the chapter would likely be helpful to teachers in understanding this overall vision, and in improving instructional practice in their particular contexts.

Boyer's definition of the scholarship of teaching and learning as it relates to physics education at NC State is to prepare high quality students. The Boyer Commission (1998) called on universities to commit to the scholarship of discovery, integration, application and service in order to impact the greater community by (a) helping meet the challenges of local communities, (b) creating partnerships with the local schools, and focus on the practical, field based learning, and with some special attention given to promoting social values. This is promoted through the scholarship of teaching, which claims that the "work of the professor" will include creating a sense of awe and wonder within students that will foster a passion for lifelong learning.

The first element of SOTL requires that the professors have a vision of what will transform the classroom to a place where meaningful learning can occur. Vision will provide an opportunity for professors to analyze a variety of lessons in relation to these key elements of high quality instruction, particularly teacher questioning and sense-making focused on conceptual understanding (Shulman, 1998). For example, it may be necessary to form group discussions with videos of other teachers' practice, and moving toward examining their own practice, a lesson study could be conducted with knowledgeable facilitators to provide teachers with helpful learning opportunities. Based on the observations, the physics professors also need expertise to help students develop an understanding of that content, including knowing how students typically think about particular concepts, how to determine what a particular student or group of students is thinking about those ideas, and the

availability of instructional materials (and possibly other examples, investigations, and explanations) to help students deepen their understanding.

Once the professors complete this task, the professors will have the opportunity to design/redesign their courses. The instructors will then have the opportunity to investigate whether their own teaching practices are helping students meet the objectives of the course (Shulman, 1998). The teachers can plan to incorporate research-based teaching methods by becoming aware of the support materials that accompany textbooks and other student instructional materials that provide more targeted assistance in clearly identifying the key learning goals for each suggested topic, sharing the research on student thinking in each content area, suggesting questions/tasks that teachers can use to monitor student understanding, and outlining the key points to be emphasized in helping students make sense of the physics concepts. Once faculty members develop the course objectives and design course activities, the next step is implementing the new material in the course. Then the methods can be analyzed and assessed.

Once the design phase is accomplished, the class is ready to be taught. Once the class is taught, it should be assessed based on student learning which includes a process of reviewing and reflecting on teaching method in order to see if the students are meeting the expectations and objectives of the course. The results of assessment measures can help faculty learn how the teaching practices and class activities affect student learning and development. After the faculty reflects on the assessment, the results can be disseminated throughout the discipline.

Establishment of Professional Learning Communities

Within the university, a professional learning community can be defined as a group of individuals "…that interact and influence each other to perform a task" (DuFour, 2004). Ongoing diversification and specialization in science and the increase in technological innovations lead to the establishment of professional learning communities that operate under the systems thinking theory (Senge, 2000). This theory suggests that all systems are interdependent and interconnected and cannot stand alone. Systems' thinking requires that all systems must be *all* inclusive addressing everyone and everything and kept in balance. In education, the belief that "all students can learn" reflects systems thinking. For the system to remain in balance, it *must* include *all* -- inclusive of every man, woman and child in the world. No one can be excluded, exempted or opted out.

This change in thinking requires a paradigm shift (Barr and Tagg, 1995) at the university level with the creation of professional learning communities, a focus on learning rather than teaching, working collaboratively, and holding individuals accountable for results (DuFour, 2004). The concept of professional learning communities is borrowed from the business world in an attempt to improve student learning. Professional learning communities, or PLCs, operate with the belief that if adults communicate about teaching and learning and if they act on what they have talked about, then student learning and achievement will improve (Thompson, 2004).

The findings of this study align with the work of Lee Shulman (1998) which suggests that teaching is not just technique, but an enactment of the professors' understanding of their

professional field. Therefore, teaching needs to be reconnected to scholarship and to the scholarly communities through habits of documentation, exchange, and peer review. Lesson study might help to address this. Lesson study is a professional development activity originally created to improve teaching in Japanese elementary schools that utilizes research based components of effective teaching practices (Takahashi & Yoshida, 2004 and Lewis, 2002). Although, lesson study is most commonly conducted at the elementary level, it can easily be performed at the university level. Generally, a team of 3-6 people teaching the same class is formed to discuss what they would like students to learn as a result of the lesson. The instructors develop a lesson to research and predict how students will respond. An instructor on the team teaches the lesson while the others observe and collect evidence of student learning. The team analyzes evidence by discussing the results and assesses the progress toward learning goals. The team revises the lesson and shares finding until the members are all satisfied. The established professional learning communities based on the Concerned Based Adoption Model (CBAM) would likely be helpful to teachers to understand this overall vision, and to improve instructional practice in their particular contexts.

Graduate Student Teaching Programs

The simplest and most logical approach to innovating physics instruction is to focus on the development of programs that prepare graduate students to teach since the graduate assistants in this study were found to hold an expert view on the nature of science. The research is full of studies focusing on the professional development of graduate students focusing on teaching that have seen positive results (Brainard, 2007; Elmendorf, 2006; Luft,

Kurdziel, Roehrig, & Turner, 2004; Trautmann, & Krasny, 2006; Wieman, 2007 and Austin, 2002). At the very least, graduate students who are considering a career in teaching physics at the university level should be required to take at least three classes in the science education department; most highly recommended is a science methods course in order to broaden their understanding of alternative instructional methods. Courses that also focus on working with mentors and courses to address difficulties that arise in the classroom or laboratory are recommended.

Establishment of a Center Of Pedagogy

One of the current initiatives at NCSU is to become an "engaged university", a university that provides learning opportunities that promote unity within the community for both students and faculty. One way that an "engaged university" can impact science teaching and learning is to establish what Goodlad (1990) calls centers of pedagogy where the instructors from science departments, the college of education, and school districts collaborate. These centers would have their own faculty curricula and budget in order to improve the quality of education. Goodlad (1991) studied twenty- nine public and private institutions and found that the teacher education programs lacked a clear mission, had poorly developed curricula and graduated teachers that lack vision. These centers provide an opportunity for interested students to learn necessary skills to change their methods of instruction. The students within the center of pedagogy are taught using the latest technological innovations.

Direction for Future Research

Even at the onset of this research, the main objective was to look for future questions to begin asking and probing more deeply into ways to improve instruction in the undergraduate physics classroom. This study shows a general landscape of the faculty beliefs about science and the methods used in introductory physics classes but it leaves open several questions:

- What are teacher beliefs about inquiry-based teaching in the university?
- How do undergraduate physics instructors use their instructional time and implement their understanding of inquiry-based teaching?
- What is the nature of interaction between teachers and students in the introductory physics classrooms?
- If we were able to get a better understanding of physics faculty beliefs on the nature of science, how would they compare to the graduate assistants? Assuming that they are different; can we pinpoint a cause for this difference? In other words, at what point in a scientist's career/education is there a change in NOS conceptions – or does such changes ever take place?
- Is there any correlation between a physicist's views of the nature of science and their level on the CBAM stages of concern?

In order to address these questions the following must take place:

1. *Reinvestigate university professor's beliefs using a larger sample and a better means of assessing teacher's view about science.*

   The small sample size could have contributed to many of the non-significant results.

   The study should be replicated on a larger sample. The Views about Science Survey

may not have been the best measure of university teacher's views on the nature of science. To address this problem other instruments should be investigated.

2. *Use case studies, ethnographies, or phenomenological studies to examine physics faculty and graduate student perceptions*.

   In science, quantitative research is the most common method of research. Qualitative research suggests that there are multiple ways to interpret data to better understand the problem. Research and graduate assistants should be able to shed some light on their experience as teachers.

3. *Reinvestigate the variables using a sample demographically different from the original.*

   This sample was representative of the population that studies physics and was constructed in a homogeneous manner, containing primarily white males. It may be difficult to find a sample that includes more diverse individuals but it may not be as difficult to find those that teach a more diverse student population in an attempt to expand the knowledge base.

CONCLUSION

Colleges and universities have administered many changes and revisions in their science curriculum. Universities have the academic freedom to do what they want and the diversity of skills to develop new ideas and engage in activities that stimulate change, yet it is difficult to change and reform instructional practices. However, there will be no change until

new practices are implemented. Systems may adopt change, but individuals implement change (Hall and Hord, 2006).

This change is more than important than ever because science is more vital to our lives than ever before. The business community is not getting the employees with the necessary skills to compete in a global economy and many are lacking (1) oral communication skills, (2) collaboration skills, (3) professionalism, (4) basic science skills, and (5) critical thinking skills.

The classroom is changing fast in new millennium. However education is transitioning fast. Many of the students have lost their jobs, homes, and are struggling to make ends meet. The students need faculty that can create a classroom environment that can offer hope when things look bleak.

The last few decades have seen unprecedented numbers of scientific and technological advances and the world economy is increasingly driven by scientific businesses including bio-technology, information technology and energy.

As a leader of scientific innovation, currently America is facing great competition from India and China. Both countries graduate more PhDs in science and engineering than the United States. The future holds great challenges for American students, many of them created by the scientific and technological advances of the last century. Teachers at the university level must learn new educational methods to make them and their students' life-long learners**. It is clear that educating students in science in all its forms will be critical to America's future.**

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APPENDICES

APPENDIX A-CONSENT TO DO RESEARCH

You are invited to be in a research study of physics teaching. You have been selected because you have taught introductory physics at North Carolina State University (NCSU) during the last five years. You are asked to read this form and ask any questions you may have before agreeing to be in the study.

This is a dissertation study conducted by Willyetta Brown for NCSU under the supervision of John Penick, John Hubisz and Michael Paesler.

BACKGROUND INFORMATION
This study will attempt to determine how physics faculty view physics and how it affects teaching and learning in the undergraduate classroom. This information will be used to design professional development workshops and improve the design of curricular materials.

PROCEDURES
If you agree to be in this study, you will be asked to complete a modified *The Views About Science (VASS-20) Teacher Study. This is on-line survey should take no more than 20 minutes.* If you agree to provide further information about your own teaching, you will be asked to participate in an interview. This interview should take only about one hour. The interview will be audio taped and focus on your own teaching.

RISK AND BENEFITS
There are no risks involved in participating in this study. I hope that you find the interview questions interesting and that they allow you time to think about aspects of physics instruction that you might not frequently have time to consider.

CONFIDENTIALITY
The records of this study will be kept private. Any report published, any information that will make it possible to identify you will not be included. Research records will be kept in a locked file off-campus. The audiotapes will only be assessable to physics education researchers. They will be kept for three years after the completion of the study and then destroyed.

VOLUNTARY NATURE OF THE STUDY
Your decision whether not to participate will not affect your current or future relation with North Carolina State University. If you decide to participate, you can withdraw at any time without affecting those relationships.

CONTACTS AND QUESTIONS
The researcher conducting this study is Willyetta Brown under the supervision of John Penick, John Hubisz and Michael Paesler. If you have any questions, please contact Ms. Brown at wabrown3@unity.ncsu.edu . You may print a copy of this form to keep your records.

STATEMENT OF CONSENT
I have read the above information and I consent to participate in the study.

APPENDIX B-VASS QUESTIONNAIRE

Views On Physics Teaching Survey

This survey is intended to identify factors that contribute to faculty conceptions of teaching and learning physics and to assist in the design of instructional material. All data are confidential. Your identity will not be disclosed to any party. Please do not skip any questions. Avoid guessing. Your answers should reflect what you actually and honestly think. Plan to finish the survey in 20 minutes.

For information about the survey at North Carolina State University, please contact Willyetta Brown wabrown3@unity.ncsu.edu.

Section A
Each of the following 23 questions consists of two statements about a given issue, followed by five contrasting alternatives regarding the two statements. Please answer each question by choosing only one of the corresponding five alternatives. The example below describes the five choices for question 1.

Example

Learning physics requires:
(a) a serious effort.
(b) a special talent.

1. Only (a)
2. More (a) than (b)
3. Equally (a) & (b)
4. More (b) than (a)
5. Only (b)

What would each one of the five choices mean?

1. Only (a) Learning physics requires a serious effort and no special talent (or mainly the former and hardly ever the latter).
2. More (a) than (b): Learning physics requires more a serious effort than a special talent.
3. Equally (a) & (b): Learning physics requires as much a serious effort as a special talent.
4. More (b) than (a): Learning physics requires more a special talent than a serious effort.
5. Only (b): Learning physics requires a special talent and no serious effort (or mainly the former and hardly ever the latter).

1. Learning physics requires:
(a) a serious effort
(b) a special talent

2. I studied physics:
(a) to satisfy course requirements
(b) to learn useful knowledge.

3. Reasoning skills that were taught in physics courses were helpful to me:
(a) in my everyday life
(b) when I became a scientist.

4. My students score on physics exams is a measure of how well:
(a) they understand the covered material
(b) they can recall rote things by the teacher or in some course materials

5. For me, a student doing well in physics courses depends on:
(a) how much effort they put into studying
(b) how well the teacher explains things in class.

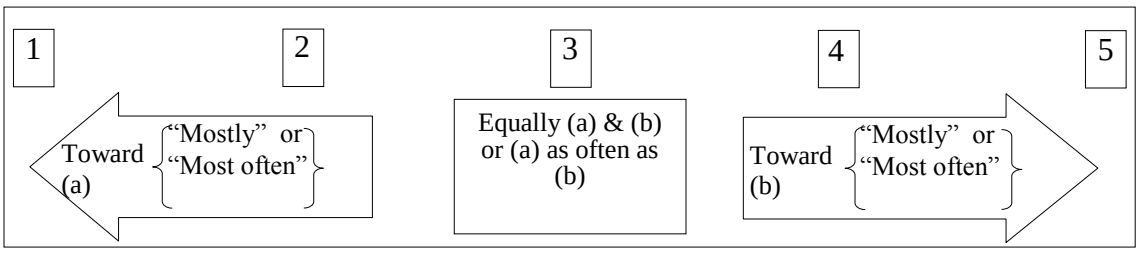
6. In my opinion, for any question asked in class, a good physics teacher should be able to:
(a) provide the correct answer
(b) show how or where one may get the answer.

7. When my students experience difficulty while studying physics:
(a) they seek help,
(b) they try to figure it out on their own

8. When studying physics in a textbook or in course materials:
(a) students find the important information and memorize it the way it is presented
(b) students organize the material in their own way so that they can understand it.

9. For me, the relationship of physics courses to everyday life is:
(a) easy to recognize
(b) hard to recognize.

10. In physics, it is important for students to:
(a) memorize technical terms and mathematical formulas
(b) learn ways to organize information and use it



12. After students go through a physics text or course materials and feel that they understand them:
(a) they can solve related problems on their own
(b) they have difficulty solving related problems

13. The first thing I do when solving a physics problem is:
(a) represent the situation with sketches and drawings
(b) search for formulas that relate givens to unknowns

14. In order to solve a physics problem, I need to:
(a) have seen the solution to a similar problem before
(b) know how to apply general problem solving techniques

15. For me, solving a physics problem more than one way:
(a) is a waste of time
(b) helps develop my reasoning skills

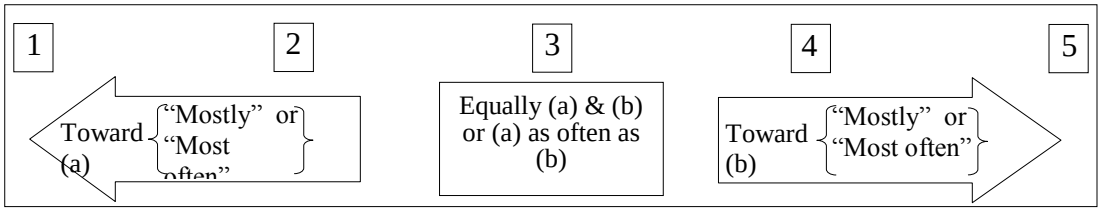
16. After the students have answered all questions in a homework physics problem:
(a) they stop working on the problem
(b) they check the solution set or ask the professor how to get the answer

17. After I solve a physics problem for which students got a wrong solution:
(a) The students discard their solution and learn the one presented by me
(b) The students try to figure out how my solution differs from theirs

18. How well students do on physics exams depends on how well they can:
(a) recall material in the way it was presented in class
(b) solve problems that are somewhat different from ones they have seen before

19. To me, physics is important as a source of:
(a) factual information about the natural world
(b) ways of thinking about the natural world

20. The laws of physics are:
(a) inherent in the nature of things and independent of how humans think
(b) invented by physicists to organize their knowledge about the natural world



21. The laws of physics portray the real world:
(a) exactly the way it is
(b) by approximation

22. Physicists use mathematics as:
(a) a tool for analyzing and communicating their ideas
(b) a source of factual knowledge about the natural world

23. Scientific findings about the natural world are:
(a) dependent on current scientific knowledge
(b) accidental, depending on scientists' luck.

Section B
Please answer each of the following questions by choosing one of the alternatives:

1. **How often do you discuss with your students how they should go about using their physics textbook for study?**
   More than once a week About once a week About once a month Seldom Never

2. **How often do you discuss with your students how they should go about solving homework problems on their own?**
   More than once a week About once a week About once a month Seldom Never

3. **How often do you discuss in class misconceptions that students typically have about real world systems and phenomena?**
   More than once a week About once a week About once a month Seldom Never

4. **How often do you discuss in class mistakes that students make in their homework?**
   More than once a week About once a week About once a month Seldom Never

5. **How often do you discuss in class mistakes that students make in their exams?**
   More than once a week About once a week About once a month Seldom Never

6. **How often do you get students engaged in laboratory activities at school?**
   More than once a week About once a week About once a month Seldom Never

7. **How often do you assign experiments or other practical activities for students to do at home?**
   More than once a week About once a week About once a month Seldom Never

8. **How often do you discuss the applications of physics in everyday life with your students?**
   More than once a week About once a week About once a month Seldom Never

9. **How often do you discuss with your students the relation of physics to other scientific disciplines?**
   More than once a week About once a week About once a month Seldom Never

10. **How often do you discuss with your students the relation of physics to technology?**
    More than once a week About once a week About once a month Seldom Never

11. **How often do you discuss with your students the nature of scientific laws?**
    More than once a week About once a week About once a month Seldom Never

12. **How often do you discuss with your students the nature of scientific thinking?**
    More than once a week About once a week About once a month Seldom Never

13. **How often do you discuss with your students the role of mathematics in physics?**
    More than once a week About once a week About once a month Seldom Never

Section C- General Information

Please answer each of the following 13 questions by choosing the provided alternatives.

1. **I am a/an**
   Instructor
   Associate Professor
   Assistant Professor
   Full Professor
   Teaching Assistant
   Research Assistant

2. **Gender** Female Male

3. **Ethnicity** African-American Asian White (Non-Hispanic) Hispanic

4. **I have been teaching at the college level:** 0-4 years 5-10 years 11-20 years >20 years

5. **What areas of research are you currently pursuing?**

Astrophysics	Geophysics	Nuclear	Physics Education
Atomic	Nanoscale	Optics	Mathematical
Biophysics	Molecular	Particle	Theoretical

Computational Physics Materials/Applied Physics

*If you answered "Other" for question number 5 above, please type your answer in the following blank:*_____

6. I teach, on average _____ courses per semester

7. I teach primarily
Conceptual introductory physics Algebra-based introductory physics
Calculus-based physics courses Advanced undergraduate physics courses
Graduate physics courses

8. Check all that apply. This course:
enrolls science and math majors only
is required students from a variety of majors
is required of secondary education majors
is required of all majors

9. The average percentage of students who initially enroll and successfully complete this course (earns a grade of C or above) is as follows:
>90% 80-90% 70-79% 60-69% 50-59% 40-49% 30-39% <30%

10. Who is typically in charge of your class?
I am
Someone else (Professor, staff member, teaching assistant, etc)

11. What type(s) of special assistance are offered to the students taking introductory physics?
Recitation/Discussion Session Tutorial Sessions Problem-solving Session
No Special Session

12. Please indicate the importance of the following items in the laboratory sections for students in introductory physics at NC State:
Verify physical principles
Unimportant Slightly Important Somewhat Important Important

13. Learn to use experimental tools
Unimportant Slightly Important Somewhat Important Important

14. Build conceptual knowledge
Unimportant Slightly Important Somewhat Important Important

15. Develop scientific reasoning
Unimportant Slightly Important Somewhat Important Important

16. Improve problem-solving skills
Unimportant Slightly Important Somewhat Important Important

If you are interested in participating in the interview, please enter your email below:

_____

APPENDIX C-MODIFIED CLASSROOM OBSERVATION PROTOCOL

NC STATE UNIVERSITY

# of Students: _____ Start Time: _____ End Time: _____ Observation # _____

Introduction Emphasis

	Rating	Comments
a. Provides overview		
b. Relates lesson to previous lessons/activities		
c. Assesses prior knowledge		

Scale: 3 - Clearly communicates all ideas and required information
2 - Communicates most ideas and required information (some ideas or information may be missing or not clear)
1 - Communicates only some ideas and required information (most ideas or information is missing, unclear, incomplete)
0 - Does not exhibit behavior

Modes of instruction	Rating	Comments
a. Whole class instruction		
b. Hands-on activities		
c. Lecture or recitation		
d. Drill and practice		
e. Reading textbook		
f. Teacher demonstration		
g. Small group discussion		
h. Cooperative group work		
i. Individual seat work		
j. Open ended inquiry		
k. Data collection and/or manipulation		
l. Note-taking		
m. Homework/class work review/correction		
n. Group presentation		
o. Notebook entry or log		

Scale: 3 - Evident - Very effective
2 - Evident - Somewhat effective
1 - Evident - Not effective or inappropriate
0 - Not evident

Questions	Rating	Comments
a. Knowledge, Comprehension (procedural, rhetorical, recall, recognition, factual)		
b. Application, Synthesis, Analysis, Evaluation (compare, contrast, associate, evaluate, apply, expand, consider - what if)		
c. Feeling (affective)		

Scale: 3 - Many questions 2 - Some questions 1 - Few questions 0 - No questions

Teacher Behavior	Rating	Comments
a. Explains activity-Gives concise, sequential directions to guide activity		
b. Circulates among students/ student groups asking questions		
c. Emphasizes relations to real life		
d. Uses ongoing embedded assessment		
e. Uses appropriate classroom management techniques		

Scale: 3 - Does well 2 - Does somewhat 1 - Does not do well 0 - Does not do at all

Materials Used Present? Evidence	Present?	Comments
a. Printed reading materials (books, articles, stories, etc.)		
b. Computer or computer technology		
c. Overhead projector, LCD projector		
d. Chalkboard, white board, chart tablet		
e. Videos, films, music		
f. Demonstration models		
g. Manipulatives (hands-on materials or equipment)		
h. Worksheets		
i. Science notebooks		

Classroom Observation Protocol
Project Inquiry
Definitions and Explanations for Observers

Introduction Emphasis - How a teacher introduces the lesson (could be 5-20 min)

a. **Provides overview**
Gives students an appropriate overview of what they need to get started with the lesson/activity

b. **Relates lesson to previous lesson/activity**
Relates to what students learned previously

c. **Assesses prior knowledge**
Asks students what they already know and understand about the lesson or activity's topic; also adjust lesson if needed

Modes of Instruction - What teacher directs students to do

a. Whole class instruction
Discusses topic/concept/principle; not introduction to an activity unless a discussion about what they already know and their experiences

b. Hands-on activities
Using manipulatives (including laboratory equipment) to explore, observe, collect data about a concept

c. Lecture or recitation
Teacher talks, students listen and may take notes and students answer specific questions teacher asks that usually have one right answer

d. Drill and practice
Similar to recitation but could be seat work where students answer questions on paper; is still drill and practice if students work in groups

e. Reading textbook
Printed material is used to teach science concepts.

f. Teacher demonstration
Teacher uses manipulative and/or laboratory equipment to demonstrate a concept/principle.

g. Small group discussion
Students interact around some topic; may fill in worksheet or data sheet.

h. Cooperative group work
Students have specific tasks they do to collaborate with one another in completing an activity/project, etc.; may involve solving a problem and recording results on a data sheet.

i. Individual seat work
Students working alone on worksheets, kit templates, teacher provided questions, etc. The teacher may or may not circulate around the room interacting with students.

j. Open-ended inquiry
Students are engaged in designing and implementing their own investigation rather than just "doing."

k. Data collection and/or manipulation
Data can include numbers and/or collecting and compiling information in order to answer a question/address a problem. Can be written or oral.

l. Note-taking
Students are recording what they hear from their teacher; could be part of recitation also; if they just listen without taking notes, identify that as "Lecture or recitation."

m. Homework/Class work review/correction
Anything to do with going over homework or class work in class

n. Group presentation
Students provide new information to others based on project/activity/research or use evidence from the project/activity (data) to support what they say.

o. Notebook entry or log - Students write reflections, record data, etc. or even draw pictures as a form of recording data in science notebooks they keep for science.

Questions

a. Knowledge, Comprehension - Low level questions in Bloom's taxonomy; includes non-instructional procedural and rhetorical (e.g., "Does everyone understand what they are supposed to do?") and input (recall, recognition, factual, e.g., "What type of rocks results from cooled magma?")

b. Application, Synthesis, Analysis, Evaluation - High level questions in Bloom's taxonomy; includes process questions (compare contrast, associate, e.g., "What kind of beak might a carnivorous bird have? Why?") and output (evaluate, apply, expand,

consider - what if, e.g., "If you build a house on a barrier beach, what biological and physical factors should you consider in order for it to be of minimal environmental impact?")

c. Feeling (affective) - e.g., "How do you feel about keeping public lands for natural habitats given the need for housing?"

APPENDIX D- INTERVIEW QUESTIONS

I appreciate your letting me observe your class. I have some questions I'd like to ask you related to the nature of science and your instructional practices. Would you mind if I taped the interview? It will help me stay focused on our conversation and it will ensure I have an accurate record of what we discussed. I will ask you the some questions that you may have seen before then I will ask you five open-ended questions about science and teaching science.

Teacher Practice Index
Please respond with: More than once a week About once a week About once a month
Seldom Never Feel free to elaborate on your response.

1. **How often do you discuss with your students how they should go about using their physics textbook for study?**

2. **How often do you discuss with your students how they should go about solving homework problems on their own?**

3. **How often do you discuss in class misconceptions that students typically have about real world systems and phenomena?**

4. **How often do you discuss mistake that students make on their homework in class?**

5. **How often do you discuss mistakes that students make on their exams in class?**

6. **How often do you get students engaged in laboratory activities at school?**

7. **How often do you assign experiments or other practical activities for students to do at home?**

8. **How often do you discuss the applications of physics in everyday life with your classes?**

9. **How often do you discuss the applications of physics in everyday life with your students?**

10. **How often do you discuss with your students the relation of physics to other scientific students?**

11. **How often do you discuss with your students the physics to technology?**

12. **How often do you discuss with your students the nature of scientific laws?**

13. **How often do you discuss with your students the nature scientific thinking?**

14. **How often do you discuss with your students the role of mathematics in physics?**

Open-End Questions

15. What is science? What is physics in relation to the other sciences?

16. How should physics be taught to undergraduate taking introduction physics courses?

17. What do you try to accomplish in classes? What do you want your students to know as a result of taking your class?

18. Research by Becher and Trowler (2001) suggests that physicists function in their own culture. They have a set of norms and customs, gatekeepers, language and symbols. Do you believe that physicists function in a well defined system?

19. Do you think the physics department is ready to accept the new ch**a**llenges in diversifying the cultural and knowledge base with the inclusion of women in the field? How about minorities?

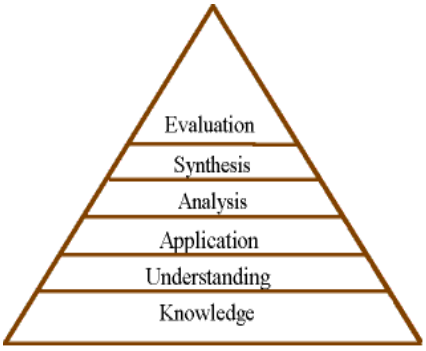
APPENDIX E-FLANDERS INTERACTION ANALYSIS SYSTEM

Flanders Interaction Analysis System

Teacher/Student/Other Behaviors Observed			Tallies	Anecdotal Notes
TEACHER TALK	IndAirect Influence	1. **Accepts Feeling:** Accepting and clarifying the feeling tone of students in a nonthreatening manner. Feelings may be positive or negative. Predicting or recalling feelings is included.		
		2. **Praises or Encourages:** Praising or encouraging student action or behavior. Jokes that release tension, but not at the expense of another individual; nodding head, saying "um hm?" or "go on" are included.		
		3. **Accepts or Uses ideas:** Clarifying, building, or developing ideas suggested by a student. As more of the teacher's own ideas come into play, shift to Category 5.		
		4. **Asks Questions:** Asking a question about content or procedure with the intent that a student answer.		
	Direct Influence	5. **Lectures:** Giving facts or opinions about content or procedures; expressing the teacher's own ideas, asking rhetorical questions.		
		6. **Gives Directions:** Giving directions, commands, or orders with which a student is expected to comply.		
		7. **Criticizes or Justifies Authority:** Making statements intended to change student behavior from unacceptable to acceptable pattern; bawling out someone; stating why the teacher is doing whathe/she is doing; extreme self-reference.		
Student Talk		8. **Responds:** Talk by students in response to teacher. Teacher initiates the contact or solicits student statement.		
		9. **Initiates:** Talk by students, which they initiate. If "calling on" students is only to indicate who may talk next, observer must decide whether student wanted to talk. If so, use this category.		
Silence		10. **Silence or Confusion:** Pauses, short periods of silence, and periods of confusion in which communication cannot be understood by the observer.		

Summary of categories for Flanders Interaction Analysis as adapted by S.J. Matthews, June 1995. Original source: Hopkins, W.S., & Moore, K.D. (1993). Clinical supervision: A practical guide to student teacher supervision. Madison, WI: Brown & Benchmark Publishers.

APPENDIX F-BLOOM'S TAXONOMY



- **KNOWLEDGE**
  - remembering;
  - memorizing;
  - recognizing;
  - recalling identification and
  - recall of information
    - Who, what, when, where, how ...?
    - Describe

- **COMPREHENSION**
  - interpreting;
  - translating from one medium to another;
  - describing in one's own words;
  - organization and selection of facts and ideas
    - Retell...

- **APPLICATION**
  - problem solving;
  - applying information to produce some result;
  - use of facts, rules and principles
    - How is...an example of...?
    - How is...related to...?
    - Why is...significant?

- **ANALYSIS**
  - subdividing something to show how it is put together;
  - finding the underlying structure of a communication;
  - identifying motives;
  - separation of a whole into component parts
    - What are the parts or features of...?
    - Classify...according to...
    - Outline/diagram...
    - How does...compare/contrast with...?
    - What evidence can you list for...?

- **SYNTHESIS**
  - creating a unique, original product that may be in verbal form or may be a physical object;
  - combination of ideas to form a new whole
    - What would you predict/infer from...?
    - What ideas can you add to...?

        - How would you create/design a new...?
        - What might happen if you combined...?
        - What solutions would you suggest for...?

- **EVALUATION**
    - making value decisions about issues;
    - resolving controversies or differences of opinion;
    - development of opinions, judgments or decisions
        - Do you agree...?
        - What do you think about...?
        - What is the most important...?
        - Place the following in order of priority...
        - How would you decide about...?
        - What criteria would you use to assess...?