THE IMPACT OF INSTRUCTOR INTENTION FOR STUDENT LEARNING AND

IMPLEMENTATON OF UNDERGRADUATE SCIENCE EDUCATON

REFORM ON STUDENT PERCEPTION OF THE

LEARNING ENVIRONMENT

by

ERIKA M. STEELE

DENNIS SUNAL, COMMITTEE CHAIRPERSON
BARBARA BURKE
JOHN DANTZLER
MARGARET JOHNSON
CRAIG SHWERY
CYNTHIA SUNAL

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ABSTRACT

The rapid advances in technology and scientific knowledge in modern society increase the need for a workforce with an understanding of technology and critical thinking skills. College graduates are entering the working world without the critical thinking skills and the ability to apply the scientific knowledge gained during their undergraduate experience (Casner-Lotto & Barrington, 2006). To prepare college graduate for the careers that they will have in the future, the current way science is taught has to be reformed. When examining the impact of reformed science teaching at the undergraduate level, the question of how students perceive their learning environment arises. To address this problem, this study examined the effects that varying levels of reformed science teaching used in the classroom had on students' perceptions of the learning environment.

The population for this study included 103 institutions that participated in the National Aeronautics and Space Administration's Opportunities for Visionary Academics (NOVA) Program. The NOVA program courses were developed by faculty teams as a part of professional development efforts for university faculty and administrators at 103 universities to work in collaborative teams to create and sustain reform in entry-level undergraduate science and mathematics courses. To determine the impact of reformed teaching on students, the National Study of Education in Undergraduate Science used surveys, interviews, and classroom observations to compare the NOVA reformed courses with similar courses that had not been reformed under the NOVA program. The study sample in this dissertation includes data from 9 of those institutions and 14 faculty members. The level of reform was measured using the *Reformed Teaching Observation Protocol*, and students' perceptions of the learning environment were determined using the *Constructivist Learning Environment Survey*. Quantitative results were corroborated with qualitative data from interviews of both the instructors and the students.

The level of reform found in the courses varied along a continuum from reformed to traditional instructor orientation, and this context significantly affected student perceptions of the learning environment. Results identified significant relationships between the level of reform implemented in the course and students' perceptions of the learning environment. The ways in which scientific ideas were communicated impacted students' perceptions of their ability to learn science. In the courses where students were given the opportunity to develop and communicate their ideas about scientific knowledge to other students and the instructor, the students perceived the learning environment more favorably. The students in these courses were more confident in their ability to learn and understand science. They also felt more confident in their ability to use their scientific knowledge in the future. Students in courses with little reform implanted in the classroom viewed the learning environment less favorably. They tended to feel the course content was irrelevant to their lives, and did not think they could and/or would use the course knowledge in their future careers.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Background

The scientific advances made in medicine, public health, computer science, engineering, and agricultural science make it imperative that all students understand science in order to make informed decisions about their lives, their careers, and their health. In 1996, a national working conference was held to discuss the state of undergraduate science education, goals for improving undergraduate science education, and the steps to achieve those goals (NSF, 1998a, 1998b). Participants discussed curricular and policy changes affecting science education at the undergraduate level and the role that colleges and universities play in the education system of the United States. Discussions from this meeting were published in a two-volume book titled *Shaping the Future*. Emphasized in both volumes of the book was science and technology's increasing importance as a part of people's daily and working lives. Corporations expect the college graduates they hire to have a basic understanding of how to use technology, how to apply scientific knowledge, and the ability think critically and creatively (NSF, 1998a, 1998b). Science research is becoming more cross-disciplinary, relying on knowledge from several fields of science as well as the social sciences for the planning of human resources in health sciences, agriculture, education, etc. (Hurd, 2000). Knowledge of the theories, methods, and tools used by scientist is not enough for college graduates to succeed in the problem-solving-oriented science industry of the 21st century (Hurd, 2000). Scientists and those working in the science industry are expected to be able to integrate their knowledge of the natural and social world in order to think creatively and to be able to develop new theories and hypotheses that can be used to solve modern problems (Hurd, 2000). Employers expect students with a Bachelor's degree in business to be able to demonstrate lifelong learning skills, communicate their thoughts verbally and in writing, think critically, and apply knowledge obtained in the classroom to real-life situations. The challenge of 21st century undergraduate science education reform is to create a curriculum that allows college graduates to develop problem solving and creative thinking skills in order to apply their scientific knowledge to solving real-world problems. Traditionally, science curricula focus on the past achievement of science; instead, science curricula should focus on how scientific knowledge is developed and used to create new knowledge that can be used to find resolutions to issues plaguing science and society such as disease control, nutrition, global warming, new energy sources, and understanding the universe (Hurd, 2000). Hurd suggested that it is not enough to use reformed teaching practices to teach science content that focuses on the past achievements of scientific research, instead, the science content should reflect science that is current and the ways in which it will continue to change in the future. Courses that focus solely on knowledge generated by past scientific achievement make science seem irrelevant and out of context with society and culture, regardless of how they are taught.

The need for workers with a Bachelor's degree is increasing and expected to continue to increase in the future (Lacey & Wright, 2009). Most of the growth in employment from 2008-2018 was projected to be in scientific and technical consulting, computer systems design, and health care (Lacey & Wright, 2009). The need for healthcare workers such as nurses and other professional staff in physicians' offices was expected to increase by 24% and 34%, respectively

(Lacey &Wright, 2009). Unskilled jobs in manufacturing and retail were expected to decrease. The need for office and administrative support jobs was expected to decline as the growth of computer usage increases (Lacey & Wright, 2009).

In April and May of 2006, The Conference Board, Corporate Voices for Working Families, the Partnership for 21st Century Skills, and the Society for Human Resource Management conducted an in-depth study of the corporate perspective on the readiness of new entrants into the U.S. workforce by level of educational attainment (Casner-Lotto & Barrington, 2006). A total of 425 participants were included in the study with representatives from manufacturing, government and education, business and professional services, finance, healthcare, and utilities and ranged in size from small companies (less than $100 million a year) to billion dollar industries. Employers participating in the study were asked whether they felt job applicants entering the workforce were being adequately prepared by their high school, 2-year, or 4-year college education. Participants reported their opinions on the content and skills that were important for applicants to obtain, how the importance of the content knowledge and skills was expected to change, and what emerging content areas were considered “most critical” over the next 5 years (Casner-Lotto & Barrington, 2006). After the ability to read and write in English, math and science were ranked as the highest basic content skills that employers participating in the study expected 4-year college graduates to have when entering the workforce. Math knowledge was ranked as very important by 64%, and science was ranked as very important by 33%. Other subjects, such as economics, government, and subjects in the humanities were rated as being very important by 20% or less of the participants. Over 90% of the participants ranked professionalism, oral and written communication, teamwork, problem solving, and critical thinking as being very important skills for entry-level job applicants with a

4-year college degree (Casner-Lotto & Barrington, 2006). Employers expect job applicants, especially those with a Bachelor's degree, to come to the job with the ability to think creatively and critically without constant input from their supervisors. The participants in the study expected college graduates to come to the job with the ability to apply their knowledge. The skills to use the knowledge obtained during the 4 years spent in college was rated as being more important than simply having the math and science knowledge to do the jobs. More than 70% of the employers ranked creativity, critical thinking, problem solving, collaboration, and information technology application as being of increasing importance in the future. The ability of college graduates to use their knowledge on the job is expected to increase in the future.

Science, mathematics, and foreign language content knowledge were ranked knowledge that would increase in importance in the future, but they were not rated as high as the ability to use the knowledge gained through obtaining a 4-year degree (Casner-Lotto & Barrington, 2006). Participants in the study felt that entry-level job applicants were underprepared to do to do the work for which they were needed. Less than 25% of the job applicants with 4-year degrees were rated as having an excellent preparation for entry-level jobs (Casner-Lotto & Barrington, 2006). People who obtain a 4-year degree should be prepared to excel at the jobs they apply for; yet a minority of the employers felt that college graduates have been prepared for the workforce. Participants rated the job applicants with 4-year degrees as being adequate in terms of content knowledge and the skills to apply and demonstrate that knowledge. If the ability to use mathematical and scientific knowledge is necessary to be considered an excellent candidate for jobs in the current and future workforce, it is necessary to reform undergraduate science courses so that graduates receive the education and preparation that they expect from obtaining a college degree. The college curriculum should be reformed in order to meet the needs of the modern workforce.

The passive learning environments prominent at colleges and universities do not give students the skills they need to use and to apply their science knowledge (NSF, 1996). The educational reforms discussed in *Shaping the Future* involved creating science experiences for undergraduate students beyond exposing them to more science content. The discussions in the meeting varied from creating living environments that would immerse the students in science experiences outside of the classroom to changes in the way courses are taught that involved implementing varying levels of inquiry-based pedagogies. Suggestions were made to switch from teacher-centered methodologies to student-centered methodologies in order to make science more relevant to all students, regardless of their major. The goal of movement from teacher-centered methodologies to student-centered methodologies was that college graduates would leave their undergraduate institutions with the ability to apply the science they learned in their classes to their careers or to use their understanding of science to make decisions about their lives as science literate citizens.

In order to produce college graduates capable of demonstrating an understanding of science and science related skills, the learning environments in colleges and universities will have to be designed to allow students to do science instead of having science taught to them (Siebert & McIntosh, 2001). At the university level, standards that indicate what a college graduate with a degree in a STEM field or what a student taking a science core course should know do not exist. The National Science Education Standards (NSES) designed for pre-college students could serve as a starting point when considering science education reform at the undergraduate level. The NSES are set to provide benchmarks in order to improve science education to ensure that all students graduating from the United States' K-12 school systems receive adequate education to become scientifically literate. The NSES not only sets standards for the content that students should be exposed to, but they also suggest the science literacy and problem-solving skills that students should acquire as a result of experiencing K-12 science. *College Pathways*, edited by Seibert and McIntosh, suggested how the NSES areas could be used to improve science education in higher education. Included in these areas were science teaching, professional development, learning environments, and content.

Two sections of the national standards deal specifically with learning environments, Standards D and E. The standards written by the NSES stressed that science instruction should emphasize the development of science inquiry skills over memorization of facts (NRC, 2011). One of the steps in accomplishing scientific literacy for all citizens has been allowing students to experience science in learning environments that promote sustained inquiry and scientific understanding about the world around them (NRC, 2011). Inquiry-based science teaching requires creating a learning environment that allows students to confront new ideas, deepen their understandings of scientific phenomenon, and learn to think logically and critically to develop hypotheses and scientific explanations based on evidence (Olson & Loucks-Horsely, 2000).

The National Science Education Standards Section D recommends that science teachers create learning environments that (1) structure the time available so that students are able to engage in extended investigations; (2) create a setting for student work that is flexible and supportive of science inquiry; (3) ensure a safe working environment; (4) make the available science tools, materials, media, and technological resources accessible to students; (5) identify and use resources outside the school; and (6) engage students in designing the learning environment (NRC, 2011; Olson & Loucks-Horsely, 2000, Siebert & McIntosh, 2001). Students should be given the time and opportunity to investigate scientific questions in ways that allow them to apply scientific knowledge in a meaningful way. Inquiry skills have to be developed over time in order to produce graduates capable of using science inquiry skills. Students must be provided with opportunities to do so early in their careers as students. Traditional lectures with laboratory exercises meant to confirm the material learned in lecture do not provide students with the skills necessary to think critically, creatively, and scientifically. This has been reinforced in 2011 through the introduction of the framework for the common core, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, Committee on Conceptual Framework for the New K-12 Science Education Standards,* designed to replace the NSES. Fewer concepts and greater depth of inquiry is recommended (NRC, 2011). In addition, as suggested by Hurd (2000), it may not be enough to simply change the way science is taught. The goals of science teaching may need to be changed from focusing on science content to the development of science inquiry skills (Hurd, 2000).

Learning environments that provide students with the opportunity to learn science by doing science, as opposed to having science taught to them, have the following characteristics as described in NSES Teaching Standard E: (1) displaying and demanding respect for the diverse ideas, skills, and experiences of all students; (2) enabling students to have a significant voice in decisions about the content and context of their work and requiring students to take responsibility for the learning of all members of the community; (3) nurturing collaboration among students; (4) structuring and facilitating ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse; and (5) modeling and emphasizing the skills, attitudes, and values of scientific inquiry (NRC, 2011; Olson & Loucks-Horsely, 2000, Siebert & McIntosh, 2001). Teaching Standard E was written to encourage teachers to develop learning communities where students are able to use their strengths and weakness to build better understandings of course content (Siebert & McIntosh, 2001). The learning environment experienced by college students should allow students to use and improve their own creativity and critical thinking skills as well as provide a better understanding of scientific knowledge that they can apply in other areas of their lives.

The 3-P Model of learning was proposed by Biggs (1989). The premise of this model is that learning is the result of the interaction of classroom context and characteristics found in individual students and instructors. The classroom context set up by instructors encourages students to develop various approaches to learning. The factors contributing to the 3-P model were called presage, process, and product factors. Presage factors included student and teaching contexts. Included in student context was prior knowledge of course content and conceptions of course materials, beliefs about teaching and learning, learning style, and abilities. Teaching context was described as characteristics associated with the course instructor, including teaching methods, beliefs about teaching and student learning, and course and departmental structures. Process factors are the result of the interaction between teaching context and student context. Process factors affect students' perceptions of the learning environment and students' approaches to learning or interactions with the course content. Product factors are the final outcome of student learning such as grades, the ability to apply knowledge, or other goals determined by the instructor.

Traditional university science courses tend to produce surface approaches to learning in students, which, in turn, results in low-level learning of science (Entwistle & Entwistle, 2003; Kreber, 2003; Lizzio, Wilson, & Simmons, 2002). Methods that are student centered have mixed results in that they do not always produce a deeper approach to learning by students (Trigwell, Prosser, & Waterhouse, 1999). Results found by Trigwell et al. (1999) may be problematic in promoting the need for and efficacy of science education reforms unless it is taken into account the fact that students tend to perceive these learning environments less favorably (Henige, 2011; Lake, 2001). They enjoy doing science, but they do not think they are learning science in these environments. Instructors who use these teaching methods may be rated as lower because students do not perceive their instructional methods as teaching (Lake, 2001). As critical thinking skills and the ability to apply knowledge to new context are becoming increasingly important for students leaving 4-year universities and entering the workforce, understanding the behaviors that lead to students perceiving the learning environment as being favorable for developing these skills is important. Understanding how learning environments impact students' perceptions of teaching and learning and ultimately the knowledge they gain from instruction will provide further evidence for the reason behind the successes and failures of efforts made to improve science education at the undergraduate level.

If student learning at the undergraduate level is going to prepare college graduates to meet the needs of today's workforce, the science education experienced by undergraduates has to be revised. To do so, we must start by developing a realistic picture of undergraduate science education in its current state. This picture involves focusing not only on the content being taught in the college, but on the instructors who teach college science courses, and the perceptions of the students participating in the learning. If students do not believe that developing inquiry and critical thinking skills are learning, resistance to science education reform will continue to persist.

Problem

Student learning occurs as a result of several factors such as student thinking ability, student preconceptions, instructors' beliefs about teaching and learning, and the type of instruction used in the classroom (Biggs, Kember, & Leung, 2001). Research indicated a relationship between what an instructor did in the classroom and the study habits that students adopt (Trigwell et al., 1999). When an instructor used instructional methods that were considered to be teacher-centered or an information transmission approach toward teaching, students approached learning by memorizing the course content. A relationship between student-centered instructional methodologies and students learning the course content for understanding was not found in research conducted by Trigwell et al. (1999). The lack of relationship found may have been due to the fact that the participants described their teaching using a survey-type instrument. The participants were not interviewed nor were their classes observed. It was possible that several of the instructors who indicated that they used student-centered approaches to teaching were not using student-centered techniques in their classes. Kane, Sandretto, and Heath (2002) reviewed the literature that had been written on teacher beliefs at the tertiary level and found it to be lacking in number, and cited various flaws in the methodology used by the researchers. In this review, a criticism of science education researchers for making connections between what a teachers believe about teaching and what they do in the classroom when there was no evidence of the teaching practices of the participants. For example, the Kane, Sandretto and Heath stated that many researchers did not examine what the teacher actually did in the classroom, but based their results on surveys and interviews. In research studies where classroom observations were made or where the author described changes in their own teaching, a relationship between student performance and what an instructor does in the classroom was found (Wright et al, 1998; Lake, 2001, Beichner, 2008).

Research also indicates a relationship between students' perceptions of the learning environment and their performance in the course (Trigwell et al., 1999). Students who perceive the course favorably tend to take a deeper approach to learning than students who perceive the learning as being unfavorable and who often took a surface approach to learning the course content (Entwistle & Entwistle, 2003. However, a study by Henige (2011) indicated that students have the tendency to perceive coursework with high levels of reform unfavorably. The same phenomenon has been noted by others (Lake, 2001). The students participating in research conducted by Henige (2011) indicated that they perceived they had learned less using problem-based learning even though the data collected by the researcher indicated otherwise. Other studies also found that students enrolled in active learning courses, whether they perceived the learning environment as favorable or unfavorable, believed they learned less in the more reformed sections of the course (Lake, 2001). The students participating in more reformed courses felt that the instructor was not teaching and they were not learning. The students participating in these studies had preferences for traditional teaching and learning that may have stemmed from years of teaching experience in high school and/or college (Henige, 2006). Developing an understanding of the aspects of the learning environment in reformed classes that students find favorable or unfavorable will provide information to help improve faculty development in creating reformed courses in which students perceive the teaching and learning favorably. Helping students change their perception of what teaching and learning mean may help improve science instructors' ability to implement reforms.

Studies in the literature that indicate an improvement in student learning using reformed teaching strategies sometimes only examine student outcomes (Christianson & Fisher, 1999; Lake, 2001). The knowledge, skills, and beliefs of the instructors had some influence on the improvement in student learning. Whether the effort to implement the science education reform was successful or not, it is important to know the context occurring within the learning environment that lead to the reported student outcomes. Learning environments are complex; in order to understand the impact that science education reform has on students' perceptions of the learning environment, the context in which student learning occurs should be examined from several aspects to determine how students, instructors, and course content interact in order to create a successful learning environment. If undergraduate science education is to be reformed, it has to be done in a way that results in students developing the skills they need and that allow the students to value their experiences so that they will approach learning science in a more in depth manner. In order to provide undergraduates with the science knowledge they need to be prepared for the workforce, the interactions between students, instructor, and course content in the learning environment must be better understood.

Significance of Problem

Because of the rapid advances in technology and scientific knowledge that have direct impacts on our daily lives, there is an increasing need for professionals with high technology and critical thinking skills; therefore, students leaving college have an increased need to be science literate. While there have been some changes in the way science is taught, in most cases the science taught at universities and colleges in the United States do not prepare all students to function in a world, and in careers, where science plays a central role (Casner-Lotto &

Barrington, 2006). College graduates are entering the working world without the critical thinking skills and ability to apply the scientific knowledge gained during their undergraduate experience. Most instructors teaching science do not take teacher preparation courses on how students learn, curriculum development, or effective pedagogical strategies nor do they usually receive professional development later on these topics (Seymour, 2002). Kreber (2005) stated that science instructors developed their teaching practices based on what they experience as students and then make changes to their teaching based on their personal experiences as instructors in the classroom. Very few instructors in the field use research-based literature to inform their teaching (Kreber, 2005). In order to create professional development programs to help improve the teaching of science faculty, we must understand how the dynamics within a classroom interact in order to create student learning. In addition to understanding what instructors do in the classroom that leads to favorable student outcomes, it is imperative to understand the beliefs that students bring to the classroom. Student beliefs that they are not learning and the instructor is not teaching are detrimental to even the most successful implementation of science education reform. The learning environment needs to be examined for factors that allow students to perceive reformed teaching methods as conducive to their learning.

Need for the Study

The literature on reform in science teaching at the undergraduate level is full of examples of what needs to be done in order to meet the national educational goals (NRC, 2003, 2009; Seibert & McIntosh, 2001). The majority of the current research on learning environments at the college level concerns online learning environments (de Leng, Dolmans, Muijtjens, & van der Vleuten, 2006; Tu, 2002) and distance learning courses (Graham & Scarborough, 1999). A small number of reports and artiCLES deal with the learning experiences of students inside a physical classroom. The few that have been published in the last few years are largely based on quantitative data or interviews with students (Kreber, 2003; Partin, 2008). Classroom observations were not made (Kreber, 2003; Partin, 2008), and student outcomes were often reported based on students' grades (Partin, 2008). The students were generally not given a standardized test to show that they were able to develop a deeper understanding of the science content (Kreber, 2003; Partin, 2008). In order to determine the impact the classroom environment has on students, the factors in the environment that influence student learning should be identified, and students' accounts of the learning environment should be triangulated with the instructors' account and classroom observations.

Research Questions

This study addressed how variations in the level of reform implemented in the classroom impacted students' perceptions of the learning environment in the classroom by addressing the following research questions:

1. At what level of implemented instructional reform do students notice the learning environment as being different?

2. Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?

3. What aspects of instructional reform are most associated with students perceiving the learning environment as different?

4. Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?

Overview of Research Design

This study investigated aspects of reformed undergraduate science courses that are correlated with students' perceptions of the learning environment. It also attempted to determine which factors in the learning environment were most highly correlated to positive perceptions of the learning environment. The data used were secondary data obtained from a larger set of data collected as a result of a current national study of undergraduate science. This study included both qualitative and quantitative measures on the instructor's teaching practice. The quantitative and qualitative measures were triangulated with multiple observations of classroom instruction. The classroom environment was described from the students', instructors', and observers' point of view.

The current study was both quantitative and qualitative in design. Concurrent triangulation of mixed methods design (Rauscher & Greenfield, 2009; Wengraf, 2001) was utilized to analyze the relationship between instructional reform and how students perceive the learning environment. Further, the relationship between what an instructor does in the classroom and what students think about their abilities to learn science was investigated.

Students' perceptions of and preferences for the learning environment was determined using the *Constructivist Learning Environment Survey* which asked the students to rate their preference or perception of the learning environment. In particular, the instrument measured the amount of constructivist instructional methodologies that were preferred or perceived by the student participants. Student satisfaction with the learning environment was determined by comparing the preferred and perceived versions of the instruments. Dissatisfaction with the learning environment as measured by the instrument was indicated by significantly higher scores on the preferred version. Exceeding student expectations was indicated by significantly lower scores on the perceived version of the instrument. These data provided a quantitative account that can be used to measure the impact that teaching style and level of classroom pedagogical reform have on students' perceptions of the learning environment.

Focus group interview data were used to provide triangulation for differences in perception of the learning environment.

Student perception of the learning environment was believed to be impacted by the amount of instructional reform implemented in the classroom. The *Reformed Teaching Observation Protocol* (*RTOP*) was used to determine the level of instructional reform implemented in the classroom. Once the level of reform necessary to be implemented for students to perceive differences in the learning environment was determined, the beliefs that the instructors held about teaching and learning were compared. Differences between the way their students thought about the learning environment and learning science were compared and a relationship between students' perception of the learning environment.

Operational Definitions of Terms

Aspects of reform: Aspects of reform include but is not limited to the following: (1) course design, for example an integrated lab and lecture (McIssaac & Falconer, 2004). (2) Instructional techniques that are designed to be student centered in order to allow the student to become more responsible for their own learning such inquiry based and problem based learning (Seibert & McIntosh, 2001). (3) Professional development designed to help instructors approaching teaching in a way that is more in line with current science education *research, and* (4) the formation of collaborative relationships in order to develop and maintain science education reform once it has been implemented.

Classroom learning environment: A place real or virtual where learning occurs.

Learning environment: Using the 3-P Model developed by John Biggs (Biggs, 1989), the learning environment is a result of 3 factors (1) factors that are inherit to the perceptions and beliefs of the student and instructors participating or presage, (2) events occurring during instruction, or process factors, and (3) the end results of the interactions between presage and process factors, or the product.

Level of instructional reform: The level of instructional reform is a measure of how different a course is from a traditionally taught college science course. The level of instructional reform was determined by scores on the *RTOP* (McIssaac & Falconer, 2004). McIssaac and Falconer (2004) defined a reformed course as one that received a score of 50 or above on the *Reformed Teaching Observation Protocol*.

Student satisfaction: Satisfaction with the learning environment as measured by *Classroom Learning Environment Survey* was indicated by scores on the perceived version being not statistically different from or higher than the preferred version of the *Classroom Learning Environment Survey* indicating that the students preferences for learning science were admit or exceeded by what they perceived happening in the classroom.

Teacher beliefs: The ideas and reasons that instructors use to justify their teaching methods.

Instructor: the person in the learning environment charged with planning the learning, in this study, the person teaching was a person who taught a university level science course.

Student: the person or people in the learning environment responsible for learning.

Secondary data: data collected by another source other than the author.

Student learning outcomes: The change that experiencing classroom instruction produces in students. Learning outcomes can either be on the surface where the student elects to

Teaching style: The instructional methods chosen by the teacher in order to best get students to learn. Teaching style can focus on what the student is, what the teacher does, or what the student does. (Biggs, 1999)

Reformed undergraduate science course: A course that incorporates one or more strategies designed to allow students to develop their own understanding of scientific concepts through inquiry and critical thinking (Seibert & McIntosh, 2001).

Traditional undergraduate science course: Courses in the person which the majority of the communicating of ideas comes from the instructor through lecture.

Student approach to learning: The method in which students choose to approach learning the course material. The students can choose an in-depth or surface approach.

Process factors: the actions that an instructor takes in the classroom

Product factors: outcomes resulting from the process factors. These may be student learning or an instructors decision to change the way the teach.

Presage factors: characteristics that exist in the teacher, instructor, or learning environment prior to the beginning of instruction. These include beliefs and attitudes held by the instructor or students.

Assumptions

It was assumed that beliefs about teaching and student learning can be captured, documented, and compared. It was assumed that the participants in this study's were open and honest about reports of classroom context, teaching practices, beliefs about teaching and student learning. It was assumed that students' perceptions of the learning environment could be captured, documented, and compared. It was assumed that student participants in this study were honest and open on their surveys and during their interviews.

Limitations

One of the limitations in research on instructors' beliefs about teaching and learning is that it was difficult to capture a person's thoughts. The researcher had to make assumptions about the intentions and actions of the person being researched. These assumptions were affected by the researcher's own experiences and biases. Information obtained during interviews with instructors was dependent on the skills of the researcher's and instructor's reasoning about each strategy questioned during the interview (Friedrichsen & Dana, 2003).

Attrition was also a limitation to the study. Due to the sample size, outliers in the sample have the potential to influence the results. The small sample size may have limited the generalizability of the findings from the study.

The instructors were observed for a one-week period. This short observation period only allowed the observation of a few science concepts to be addressed during a complete course. The instructor's method of teaching different concepts in the course may vary and this variation may have affected scores on instruments designed to measure the level of reform used in the classroom.

It is difficult to capture everything an instructor does that is relevant in the classroom to what may be perceived as important to the students. It is also challenging to capture beliefs about teaching and learning an instructor may have that could impact their instructional methods. Other aspects not examined in this study or not captured during on-site visits may have been factors determining how an instructor teaches that impacted how students learn. The researchers were outside observers; they were unaware of the cultural contexts of the classrooms they visited. When making observations of classroom occurrences, bias based on their own experiences may have potentially influenced interpretation of events that occurred in the classroom. Even when the instructor being observed explained events, those events may have been subject to misinterpretation; bias still had the potential to influence the researcher's analysis.

The study was not experimental in design. Student outcome may have been influenced by factors not studied or controlled for in the original study for which the data were collected. Interviews collected from the students were subject to the same limitations as interviews from the instructor. Moreover, student interviews were conducted as focus groups. Students who did not agree with the consensus may not have felt comfortable voicing their opinion.

Students' perceptions of the learning environment were measured using an instrument with a Likert-type scale. The use of a survey with a Likert-type scale constrains the study in two ways: (1) the instrument may have included measures that the students did not perceive as being important, while missing those that students saw as being important, and (2) measuring perceptions using discrete choices may have been too constraining (Richardson, 1996). Instruments and interview questions selected by the researcher not only limit the data that are collected, but they add a bias toward the researcher's views and beliefs.

CHAPTER 2

LITERATURE REVIEW

Introduction

In view of recent efforts to reform undergraduate science, this study investigates the impact that teaching style and level of reform have on students' perceptions of the learning environment. This chapter addressed the following areas: (1) science education policy, (2) science reform in higher education, (3) reformed and traditional science teaching in higher education, (4) and learning environments.

Science Education Policy

A Nation at Risk: the Imperative for Educational Reform, published by the National Commission on Excellence in Education in 1983, reported on the quality of the education system in United States, and offered ways in which the identified problems could have been resolved. The concerns with the education system at the time *A Nation at Risk* was written were similar to the concerns we have presently. The education system seemed to be failing to prepare students to compete in a global market that was becoming increasingly more technological and scientific. Standardized test scores were declining, students in the United States did not do as well on standardized tests as students in other industrialized nations, and students were leaving high school ill-prepared for the workforce, military, or college. Moreover, the tested achievement of students graduating from college was on the decline. To remedy the deficiencies of students graduating from high school and universities, it was suggested that the amount of math and science courses taken by high school students be increased. It was also suggested that education majors should focus less on methods courses and more on subject courses, especially those students who intended to teach math or science.

Current reports of the preparedness of graduates from 4-year colleges and universities indicate that students are still leaving college without the skills they need for the workforce (Casner-Lotto & Barrington, 2006; Deboer, 2011). The Conference Board, Corporate Voices for Working Families, the Partnership for 21st Century Skills, and the Society for Human Resource Management used surveys and interviews from 425 employers in the United States to gather data about opinions of the workforce readiness of graduates from high school, 2-year postsecondary institutions, and 4-year postsecondary institutions (Casner-Lotto & Barrington, 2006). The participants were businesses and corporations that employed 500 or more people and were classified as small, grossing less than $100 million a year; mid-market, grossing between $100 million and $1 billion a year; and large, grossing over $1 billion a year. The participants invited to participate were corporations of various sizes throughout the United States. The identities of these corporations were not revealed but they came from various areas including manufacturing, healthcare, energy, and utilities. Participants were given the option to take the survey online or fill out a paper version in which they were asked to rate the importance of 20 areas of basic knowledge and applied skills; the readiness of high school, 2-year college, and 4-year college graduates on each of these skills; and whether the 20 areas were expected to increase or decrease in importance within 5 years. The data from the surveys and interviews were used to create a qualitative analysis of how well-prepared graduates from the United States' high schools and colleges are for current jobs on the market (Casner-Lotto & Barrington, 2006). Four questions were investigated: (1) What are the skill levels that new entrants are currently bringing to their jobs deemed *excellent*, *adequate*, or *deficient*; (2) applied skills they consider *very important*, *important*, or *not important*. Basic knowledge refers to the academic subjects and skills acquired in school, (3) which skills were considered *most critical* over the next five years, and (4) what are the nature and costs of remedial training or initiatives, if basic skills are lacking. The basic knowledge skills were created from core academic subjects as identified by the No Child Left Behind Act. They included reading comprehension, English writing skills, English language skills (spoken), science, and mathematics. Applied skills were defined as the cognitive and social ability to use basic knowledge skills in the workforce. The classification and definition of these skills were obtained from a framework created by The Partnership for 21st Century Skills. These skills included creativity, the ability to do self-directed work, problem-solving skills, the ability to work collaboratively with others, and oral and written communication skills. The survey was not included in the report. In addition to the survey, 12 participants were interviewed to provide further insight into the survey reports. The interview participants were selected so that businesses of different sizes and types were represented.

Results from the survey revealed that employers felt that applied skills were more important than basic knowledge skills in particular for job applicants with a 4-year degree (Casner-Lotto & Barrington, 2006). Employers expect that the applicants with 4-year degrees who they hire should be able to use the knowledge they obtained in the courses they took, be able use that knowledge to collaborate with others, think creatively to solve problems, communicate their ideas through speech and writing, and function independently without input from a superior. The participants expected that these abilities were going to become increasingly important characteristics of job applicants in the future. More than 80% of respondents viewed writing and oral communication as being very important. Science and math were seen as important basic knowledge skills for job applicants to possess. Science and math were ranked as being very important by 1/3 and 2/3 of the respondents, respectively, while less than 1/4 of the respondents viewed basic skills in economics, government, or history as being important. Applied skills were rated as being more important than basic knowledge skills. The five most frequently reported applied skills for 4-year college graduates to have when entering the workforce were (1) oral communications, (2) teamwork/collaboration, (3) professionalism/work ethic, (4) written communication, and (5) critical thinking/problem solving.

> At the college level, students are acquiring great theoretical knowledge, but they're deficient when it comes to applying it--they're just not able to connect it to real life. One exception is medicine, which is hands-on. Even in engineering, with some notable exceptions, there has been all too little hands-on experience in design, build and innovate. (Bernie Trilling, Senior Director of Oracle Educational Foundation, as cited in Casner-Lotto & Barrington, 2006, p. 28)

Only 24% of participants felt that 4-year college graduates had the skills to be considered excellent job applicants. College graduates receiving degrees from 2-year colleges were ranked even lower, with only 10% being considered excellent job candidates. Very few job applicants with 4-year degrees were ranked above 27% in any of the important basic knowledge skills. Science and math were ranked 14% and 18%, respectively. Job applicants with 2-year degrees were ranked as being even weaker in their basic knowledge skills, with 6% or less being considered excellent in any of the basic knowledge skills considered as very important. Only 3% of job applicants with 2-year degrees were ranked as having excellent basic math and science skills. Less than 30% of the applicants with 4-year degrees were ranked as excellent in any of the top five applied skills. Graduates with 2-year college degrees were ranked even lower; less than 15% were ranked as excellent in any of the top five categories.

Research indicates that undergraduates attending colleges and universities in the United States are not being challenged academically. The learning environments found in college classrooms do not encourage the kinds of skills the employers view as being essential to being an excellent job applicant.   A longitudinal study of traditional-aged undergraduates from the fall of 2005 until the spring of 2009 at various 4-year colleges and universities throughout the nation was conducted to determine the kinds of educational and social experiences college students had while obtaining their Bachelor's degree (Arum, Roksa, and Cho, 2011). The Council to Aid Education conducted surveys and skills test throughout the 4 years of the study to determine how much the participants had learned during their undergraduate study. The sample included 2,322 college students who had valid demographic information and pre- and post-test scores. The students were selected from various types of institutions that included historically Black colleges and Hispanic-serving institutions located in various regions throughout the United States. The participants were selected such that the sample was representative of the college student population in terms of racial background, ethnicity, and social economic status.

The participants were given an initial survey, and follow-up surveys were given the Fall of 2007 and Spring of 2009, respectively (Arum et al., 2011). The survey was administered to question the students about their college experiences including the following: (1) work, (2) participation in extracurricular activities, and (3) time spent on academic obligations. The researchers also administered an instrument called the *Collegiate Learning Assessment* (*CLA*), which consisted of three sets of open-ended questions designed to measure critical thinking, analytical reasoning, and written communication skills using problems that required participants to perform a task, make an argument, and break an argument using real-world scenarios.

The *CLA* was selected over a multiple choice test measuring competencies in course content, in order to demonstrate the skills that students gained over their 4-year experiences in college (Arum & Roksa, 2011). The published research focused on the performance task portion of the *CLA,* which allowed the students 90 minutes to respond to a writing prompt associated with a set of background documents that they were able to access online. An example performance activity included the DynaTech problem, which can be found at http://www.cae.org/content/pro_collegiate_sample_ measures.htm:

> You are the assistant to Pat Williams, the president of DynaTech, a company that makes precision electronic instruments and navigational equipment. Sally Evans, a member of DynaTech's sales force, recommended that DynaTech buy a small private plane (a SwiftAir 23(5) that she and other members of the sales force could use to visit customers. Pat was about to approve the purchase when there was an accident involving a SwiftAir 235. You are provided with the following documentation:
> 1: Newspaper artiCLES about the accident
> 2: Federal Accident Report on in-flight breakups in single engine planes
> 3: Pat's e-mail to you & Sally's e-mail to Pat
> 4: Charts on SwiftAir's performance characteristics
> 5: Amateur Pilot article comparing SwiftAir 235 to similar planes
> 6: Pictures and description of SwiftAir Models 180 and 235
> Please prepare a memo that addresses several questions, including what data support or refute the claim that the type of wing on the SwiftAir 235 leads to more in-flight breakups, what other factors might have contributed to the accident and should be taken into account, and your overall recommendation about whether or not DynaTech should purchase the plane. (http://www.cae.org/content/pro_collegiate_sample_ measures.htm)

The students were scored on the following skills: (1) analytic reasoning and evaluation, (2) writing mechanics, (3) writing effectiveness, and (4) problem-solving skills. Analytic reasoning and evaluation was defined as the ability to interpret, analyze, and evaluate the quality of sources to identify information that is relevant to solving the problem. Writing effectiveness was described as the ability to construct, explain, and support arguments using evidence. Writing mechanics was described as the ability to write using Standard English. Problem-solving skills was described as considering information based on the source and making logical decisions, drawing conclusions, or deciding on a course of action. Each participant was scored using a 6-point rubric, described in detail here: http://www.collegiatelearningassessment.org/files/CLAScoringCriteria.pdf. The relationship between the score on the *CLA* and other measurements such as race and SES was investigated using a multivariate framework. Specifically, the researchers compared scores on the *CLA* between racial and ethnic groups, parental education, language, and whether or not the student attended a high school where the majority of students were minorities.

The results of this study were published in a book titled *Academically Adrift: Limited Learning on College Campuses* (Arum & Roksa, 2011) and a follow-up report published by the Social Science Research Council. Research conducted by the Council for Aid to Education (CAE) indicated that undergraduates participating in the study showed little improvement in their critical thinking, complex reasoning, and written communication as measured by the *CLA*. On average, the students only showed an improvement of 7 percentile points between their freshman and sophomore years. The impact of 4 years of college education barely had an impact (.18 standard deviation) on the participants' critical thinking, reasoning, and writing skills. Many of the participants (45%) showed no statistically significant gain in score on the *CLA* between their freshman and sophomore years.

Results from the *CLA* indicated that the students showed little improvement in problem solving, and creative and critical thinking skills between their freshman and sophomore years. Only a small portion of the participants (10%) showed significant gains on the *CLA*. This portion of the participants was able to succeed despite what was determined by the SES factors used to predict their post-test scores. This group of students prompted the question, "What experiences in college lead to student learning?"

In order for students to learn or make academic achievements during their college careers, students have to be engaged with coursework and the faculty teaching these courses (Arum & Roska, 2011). In order to get a better understanding of how college experiences differ among college students, participants were asked about their experiences with (1) interactions with their instructors, (2) interactions with peers in terms of academic success, (3) the amount of time outside of the classroom spent on studying or coursework, (4) courses taken, (5) grade point average (GPA), (6) social life, and (7) financial challenges. Student participants indicated a lack of challenge and rigor in their classes, they spent little time studying for their courses, and the majority of their time was spent socializing or working. The typical student participating in this study meets with faculty outside of the classroom only once per month, with 9% of the students stating they do not meet with faculty members at all outside of the classroom. Despite the fact the average GPA of the participants was a B-, the average student studied less than 2 hours a day. Half of the students (50%) had never taken a course that required them to write more than 20 pages, and 33% had never taken a course that required them to read more than 40 pages per week.

The academic culture at the institution had a bigger impact on students' interactions with their coursework and instructors than the SES factors investigated in the study. At institutions with high expectations for student achievement and increased faculty-student interactions, students spent more time on academic pursuits and higher achievement on the *CLA.* Students' who perceived their as instructors as having high expectations for their achievement scored 27 points higher on the *CLA* than students who perceived their instructors as having medium or low expectations for their achievement. Similarly, students who were challenged in their courses performed significantly better on the *CLA* than students who perceive their courses as being a medium or easy level of difficulty. The interactions that occurred in the classroom were more important than interactions with faculty outside the classroom in terms of impact on *CLA* score. The type of courses that the participants took impacted their scores on the *CLA.* Students majoring in the social sciences, math, and sciences scored better than students majoring in business and education. The authors postulated that this might have been due in part to the nature of the courses offered in the fields where students scored higher and the students scored lower. Students in STEM and the social sciences may be exposed to problem-solving skills in their classes earlier than students majoring in business or education. Students spent far more time on pursuits outside of the classroom than they did studying for their courses. Even students who had jobs spent an hour more socializing or doing volunteer work than they did studying. The time spent working and doing extracurricular activities distracts from the time spent studying and interacting with their course content. The study by Arum and Roska (2011) reported student learning results from the interaction between students and instructors in the classroom. Instructors can start by creating a learning environment that is challenging and encourages the students to interact with the course content beyond a surface level.

The *University of California Undergraduate Experience Survey* (*UCUES*) was used by Brint, Cantwell, and Saxena (2011) to compare the study behaviors and critical thinking skills of upper-division students across disciplines to determine differences in (1) study time, (2) academic conscientiousness, and (3) critical thinking. Academic conscientiousness was measured using a 5-item scale with items describing how the students interacted with the course material outside of the classroom. The academic conscientiousness scale had an alpha reliability of .72. Critical thinking was measured using a 9-item scale that measured the frequency that participants reported experiences with problem solving, analyzing data, etc. The critical thinking scale had an alpha reliability of .87. The scales were compared between the following areas of study: (1) engineering, (2) physical sciences, (3) life sciences, (4) social sciences, (5) humanities, and (6) arts. The data were analyzed using ordinary least square regression. The 16.000 participants were upper-division undergraduates who had attended any of the colleges in the University of California system, with the exception of the Merced campus.

The authors believed that the nature of social science and humanities would lead to increased critical and analytical thinking skills in students majoring in those fields. Research indicates that epistemological differences between the “soft” sciences, such as psychology, and the “hard” sciences, such as biology, lead to the development of different characteristics in students (Brint et al., 2011). Courses in “soft” sciences tend to be loosely structured intending to develop the students’ characters and critical thinking skills. Courses in the hard sciences tend to be tightly structured, based on factual information intending to prepare students for their careers. The types of assessments used in courses in hard and soft sciences require students to develop different skills. The soft sciences tend to emphasize creativity, writing skills, and analysis and synthesis of course materials in their assessment while the hard sciences tend to emphasize memorization of facts (Brint et al., 2011).

The researchers found that there was no difference in critical thinking skills in undergraduate students based on major. Results from the study indicated that students are not being challenged by their classes and that the majority of their time was spent on extracurricular activities (Brint et al., 2011). Though students in the sciences reported studying more hours and scored marginally higher on the academic conscientiousness scale than students in the social sciences and/or humanities they did not score significantly higher or lower on the critical thinking scale of the UCUES. This indicates that students in the “soft” sciences were not given more opportunities to use critical thinking, problem solving, or writing skills than students in the "hard" sciences as originally predicted. Of all the covariates investigated in the study, class participation had the biggest influence on the variation in scores on the scales of the UCUES. Students who reported participating in class more often studied more and had higher scores on the academic conscientiousness and critical thinking scales of the UCUES.

The critical thinking scale was measured by student self-reports, the students did not demonstrate their ability to use critical thinking skills, a relationship between critical thinking skills and the covariates investigated cannot be established (Brint et al., 2011). Moreover, without data on what actually occurred in the classroom, it is hard to determine whether the students were interpreting "problem solving" and "critical thinking" in the same way science education research does. What could be concluded from the findings is that class participation encouraged students to study and interact with the course materials outside of the classroom. Because there was also a relationship between class participation and increased reports of using critical thinking skills in the classroom, perhaps the increased use of activities that engage students in the lesson would encourage increased participation and increased student learning.

In order to provide students attending colleges and universities in the United States with an education that will develop the kinds of skills necessary for the modern workforce, undergraduate learning experiences need to be reformed (Arum & Roska, 2011; Arum et al., 2011; Brint et al., 2011; NRC, 2003; Siebert & McIntosh, 2001). Policy papers on undergraduate science education reform suggest a move from traditional science courses to science courses that encourage students to be more actively involved with the course content through the use of inquiry (NSF, 1996, 1998a, 1998b; Seibert & McIntosh, 2001). Inquiry is an instructional strategy that allows students to be engaged in science by doing science. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understandings. Inquiry is a learning goal that includes developing students' understandings about how to begin to gather, evaluate, analyze, and synthesize data in order to solve a problem. Teaching science using inquiry allows students to develop a better understanding of the nature of science because science is not taught as a set of facts and the focus of the course is not on the past accomplishments of scientists. Instead, students are allowed to see why science knowledge changes in response to new evidence, logical analysis, and modified explanations debated with a community of scientists by learning to use what they understand of the science content to solve problems (Hurd, 2000; NRC, 2003; Seibert & McIntosh, 2001). A reformed science course is a course that has been adapted to increase students' chances to practice using science inquiry skills in order to develop their ability to apply their scientific knowledge.

On April 9-11, 1995, a conference was held in Washington D.C., to begin to establish a common vision and common goals for undergraduate STEM education. Discussed at the conference were goals for undergraduate STEM education, how faculty could contribute to achieving the goals, and the role of institutions in meeting undergraduate STEM goals. The main recommendations that emerged from the conference were as follows: (1) all undergraduate students should have access to excellent STEM education, (2) institutions must support teaching in the same way that it supports research, (3) departments should establish and evaluate educational goals with the same rigor that they approach scientific research, (4) professional development and training of faculty should emphasize teaching as well as research, (5) articulation between educational institutions and education and the workplace should be established, and in order to sustain innovative teaching, and (6) institutions and departments should establish a cultural change that supports teaching.

The findings of the NSF's review of undergraduate STEM education were described in two reports: *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1998b) and its companion document, *Shaping the Future Volume II: Perspectives on Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1998b). The two volumes detailed the history of science reform that had occurred to date, examined the need for sustained and continued improvements in undergraduate STEM education, and future directions for undergraduate STEM. At the time the reports were written, the changing economy, demographic changes occurring in the United States, rapid increase in the production of scientific knowledge, and increasing technological advances provided incentive for change in higher education. The report indicated that the higher education system was unprepared to fulfill students' needs for STEM education. Student preparation, curricular and pedagogical problems, ineffective use of instructional technology, a system that did not reward teaching, inadequate course evaluation, lack of faculty development, and poor articulation between higher education, the K-12 education system, and employers were all indicated as barriers to improving undergraduate STEM education. Suggestions to overcome the barriers facing improving undergraduate STEM education included the following: (1) all students should have access to first-rate STEM education; (2) curricula and pedagogy used should be rooted in research about human learning; (3) teaching strategies should be student centered; (4) students should be prepared to apply and use their scientific knowledge in their jobs or as science literate citizens; and (5) teaching in higher education must be made a priority by giving faculty the support, incentive, and professional development needed to develop their teaching skills.

The book, *Shaping the Future: Strategies for Revitalizing Undergraduate Education* (NSF, 1998), outlines the proceedings from a National Conference on improving undergraduate science education held in Washington, D.C., during July 1996. The focus of the conference was planning and implementation of strategies for improving undergraduate science education discussed in the previous two volumes of *Shaping the Future.* The meeting consisted of roundtable sessions where participants from higher education and industry and legislators planned strategies to reform undergraduate science education. Models for institution-wide change were discussed in order to create sustained reform. Included in this document were plans for implementing reform at 45 colleges and universities throughout the nation. Strategies were made (1) to ensure a culture in which all students can learn by redefining what it means to learn and the kinds of learning experiences to which students are exposed; (2) to aid faculty to become effective teachers by creating new models for teaching and providing financial and professional development support; and (3) to form collaborations between faculty, administrators, students, and employers to promote a coherent undergraduate experience.

The educational reforms discussed in *Shaping the Future* involved creating science experiences for undergraduate students beyond exposure to more science content. The passive learning environments prominent at colleges and universities do not give students the skills they need to use and apply their science knowledge (NSF, 1996). Traditional science teaching where content is delivered through a lecture and confirmed through laboratory exercises was recognized as lacking in its ability to foster student understanding. Students participating in the Shaping the Future discussion panel described traditional lecture courses in ways that were mostly negative.

Students who are not majoring in sciences reported being made to feel as if science were not for them. All students who participated in the student surveys felt as if the science being taught in their classes was irrelevant to their daily lives.

The Science, Technology, Engineering, and Mathematics standards set for K-12 education were to create a more science literate citizenry. There are no STEM standards for higher education in the United States, yet the higher education system is expected to prepare people for a workforce that requires an understanding of science and technology (Siebert & McIntosh, 2001). The science education system should have congruent policies influencing teaching, professional development, assessment, content, and programs and coordination across agencies, institutions, and organizations involved in providing science education for students. The National Science Education Standards (NSES) created by the National Research Council in 1996 suggested a set of standards intended to improve science education based on consensus within the scientific and science education communities and research in science education (Siebert & McIntosh, 2001). These standards were intended to produce a more science literate society. Science literacy was defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p xiv). Standards were set for the following areas: (1) teaching, (2) professional development, (3) assessment, (4) content, (5) science education programs, and (6) science education systems (Seibert & McIntosh, 2001).

In *College Pathways to the Science Education Standards,* edited by Seibert and McIntosh (2001), suggestions were made based on the science standards set by the National Committee on Science Education Standards and Assessment to improve undergraduate STEM education. Standards were suggested for science teaching, professional development, and content that mirror the standards set for grades K-12 by NSES. Among these suggestions was that science inquiry skills should be emphasized over memorization of content. Science instructors should serve as role models to students who take their courses. For many, the science courses they take during their university years will be the last opportunity they have to experience science instruction. For those who intend to go into teaching, the science they experience in college will be the science to which they expose future generations of students when they teach. Because science instructors have the potential to influence the way science is seen in the eyes of their students, they play a pivotal role in the science literacy skills of their students.

Science teaching should reflect the way science is done over memorization of content. The lecture and lab, when there is a lab, seldom provide students with opportunities to practice authentic science. Assessment should be used to monitor student learning as well as to monitor the development of teaching skills. Science content taught should respect students' prior knowledge and allow students to understand increasingly complex concepts and relevancy between other fields within and outside of science (Seibert & McIntosh, 2001).

Professional development of science instructors should emphasize developing life-long learning skills, teaching and learning science inquiry, and the integration of knowledge about science content with knowledge about how students learn and how science content should be taught (Seibert & McIntosh, 2001). Faculty development should foster both content and teaching skills. Four standards for professional development are recommended including the following: (1) learning science content, (2) learning how to teach science, (3) learning to learn, and (4) planning professional development programs (Seibert & McIntosh, 2001). A better understanding of the teaching and learning process may help faculty instructors develop new ways of teaching that will enhance their students' understanding of science. The content chosen should be relevant to students' lives and up to date with current understandings of the science content. Content knowledge is not enough to effectively teach science. Knowledge of how to teach science content and how students learn is equally important (Seibert & McIntosh, 2001).

There are two NSES report sections that deal with learning environment, Standard D and Standard E. NSES Teaching Standard D recommends that teachers create learning environments that (1) structure the time available so that students are able to engage in extended investigations; (2) create a setting for student work that is flexible and supportive of science inquiry; (3) ensure a safe working environment; (4) make the available science tools, materials, media, and technological resources accessible to students; (5) identify and use resources outside the school; and (6) engage students in designing the learning environment (NRC, 2011; Olson & Loucks-Horsely, 2000; Siebert & McIntosh, 2001). Students should be given the time and opportunity to investigate scientific questions in ways that allow them to apply scientific knowledge in a meaningful way.

Learning environments that provide students with the opportunity to learn science by doing science have the following characteristics as described by the NSES Teaching Standard E (NRC, 2011; Olson & Loucks-Horsely, 2000; Siebert & McIntosh, 2001): (1) displaying and demanding respect for the diverse ideas, skills, and experiences of all students; (2) enabling students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community; (3) nurturing collaboration among students; (4) structuring and facilitating ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse; and (5) modeling and emphasizing the skills, attitudes, and values of scientific inquiry. Teaching

Standard E was written to encourage teachers to develop learning communities where students are able to use their strengths and weaknesses to build better understandings of course content.

In order to achieve the goals outlined in the volumes of *Shaping the Future* and *College Pathways* advocating the reform of undergraduate science education, changes have to be made in the way science is taught. The typical college science course would have to be redesigned so that students have the opportunity to do science instead of having science taught to them. However, most faculty instructors teaching in the sciences have few experiences that allow them to teach using science inquiry, even though they practice it in their professional lives. For many, their preparation for teaching science courses was through graduate teaching assistantships. The teaching skills gained in these positions rarely included researched knowledge of student learning or pedagogy (Tanner & Allen, 2006). Even when there are programs that provide professional development for graduate teaching assistants, this guidance does not impart the skills necessary to teach science inquiry. For some faculty instructors teaching in the sciences, their first job as an instructor is their first time teaching. If faculty instructors in the sciences are to effectively guide students to become scientists and provide non-majors an opportunity to experience science, then it is necessary to provide future faculty with the tools to accomplish these goals (Sunal, Hodges, Sunal, Whitaker, Freeman, Edwards, Johnston, & Odell, 2001).

Traditional and Reformed Science Teaching in Higher Education

Traditional introductory university science courses have been described in the literature as consisting of large enrollment lecture and lab courses. The large enrollment lecture/lab format is the most cost effective way to deliver course materials to a large group of students using the least amount of resources (Hamer, 2000; Wyckoff, 2001). Lectures allow the delivery of large amounts of facts and information to students (Hamer, 2000). If the assumption that lecturing equals learning is true, lecturing allows students to learn the most material in the least amount of time (Hamer, 2000). Under the same assumption, lecturing allows the learning to be controlled by giving the instructor the power to determine how much and how fast the concepts in the course will be covered.

Students in these courses were described as having a passive role and the instructor making all the decisions about the course (Henderson & Dancy, 2007; NRC, 2003, 2009). Students were described as studying in order to memorize the course content for the test (NRC, 2003, 2009). Students were not given the opportunity to be exposed to science instruction that would allow them to develop the skills necessary to think critically, develop problem-solving skills, or apply their scientific knowledge to context outside of the classroom. Instead, the content of the courses described in the literature focused on the products of science, which are the scientific achievements of scientists that have made large impacts in the ways in which we understand our lives and world.

Traditional lecture courses have operated on the premise that telling a student the information means that they have learned the information. It was assumed that if the students hear the information and take notes, they have the information they need to learn it on their own (Hamer, 2000; Shakarian, 1995). Instructors assume that when students do not have questions after a lecture that the students understood the material, but this may not be true. Students may not have questions because they did not understand enough of the lecture to ask questions (Hamer, 2000; Shakarian 1995).

Very few students are capable of learning through lecture alone (Wyckoff, 2001). Students' attention spans have been found to drop after the first 10 minutes of lecture (Shakarian, 1995). Most students do not come to class with the motivation or drive to learn on their own

(Shakarian, 1995). They do not come to lecture with an understanding of their own prior knowledge, questions they need answered, or an ability to develop a new understanding from the content discussed (Biggs et al., 2001). Biggs theorized that student levels of engagement in the classroom fall between memorizing and theorizing. Students who take a more academic approach (Biggs et al., 2001) will be able to reach higher levels of engagement in more passive learning environments such as traditional lectures, while students taking the non-academic approach to learning (Biggs, 1999) need more active learning such as constructivist or problem based learning in order to reach higher levels of engagement (Biggs, 1999).

Despite what is known about how students learn and effective teaching practices, most undergraduate science classes fail to employ strategies that foster student learning (Hamer, 2000; Lawrenz, Huffman, & Appeldoorn, 2005; Wyckoff, 2001). Lawrenz et al. collected survey data from science content area deans or department chairpersons, faculty, and students at 55 institutions between 2001 and 2005 to obtain data about the current state of institutional and classroom environments in order to address the goals of introductory science courses for the Collaboratives for Excellence in Teacher Preparation Program. The faculty participating were asked their beliefs about teaching and how often they used instructional methods recommended by the NSES. Students were asked how often their instructors used instructional methods suggested by the NSES and how helpful these methods were. The sample included 148 instructors and 2,777 students in 72 different science classes at 55 colleges and universities. The course content included biology, biochemistry, chemistry, physics, geology, and general science. The faculty members participating in the study were surveyed about their instructional methods, using a 14-item instrument. Faculty reported *seldom* or *never* allowing students to work on a group product for a grade, allowing students to dominate the discussion during class discussions, reflecting on their learning, or using portfolios as a form of assessment. Faculty reported they only occasionally used real-world examples, allowed students to make connections between course content and real-world problems or other courses, or used inquiry to investigate problems. None of the items were reported as being regularly used by more than 2.6% of the participants. The results from the student survey matched the results of the responses by faculty. Students reported that they were only occasionally exposed to the types of science instruction recommended by the NSES.

Science taught in the traditional way, with a lecture where students listen passively, a lab where students do activities to confirm what was presented in lecture, and then are tested on their ability to regurgitate information, makes science seem irrelevant to students' lives (Woodin, Smith, & Allen, 2009). Traditional teaching generates student learning that is not transferable outside of an educational context (Woodin et al., 2009). Moreover, studies have shown that lectures are ineffective at fostering learning and only 14% of people learn science through lecture alone (Wyckoff, 2001). In an experiment by Birk and Foster (1993), the researchers tested the hypothesis that learning occurred in lectures. The researchers examined the relationships between lecturer and course performance and attendance and course performance in an entry-level chemistry course. The first hypothesis that the researchers tested was whether or student grade on the final exam or in subsequent courses could be predicted by lecturer. To test this hypothesis an ANOVA was run to compare student performance on the final exam. No significant relationship was found between lecture and performance on final exam or performance in subsequent course (Birk and Foster, 1993). The researchers also tested the hypothesis that students who attended class more frequently would receive higher grades on the final exam. The result indicated no difference in performance on the final exam based on attendance.

The weak correlation between class attendance and grades was also noted by Hammen and Kelland (1994). Attendance data of 556 students enrolled in a physiology course was collected over a 5 year period (Hammen & Kelland, 1994). The students were compared on their performance on two exams and the final. Each session of the lecture course enrolled between 40-183 students majoring in various sciences, education or health related fields. The lectures were designed to explain the concepts of physiology that were outlined in the textbook. The daily attendance and test scores for each student were recorded. A Correlation analysis showed a 2-point decrease for each absence, indicating that lecture attendance played only a small part of learning the course materials. Both the study by Hammer and Kellen (1994) and Birk and Foster (1993) indicate that attendance in a lecture based course have minimal impact on student learning.

Efforts to improve student learning in courses can range from traditional methods that change little about the way the course is taught to highly reformed methods that change many aspects of the course. For this study, a reformed science course will be defined as any science course where the ways in which students interact with the course content has been changed (NRC, 2003, 2009). In reformed science classes, students were provided with the opportunities to think about their own understandings of the course content, question their understandings, and refine those understandings based on their experiences in their courses through inquiry (NRC, 2003, 2009). Inquiry is an instructional strategy that allows students to be engaged in science by doing science. Learners give priority to evidence which allows them to develop and evaluate explanations that address scientifically oriented questions. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understandings. Inquiry is a learning goal that includes developing students' understandings about how to begin to gather, evaluate, analyze, and synthesize data in order to solve a problem. Teaching science using inquiry allows students to develop a better understanding of the nature of science because science is not taught as a set of facts and the focus of the course is not on the past accomplishments of scientists. Instead, students are allowed to see why science knowledge changes in response to new evidence, logical analysis, and modified explanations debated with a community of scientists by learning to use what they understand of the science content to solve problems (Hurd, 2000; NRC, 2003; Seibert & McIntosh, 2001). A reformed science course is a course that has been adapted to increase students' chances to practice using science inquiry in order to develop their ability to apply and use their scientific knowledge to solve real-world problems (NRC, 2003).

In many traditional lecture-based courses, the only encouragement to interact with science that the students receive are designed to get them to read the text or lecture notes in order to do better on the test (Collard, Girardot, & Deutsch, 2002; Slunt & Giancarlo, 2004). In separate artiCLES published in *The Journal of Chemical Education,* the authors (Collard et al., 2002; Slunt & Giancarlo, 2004) in both groups were concerned with student performance in an undergraduate introductory level lecture course. To improve student performance, both designed an intervention to get students to read the textbook more in order to improve student grades. Collard et al. reported the results from the implementation of an instructional method designed to increase student engagement in a lecture course by increasing student preparation. The researchers used HWeb assignments that were intended increase student preparation by getting students to read the textbook more. The students participating in this study were enrolled in a two-semester organic chemistry course that enrolled 120-140 students. Each HWeb assignment contained three multiple choice questions that could be answered using the textbook or other resources: "How many of the constitutional isomers of C_7H_{16} have no 3° hydrogens?"

The researchers gave the students a survey to ask them about their textbook use in previous courses, and the majority of the students stated that the HWeb assignments caused them to use the textbook more than they did in other classes. The researchers analyzed the relationship between students' grades and use of the textbook through the HWeb assignments. Students who completed the HWeb assignments did better in other aspects of the course than students who did not complete the HWeb assignments. Students who did well on the HWeb assignments had higher grades than the students who only attempted the HWeb assignments or did not do the HWeb assignments; however, these results may be due to an artifact. The students who did well in the course may have done well with or without the HWeb assignments because of individual factors within the student. Similarly, students who completed the HWeb assignments, but did not do well on them and received a B or C in the course, may have taken an approach to studying and learning where they put in only the amount of effort that was required of them. The students who failed the course would have done so regardless of the efforts of the instructor. Analysis of the survey provides evidence that this may be true. The students who received a higher grade (A) were more likely than students who received a B or a C or lower grades (D or F) to agree with the items on the survey. Students receiving higher grades were more likely to agree that they read the textbook more often and the textbook helped them understand the course material better. The researchers suggested that using the HWeb assignments or similar interventions may help other instructors improve student learning without making big changes in the course format. However, they did not provide evidence that doing so improved student learning.

Similar methodologies were used by Slunt and Giancarlo (2004) to improve student preparation for lecture and learning in sections of general chemistry, organic chemistry, and biochemistry courses. Each course enrolled a maximum of 24 students. Concept Checks are pauses in the lecture that allow the students to demonstrate their understanding of the concepts being covered in the lecture. These breaks in instruction give the instructor a chance to assess how well the students are following the lecture and to make decisions about how to address misunderstandings or move on (Slunt & Giancarlo, 2004). The researchers wanted a better way to access student understanding and learning of the course materials so JiTT was initiated for some sessions of the courses. JiTT for both courses involved the use of Web-based drills and preview quizzes that were to be completed prior to the lecture. The web-based drill questions were directly related to the previous lecture and came from test banks. Typical preview questions were questions the student could have answered using prior knowledge, textbook, or other source of knowledge such as, “What is a “mole?” “What does it represent?” “Why is it important?” and “Covalent bonds can be cleaved homolytically or heterolytically. Explain what is meant by these terms.” The instructor viewed the responses and tailored the lecture based on students’ responses. The instructor spent the first few minutes of the lecture reviewing the homework assignment. The instructor used the rest of the lecture to tell the students how the preview questions were related to the current lecture.

The qualitative results by Slunt and Giancarlo (2004) indicated that the JiTT interventions implemented worked to improve students’ grades and test scores. Classes in which the JiTT intervention was used had a GPA of 2.3 for the course, while classes where only the Concept Check or lecture only was used had a GPA of 2.1. The average test score on the first exam in the organic chemistry course was higher for students in the section with the JiTT intervention than it was in the course using Concept Checks only, but there were no differences between the two sections on the final exam. Students enrolled in the JiTT section of the biochemistry section of the course scored higher than the students in the section where only Concept Checks were used on both the first and final exams. However, the investigators did not conduct statistical analysis to determine whether the differences in test scores were significant.

To investigate the impact that the JiTT intervention had on the long-term performance of students, the researcher compared the performance of students who had experienced the JiTT intervention with students who had not experienced JiTT in a subsequent course, by comparing their grades at the end of the semester. The researchers found that the students performed the same in the subsequent course regardless of whether they experienced the JiTT intervention in their general chemistry course suggesting that the JiTT intervention impacted short-term but not long-term learning. The results from this study may have been due to the kinds of questions asked in the JiTT intervention and used in the Concept Checks. Both interventions used questions that assessed students' abilities to recall information. The Concept Check assessed students' ability to recall information during the lecture and the JiTT assessed students' ability to recall information after (Web-based drills) and before (preview quiz questions) the lecture. Simply increasing the amount of time students spend studying test questions intended to increase memorization will not produce the results necessary to produce science literate students, or long-term learning of the course concepts if the students are only doing work to increase memorization (Brint and Cantwell, 2008; Brint et al., 2011).

Large changes do not have to be made in order to increase student learning. There are several published accounts of individuals making small changes that impact student learning, but there are few where the instructor implementing the changes measures the impact in a scientific manner (Geske, 1992). Many instructors who implement instructional changes in their courses publish accounts of those efforts that are not experimental in design. For example Donald Paulson reports on how small changes in instruction can produce changes in student learning and increase retention rates in an article published in *Chemical Education Research.* Donald Paulson described his frustration that less than 50% of the students enrolled in his organic chemistry course pass, and most drop out before the end of the semester. By moving away from lecturing all the time and allowing the students time to think about the materials through group work, the minute paper (Angelo & Cross, 1993), breaks in lecture (Shakarian, 1995), cooperative learning groups, and other active learning techniques he was able to significantly improve grades in the first quarter of his organic chemistry course (Paulson, 1999). In addition, he was able to improve the retention rates of students enrolled in both the first and second quarter of the same course. Students enrolled in the classes where course reforms were implemented had a higher retention rate than students enrolled in the traditional lecture (Paulson, 1999). Though Paulson did make comparisons, he compared results from past years when he did not use active learning techniques to the years after he implemented active learning techniques. Other studies that used an experimental or quasi-experimental design have used active learning to get similar results.

A study conducted at the University of Wisconsin in Madison compared the impact of lectures and active learning in an analytical chemistry course intended for science and engineering majors whose placement test scores placed them in the top 10-15% of entering chemistry students (Wright et al., 1998). One section of the course was labeled responsive lecturing (RL) and the other labeled structured active learning (SAL). The RL section was taught using lectures, spreadsheets, homework problems, and group projects. A total of 95 students were enrolled in the RL section. Students in the RL section primarily worked on their own to learn the content on their own.

The instructor and the teaching assistants directed the learning in the course labeled RL (Wright et al., 1998). The lecturing style used in the course was designed to encourage student participation in the lecture. Even though the topics and discussion centered around the instructor and teaching assistant, students in the course were still encouraged to participate.

The SAL section was taught in an interactive classroom that included cooperative homework assignments and tests, group projects, research papers, and open-ended laboratory projects. A total of 108 students were enrolled in the SAL section. Students participated in planning of the course curriculum as well as classroom activities (Wright et al., 1998). Both sections of the course used the same textbook and covered similar content, except the RL course included one topic, precipitation equilibrium, which was not covered in the SAL course.

The UW-Madison's Learning through Evaluation, Assessment, and Dissemination (LEAD) Center was used to aid the faculty members that evaluated the students of the course in designing and assessing the oral exams used to evaluate the students participating in the course. The faculty members conducting the oral exams did not teach the courses being evaluated. The students were divided into eight groups, containing 24 students each, based on student rank. Three faculty evaluators were assigned to each group. The faculty evaluators did not know how the students were assigned to them, which course they were enrolled in, or the teaching methods used in either of the sessions. The students were told that a small portion of their grade would come from the oral exam (Wright et al., 1998).

The LEAD center conducted qualitative research to ensure that differences seen in student performance on the oral exam were due to differences in course instruction and not other reasons such as student learning style, difference in teaching ability, differences in teaching assistants, etc. Interviews, observations, and surveys were used to study the students, teaching assistants, and faculty in both sections throughout the semester (Wright et al., 1998). The data were used to create case studies describing the interactions between the instructors, students, and teaching assistants in each course (Wright et al., 1998).

The interview data showed that students in each section noticed different things about their learning environments (Wright et al., 1998). Students in the SAL section stated the interactions with their peers helped connect the lecture, laboratory, and other course components. The students expressed achieving a better sense of self-reliance through having to work on open-ended problems. The students felt that the course gave them a better idea of how science was really done and how scientists collaborate with others to come up with solutions to problems. Even students who expressed dissatisfaction with their group dynamics felt that their frustrations reflected the reality of how science is done. The students felt that the work was difficult, but the learning they achieved from doing it was worth the effort.

The students in the RL section viewed the instructor and TAs of the course with great respect and some saw them as role models (Wright et al., 1998). The students felt that the instructors and the teaching assistants were the sole source of information in the class. The students expressed appreciation for the time that the instructor took to create step-by-step problem-solving guides to help them learn the course materials. Some students in this section expressed frustration about their inability to connect the lecture and laboratory components of the course (Wright et al., 1998).

The Mann-Whitney test of significance was used to determine differences in student and faculty perceptions of the SAL and the RL sections based on a questionnaire. Students and instructors in both of the sections had a favorable view of the course; however, the students in the SAL section felt more prepared for other science than students in the RL section (p = .0005). The faculty also felt the students in the SAL section were more prepared for other science classes (p = .045). Students in the SAL section felt more confident in their ability to apply their scientific knowledge than students in the RL section. For example, students in the SAL section indicated a higher level of agreement (p = .0066) to the question "I demonstrated I am knowledgeable in chemistry." Students in the SAL section were ranked higher on student performance tests than students in the RL course (p = .0002).

When individual students in each section were compared with each other, students in the SAL section outperformed students in the RL section on questions that involved higher level thinking skills, but there was no difference between the two sections on problems that measured how fast the student could solve a problem or on traditionally formatted exam questions (Wright et al., 1998). The researchers felt that there was no reason to believe the students in the SAL section would outperform the students in the RL section when the goal was to help the students develop "scientific maturity." They felt they had achieved their goal based on the fact that the faculty ranked the students in the SAL section higher than the students in the RL on an oral exam that was intended for the students to demonstrate their ability to apply scientific knowledge.

The *Odom and Barrow Diffusion and Osmosis Diagnostic Test* (*DODT*) was used by Christianson and Fisher (1999) to determine the difference in learning between students enrolled in traditional and constructivist science courses (Odom & Barrow, 1995). The *DODT* used a two-tier multiple choice format which was intended to identify student misconceptions about osmosis and diffusion, and determine whether students differ in their understanding about osmosis and diffusion. The odd numbered questions accessed student understanding of the concepts, and the even numbered questions accessed student reasoning for selecting their answers (Christianson & Fisher, 1999).

The researchers compared students enrolled in (1) Course 1: a large lecture-based classroom that enrolled 150+ students per section, (2) Course 2: a medium lectured-based classroom that enrolled 150 students per section, and (3) Course 3: a small discussion-based integrated lab-lecture that enrolled 30 students per section. Students enrolled in Courses 1 and 2 received 2 hours of laboratory and 30 minutes of discussion on diffusion and osmosis. Students enrolled in Course 3 received 3.66 hours of laboratory instruction on osmosis and diffusion. In addition, the students were expected to continue their work outside of the classroom by constructing semantic networks of these processes.

The aspects of diffusion covered varied in the three courses. To cover diffusion, the instructor of Course 1 used (1) solid into liquid, (2) the effects of temperature, and (3) concentration on rate of diffusion, and diffusion through a membrane. The instructor of Course 2 covered liquid into colloidal suspension to demonstrate diffusion. The instructor of Course 3 covered diffusion by using the following topics: (1) liquid into liquid, (2) solid into solid, (3) diffusion of aromatic substances into the air, and (4) the effect of temperature on the rate of diffusion. Osmosis was taught similarly in each course by using dialysis bags and plants (elodea and produce) to demonstrate turgor pressure.

A Chi-square (χ^2) test was used to determine whether there were significant differences in students' scores on the *DODT* prior to instruction. The researchers reported differences between students' scores between Courses 2 and 3, but considered them negligible $\chi^2 = 18.34$, $.1 > p > .05$. The results for the pre-test comparisons between Course 1 and Course 3 were not reported. The researchers found that the students in Course 3 outperformed the students in

Course 2 on the *DODT* (p = .001). However, considering the fact that the students in Course 2 used fewer methods to teach the concept of diffusion, it is difficult not to be leery that the students may have performed more poorly on the test because they were not given similar exposure to the content. Students in Course 1 also had lower scores on the *DODT*, but the significance of this difference was not reported. The students in Course 1 were exposed to several methods intended to teach diffusion, but still did not develop the conceptual understanding that students in Course 3 developed. It was concluded by the researchers that the instructional methods used in Course 3 allowed the students to develop a deep understandings of osmosis in diffusion. The students in the lecture courses, Courses 1 and 2, were passive and their experience with the content involved the teacher telling them what they needed to know. The researchers indicated that in addition to the difference in the teaching methodologies between Courses 1 and 2 and Course 3, the class size may have made a difference in the student performances. The students in Course 3 were given more opportunities to work with the instructor than the students in Courses 1 and 2.

Student learning and student perceptions of course and instructor effectiveness, course difficulty, and amount learned between 170 physical therapy students enrolled in an active learning or lecture based course on physiology were compared in a study conducted by David Lake (2001). The students enrolled in both courses, freshman-level undergraduates working on their Bachelor's degree in physical therapy, had completed the prerequisite science and liberal arts courses to qualify for the professional training portion of the physical therapy program.

The lecture course met for four 1-hour lectures per week and enrolled 58 of the participants. The other 78 participants were enrolled in the active learning course, which also met for four 1-hour periods with 50% of the time spent in lecture and the other 50% of the time spent in discussion. Both courses used the same content, level of difficulty, quizzes, exams, study materials, etc. Student performance was based on grades, and students' perceptions of the course were based on students' course evaluations.

The Kruskal-Wallis test, with an alpha level set at .05, was run to determine differences between students' perceptions of the courses. Post-hoc analysis using individual Mann-Whitney U test and Bonferroni correction and set at .017 were also performed to determine differences in students' grades between courses. Results indicated that the students enrolled in the active learning course received higher grades ($p < .001$) than students enrolled in the lecture course. Despite the fact that the students learned more in the active learning course, the students in the active learning course felt that they learned less and had lower perceptions of the course and instructor effectiveness than students in the lecture course. The students in the active learning course may have believed they learned less based on their perceptions of "good teaching." Many of the students indicated that the instructor did not teach them anything. The students needed time to adapt to and accept a teaching style that was different than their previous experiences with teaching at the college level.

The Student-Centered Activities for Large Enrollment for Undergraduate Physics/Programs (SCALE-UP) is a project representing a large change from a traditional course. The (SCALE-UP) project was developed to implement reform methods in large physics classrooms but the methods have been adapted for use in other fields (Beichner, 2008; Beichner, Saul, Abbott, Morse, Deardorff, Allain, Bonham, Dancy, & Risley, 2007). At the time of this proposal, it was being utilized in over 50 universities across the country (Beichner, 2008; Beichner et al., 2007). SCALE-UP was based on the NSES suggested in *College Pathways.* In the SCALE-UP model, large lecture classes are moved out of the lecture hall into classrooms that facilitate student collaboration. The lessons are designed in a way that promote student conceptual understanding through hands/minds-on activities called “tangibles” and problem solving abilities through activities called “ponderables” (Beichner et al., 2007).

Evaluation of the original SCALE-UP project at North Carolina State University includes student pre- and post-diagnostic tests, a concept test, individual and group exams, peer evaluation, focus groups, classroom observations, etc. (Beichner, 2008; Beichner et al., 2007). The results from the diagnostic tests were compared with traditional physics courses at North Carolina State University. FCI (Hestenes, Wells, & Swackhamer, 1992), Force and Motion Conceptual Evaluation (FMCE; Thornton & Sokoloff, 1998), Conceptual Survey of Electricity and Magnetism (CSEM; Maloney, O’Kuma, Hieggelke, & van Heuvelen, 2001), Determining and Interpreting Resistive Electric Circuits Concept Test (DIRECT; Engelhardt & Beichner, 2004), and Electric Circuit Conceptual Evaluation (ECCE) were used. Students in the SCALE-UP science course showed greater gains on the FCI than students enrolled in traditional courses (Beichner, 2008; Beichner et al., 2007). The students enrolled in the SCALE-UP science class also outperformed their peers enrolled in the traditional class on the FMCE. Results for student performances on the CSEM and DIRECT were mixed; a significant difference between the two classes was only seen when the number of lectures was reduced and the number of activities was increased (Beichner, 2008; Beichner et al., 2007).

The SCALE-UP model was used to reform a general chemistry course by Oliver-Hoyo, Allen, Hunt, Hutson, and Pitts (2004). Mixed results were also found. Students in the SCALE-UP course outperformed students in the traditional course on two of the exams, but no significant differences were found in their performance on the other examinations in the course (Oliver-Hoyo et al., 2004). However, the authors did not state the nature of the exam questions. It could be that the exam questions were aiming to determine how much content the students have learned as opposed to higher level thinking skills. If this was the case, the students may have performed similarly on the exam because the students in the lecture course were able to remember the content for the exam (Wright et al., 1998). It is also possible that when the students in the SCALE-UP course did outperform the students in the lecture course, it was because the concepts were best taught through increased activities as seen in Beichner et al. (2007). That is, the students struggled to memorize the content in the lecture course, but the students in the SCALE-UP course showed mastery because of the activities in which they participated.

Other efforts to reform science education include Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT), Project Kaleidoscope (PKAL), and the National Aeronautics and Space Administration's NASA Opportunities for Visionary Academics (NOVA) Program. Each of the efforts involved faculty development, training, and collaborations in order to improve undergraduate science education. The ACEPT program was a National Science Foundation supported program for improving mathematics and science courses at Arizona State University, particularly courses that enrolled pre-service teachers (Lawson, Benford, Bloom, Carlson, Falconer, Hestenes, Judson, Pilburn, Sawada, Turley, & Wycoff, 2002). The program consisted of professional development for college science and math instructors who exposed them to reformed science teaching and aided them in implementing reform in their classrooms. The reformed teaching methods recommended by ACEPT were based on cognitive-related teaching principles in *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989). The teaching methods were based on the assumption that learning is an active process in which students learn by connecting new knowledge to the conceptual understandings they already have. Further, students have to be given the opportunity to restructure their understanding or misunderstanding through events that allow them to question and become dissatisfied with their beliefs. Evaluation of the program focused on the affect the program had on the instructors' teaching methods and the impact of those methods on student achievement (Lawson et al., 2002). Teaching methods of instructors who had participated in the ACEPT program and those that had not participated in the program were evaluated using the *Reformed Teaching Observation Protocol* (*RTOP*), which was designed specifically for monitoring the teaching methodology used by ACEPT program participants. The *RTOP* instrument contained 25 statements dealing with the degree to which reform has been implemented into the classroom (Sawada et al., 2002). The observer scores each statement from 0-4: *Never Occurred* to *Very Descriptive* (Sawada et al, 2002). The instructors who participated in the professional development offered by ACEPT implemented reform at various levels. The instructor *RTOP* score was found to be correlated with student achievement gains. The more reform observed, through *RTOP* scores, in the classroom the greater the student gains in scientific reasoning skills and understanding and significantly greater gains on the Force Concept Inventory (Lawson et al., 2002). No relationship was found between *RTOP* score and student scores on tests that required students to recall memorized information (Lawson et al., 2002). The fact that students enrolled in reformed courses do not outperform their peers enrolled in courses with typical formats on traditional tests does not undermine the effectiveness of reformed teaching methods. The goal of instruction under the ACEPT model was not to improve student memorization skills, but to improve scientific reasoning, knowledge of the nature of science, and to apply scientific knowledge to contexts outside of the classroom. The fact that students who participated in the ACEPT course did better on the FCI than students enrolled in traditional courses indicated that innovations implemented by instructors participating in the ACEPT courses gave students the opportunity to not only learn the course content, but to understand it in such a way that they were able to apply their knowledge.

The NOVA program was a National Aeronautics and Space Administration supported program for improving science and mathematics courses at The University of Alabama with a specific focus on discipline courses that enrolled pre-service teachers (Sunal, Hodges, Sunal, Whitaker, Freeman, Edwards, Johnston, & Odell, 2001) The NOVA program courses were developed by faculty teams as a part of professional development efforts for university faculty and administrators at 103 universities to work in collaborative teams to create and sustain reform in entry-level undergraduate science and mathematics courses. Participation in the NOVA program included opportunities to attend three levels of professional development workshops, collaborate with fellow educators in NOVA interested in improving the undergraduate STEM experience, funding for course development, and continued professional development and presentation of related action research at annual meetings. The NOVA program was designed not only to give educators the pedagogical knowledge to improve their instruction, it also provided interested faculty members with feedback and collaborative relationships in order to sustain course reforms. The innovations implemented in the NOVA reformed courses were based on the national science standards and policy and research reports by NSF and NRC. The changes made to the courses included (1) changing roles for faculty and students, (2) researched-based pedagogy with a focus on inquiry learning, (3) collaborative learning strategies for students, (4) alternative feedback and assessment strategies, and (5) use of technology to facilitate student learning (Sunal, MacKinnon, Raubenheimer, & Gardner, 2004)

Participation in the NOVA program included opportunities to attend multiple expenses-paid professional development workshops, conduct action research, collaborate with fellow educators interested in improving the undergraduate science experience, participate in annual conferences on undergraduate teaching and learning, and funding. The NOVA professional development model had three phases. The first phase was planning and development, which involved professional development and collaborating with local institution team members to address the baseline needs in faculty skills and knowledge enhancement necessary for course improvement. The second phase, development and implementation, involved course development and change, mentoring, action research, and sharing of expertise. The final phase was used to help participants continue to develop and sustain the course reforms through site visits, collaboration, networking, and dissemination of results in national workshops. The courses developed through participating in the NOVA program.

The innovations implemented in the NOVA reformed courses were based on the national science standards. The changes made to the courses include (1) changing roles for faculty and students, (2) research-based pedagogy, and (3) student learning (Sunal, Sunal, Mason, Zollman, Sundberg, & Lardy, 2008). The faculty instructors were no longer the ones who held the knowledge to be passed on to students; instead they became co-constructors of knowledge. In doing so, the instructors adopted research-based pedagogy based on constructivism and using components of the learning cycle (Sunal, Sunal, Mason et al., 2008). The learning cycle was a strategy of teaching that first engaged student interest in the course content by eliciting prior knowledge (Bybee, 1997; Eisenkraft, 2003; Karplus & Thier, 1967). By understanding the students' prior knowledge, instructors were able to help the students interact to build a more scientific understanding of course content (Eisenkraft, 2003). The learning environments of the courses were designed with student learning in mind: (1) they focused on student collaboration, instead of competition; (2) depth of knowledge was emphasized over breadth of knowledge; and (3) multiple learning formats were used to address multiple learning styles (Sunal, Sunal, Mason, & Lardy, 2008; Sunal, Sunal, Mason et al., 2008; Sunal, Sunal, Steele, Turner, Mason, Lardy, et al., 2008).

An evaluation of the Earth Systems Science class that was funded through NOVA by Boss and Beller (2006) was reported in the *Journal of Geoscience Education*. The course was designed to be a hybrid course where part of the course content was delivered online for honors college students and secondary level pre-service teachers. In the study, the researchers examined the change in student performance by using a pre-test/post-test model comparing science, non-science, and education majors (Boss & Beller, 2006). The tests were designed to measure the change in students' conception and knowledge of science, the Earth systems, and pedagogical perspectives (Boss & Beller, 2006). The students were given a series of tests that were designed to assess students' understanding of the content and their cognitive abilities at the beginning and end of the semester. Describe the tests that the students were given. Prior to instruction, students had a simplistic understanding of the course content and viewed science to be a collection of facts that stand alone to explain phenomenon in the world. The post-results indicated that science majors and science education majors gained higher order thinking skills and changed their conception of the nature of science as the course progressed. Non-science majors also improved in their conception of the nature of science but not in all the categories measured. The authors postulated that the non-science majors were more confused about the nature of science at the end of the semester than they were at the beginning. It was postulated by the authors that the non-science majors' experiences in the Earth Systems Science course caused the students to reject their prior understanding of the nature of science, but their limited experiences with science caused them to struggle to develop a new understanding of the nature of science. All students gained knowledge about Earth Systems as a result of the course. While this report indicates that science reform improves students' conceptions of the nature of science, no comparisons to a traditional Earth Systems course were made.

Project Kaleidoscope (PKAL) is an informal alliance of scientist and science educators that was created in 1989 to identify teaching practices in undergraduate science, disseminate and bring successful practices and policies to the attention of the undergraduate community, and to facilitate the adoption of these practices into more undergraduate science education programs (Sullivan, Laird, & Zimmerman, 2010). The project received funding from NSF and several private companies including Exxon, Pew, Kellogg, Research, and Dreyfus Foundations (Sullivan et al., 2010). PKAL strived to create learning environments that incorporate researched strategies that have been shown to have positive outcomes on student learning in order to recruit and sustain undergraduate students in science technology, engineering, and math fields (Sullivan et al., 2010). PKAL has three main goals: (1) to keep the focus on the future, determining what kind of undergraduate STEM community will continue to serve the national interest now and for years to come and ensuring that such an undergraduate STEM community flourishes; (2) to be a primary source of resources (ideas, people, connections) that inform the work of individuals, departments, institutions, and other stakeholders committed to the continuing effort of building and sustaining strong undergraduate STEM communities, locally and nationally, and lead them to productive action; and (3) to identify, nurture, and sustain a leadership cadre for undergraduate STEM that has a visibility at the local, regional, and national level, that understands the changing context for the work of STEM leaders, internal and external to the campus, and is committed for the long term.

Despite the dissemination of studies that demonstrate increased student learning, there is resistance to change among faculty regarding the type of teaching that should occur in introductory university science courses (Paulson, 1999). There are several reasons suggested for resistance to change. The emphasis on research, the lack of dissemination of research on teaching at the university level, and faculty resistance, due to lack of knowledge about teaching and learning are the most common reasons given for resisting science education reforms at the undergraduate level (Brainard, 2007).

Cultural and contextual factors also play a role in the resistance to the reform movement in science courses at the university level (Southerland, Gess-Newsome, & Johnston, 2003). Some instructors resist changes in the way they teach despite evidence to the contrary (Southerland et al., 2003).

Learning Environment Research

Using models of how instructors behaviors in the classroom impacted students developed by John Biggs (1999), student learning had 7 levels, (1) memorizing, (2) note taking, (3) describing, (4) explaining, (5) relating. (6) applying, and, (7) theorizing. The objective of teaching was to move students surface approaches to learning such as memorization and toward in depth learning such as applying and theorizing. In order for an instructor to achieve these types of learning in the classroom, the instructor must move away from lecturing and begin to use teaching methods that allow the students to have more active roles. In this theory, two roles for students are described, the first is able to come to a lecture class and learn on their own. The student, Susan, is able to engage in the science content through lecture, access her prior knowledge, form new understandings, and apply knowledge on her own. The other student, Robert, is unable to do this so he attempts to learn science content by memorizing and taking notes. The majority of the students in courses will be more similar to Robert than Susan (Wyckoff, 2001). A good instructor would be able to plan a lesson to reach as many students possible by providing opportunities for the students to engage in the lesson (Biggs, 1999). Problem based learning was used as an example of a method that would provide the level of engagement would allow most students in the class to learn in the paper.

Three types of instructors were described by Biggs (1999). A level 1 instructor focuses on "what the student is." The main goal of the instructor is to deliver the course content to the student and if the student does not learn, it is the students' fault. Level 2 instructors focus on "what the teacher does." Instructors at this level focus on what they can do in order present the course content in the best way. Level 3 instructors focus on what the student does and provide opportunities for students to engage in the course content that would allow them to approach learning beyond memorization.

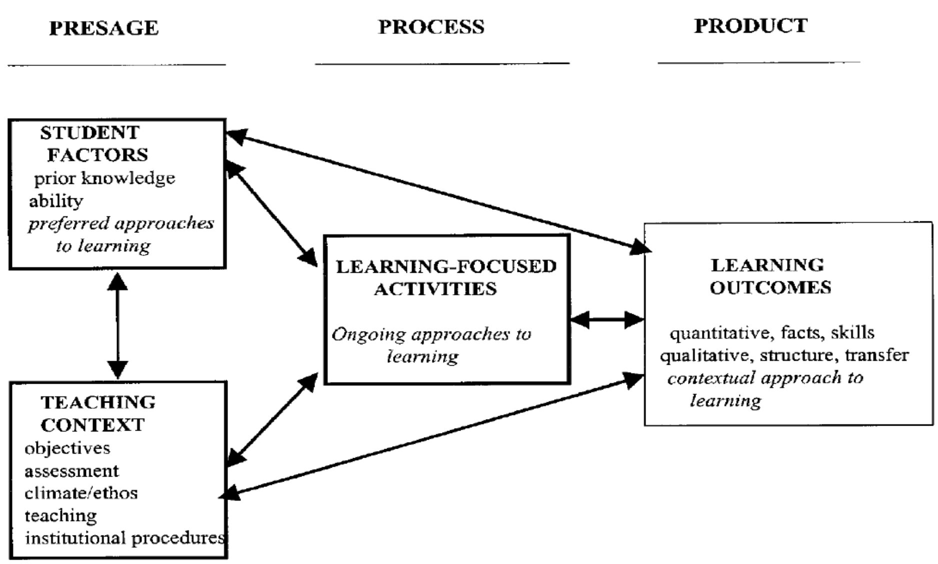

Figure 1. The Presage-Process-Product Model (Biggs et al., 1989).

The *Study Process Questionnaire* (SPQ; Biggs et al, 2001) was created to explore the relationship between what an instructor does and the approach that students take to study course material. According to Biggs et al. (2001), student learning outcomes were the result of the educational system in which the learning event was located as schematized in the Presage-Process-Product (3P) model shown in Figure 1. The 3P model described how presage and process factors in a learning environment interacted to form student outcomes, or products. Presage factors referred to characteristics in the students and instructor prior to the start of the learning event (Biggs et al., 2001). Students' prior knowledge, preferences for learning, and ability were formed prior to starting the course and each of these could impact students' ability to learn the content presented in the class. Instructors' beliefs about teaching and learning, content selected to be taught, methods of teaching and assessment, and institutional factors were also considered to be pre-existent to the start of the course. Process factors were described as the characteristics of the activities intended for student learning that occur in the classroom. The factors in the 3P model interacted in a dynamic manner; that is the model was not unidirectional. The products of learning impacted the presage and process factors, etc. (Biggs et al., 2001). An instructor may refine their beliefs about teaching and learning (presage) as a result from student outcome (product) from an instructional methodology (process) used in the classroom. Students may take a surface approach to learning prior to starting the course (presage) but adapt a deeper approach to learning in response to the learning activities in the classroom (process) and/or in response to their grades (product) from a learning activity (process) (Biggs et al., 2001).

Presage Factors Impacting the Learning Environment

Extensive research on the relationship between instructional methodologies and students' perceptions of the learning environment and their relationship to student approaches to learning has been done by Trigwell et al. (Trigwell and Prosser, 1991; Trigwell et al., 1999). The researchers used the *Approaches to Teaching Inventory* (*ATI*) to explore the teaching practices of 46 science instructors teaching 48 courses at Australian universities.

The *ATI* was developed using data from a previous study in which five approaches to teaching were identified: (1) a teacher-focused strategy with the intention of transmitting information to students (Approach A), (2) a teacher-focused strategy with the intention that students acquire the concepts of the discipline (Approach B), (3) a teacher/student interaction strategy with the intention that students acquire the concepts of the discipline (Approach C), (4) a student-focused strategy aimed at students developing their conceptions (Approach D), and (5) a student-focused strategy aimed at students changing their conceptions (Approach E). Instructors that used Approach A believed that their role as a teacher was to transmit knowledge of facts to their students. With this approach, instructors believe that students do not need to be active in the learning experience, the notes they take in lecture is all they need to learn. In this approach, the instructor does not make connections between the facts in the field, they are told to the students as they are in the textbook. Instructors that use Approach E focused on the needs of the students in order to change their conceptions and beliefs about the content. The instructor actively engages the students in the course content, and encourages them to explore their beliefs, compares them to more scientific concepts, and adopts new conceptions of the course content (Trigwell et al., 1999).

The *ATI* used Approach A and Approach E to create two scales: (1) Information Transmission/Teacher-Focused Approach (ITTFA), and (2) Conceptual Change/Student-Focused Approach (CCSFA). Each of the scales has an intention and strategy subscale. Items on the intention scale were designed to measure instructors' intentions for and beliefs about teaching and learning. An example item includes, "I feel it is important to present a lot of facts in the classes so that students know what they have to learn for this subject," which is found on the ITTFA scale. Items on the strategy scale were constructed to measure the methods instructors used in the classroom based on their beliefs about teaching and learning. An example item includes, "We take time out in classes so that students can discuss among themselves the difficulties that they encounter studying this subject." The *ATI* used a 5-point Likert-type scale in which the participants could choose from *almost always true* to only *rarely true*.

A modified version of Bigg's *Study Process Questionnaire* (*SPQ*) was used to determine how students in these courses learned course content. The questionnaire was modified to be appropriate for the students participating in the study. A total of 3,956 students enrolled in introductory level physics or chemistry classes participated in the study. The classes ranged in size from 33-243 students. The *SPQ* contained two scales: (1) Deep Approach to Learning, and

(2) Surface Approach to Learning. A surface approach to studying is memorizing facts to pass the exam and to complete a letter grade. Students who take the deep approach to learning study with the intention to understand the course material in order to make connections between course content, the course content and other courses, and to the students' personal and professional lives. Each scale on the *SPQ* had two subscales: (1) intentions, and (2) strategies.

Factor and cluster analyses were used to determine the relationship between approaches to teaching and approaches to learning. A principal components factor analysis using varimax rotation was to look at the structural relationship between combinations of variables. Results from the factor analysis determined two factors. The first factor explained 39.7% of the variance. The *ITTFA* scale loaded positively with a surface approach to studying and negatively with a deep approach to learning on the first factor. This indicated a positive relationship between a surface approach to learning and teaching to transmit knowledge. Students in classes where the instructor taught to transmit knowledge approached learning the course content as a set of facts to be memorized instead of attempting to learn for understanding. The second factor explained 24.4% of the variance. The *SCCFA* scale loaded negatively with items from a surface approach to learning on the second factor. The results indicated that teaching for conceptual change encouraged students to not use a surface approach to learning, but it cannot be concluded that they took a deep approach to learning using factor analysis (Trigwell et al., 1999).

Cluster analysis was used to identify subgroups of classes (students and instructors) that approached teaching and learning similarly. Standardized scores from the four variables were used to identify the appropriate number of clusters using Ward's minimum variance method. Two clusters were identified, and statistically significant contrasts were found on all variables, with the exception of the Teacher's Conceptual Change/Student-Focused Approach to Teaching variable. The 19 instructors grouped in cluster 1 reported that they used an information transmission approach to teaching and had students that reported using a surface approach. The 29 instructors grouped in cluster 2 reported using less of an information-transmitting approach and had students that reported using either a deep approach or less of a surface approach to learning. Again, the cluster analysis indicated an association between students taking a surface approach to learning and instructors that took an information transmission approach to teaching.

The impact of professional development on instructors' approaches to teaching and their students' approaches to learning were investigated by Gibbs and Coffey (2004). The *ATI* (Trigwell et al., 1999) was used to monitor instructors' approach to teaching at the beginning and end of a 1-year professional development program (Gibbs & Coffey, 2004). The *Student Evaluation of Educational Quality* questionnaire (*SEEQ*) and the *Module Experience Questionnaire* (*MEQ*) were used to determine students' perceptions of their instructors' teaching and their own approach to learning.

The researchers used a 5-point scale rubric to describe teachers' beliefs about the object of study, or the reason students should learn the course content, and a 6-point scale rubric to describe a teachers' belief on their approach to teaching the subject. The authors found a relationship between a teacher's belief for the object of study and their approach toward teaching. The authors also found that beliefs about teaching can be observed in the classroom. A case example presented by the authors was Dr. Matthews. Dr. Matthews was categorized as an A for the object of study. Being categorized as an A means that the teacher felt that "the object of study is the subject matter as it is represented in the external world." The focus is on the part of the curriculum assigned to that teacher, the teacher will present this topic to the students. Dr. Matthews was also rated an A on approaches to teaching. Teachers using this approach "present the material to be learned with the intention of transferring the information to the students. With this approach the teacher believed there is a body of knowledge to be presented to the students. The teacher should present the body of knowledge to the students." In his commentary, it is clear that he believed that his transmission of the materials presented in the lectures is equal to the students learning the materials.

Process Factors Impacting the Learning Environment

Students' perceptions of two different learning experiences in a physiology class were compared in a study conducted by Kim Henige (2011). Students' attitudes toward science were compared after experiencing 5 weeks of traditional low inquiry labs and then again after experiencing 5 weeks of inquiry-based lab experiences. The levels of inquiry used in the lessons were measured using the four levels of inquiry proposed by Herron (1971). The lowest level of inquiry is typical of a traditional science course with lecture and lab. The lowest level, level 0, indicates that the students do not participate in inquiry at all (Herron, 1971). The highest level, level 3, indicates the students are completely responsible for an investigation, from proposing the question, developing the means to investigate, and solving the question.

The first 5 weeks of the course was spent using level 0-1 inquiry. The students were given cookbook laboratory experiments in order to learn the basic concepts, methodologies, and tools used to investigate problems in kinesiology. During the last 5 weeks of the course, students completed an investigation where they were responsible for creating a question, developing a protocol to answer the question, making observations, drawing conclusions from the observations, and communicating their ideas in a scientific paper and presentation.

The 39 participants in the experiment were students enrolled in a physiology course for undergraduates who had completed the requirements to be accepted into the university's kinesiology program. Two surveys were given three times during the semester: (1) at the beginning, (2) after the first 5 weeks, and (3) after the last 5 weeks. The open-ended survey was given to assess students' perceptions of the two instructional methodologies in terms of enjoyment, motivation, learning, and attitude toward pursuing scientific research and career paths in science. The students could pick from three choices, (1) the first half, (2) the second half, or (3) both the same; in addition, the students were asked to explain their choice.

The researchers created an additional survey by combining subscales from two existing instruments to provide a quantitative measure for student attitudes toward science. The first set of items on the survey came from the included subscale questions from the *Test of Science-Related Attitudes* (TOSRA) and was used to assess attitudes toward scientific inquiry, and the other items on the survey came from the *Student Attitudes toward Science* (STUATT) questionnaire, which was intended to measure student motivation toward scientific inquiry. The second survey used a Likert-type scale and each half was scored according to the instrument instructions.

Chi-square analysis was used to determine differences in students' attitudes toward the materials presented in the first 5 weeks of the course and participating in the inquiry-based project in the final 5 weeks. A one-way analysis of variance was used to determine whether their attitude toward science changed from the beginning to the end of the semester. Chi-square analysis determined that students felt that the second half of the course was more enjoyable ($p < .001$) but they felt that they learned more in the first half of the course ($p < .001$). The students that reported enjoying the second half of the course stated that they enjoyed the independence of doing research, they felt the course material was more relevant in the second half, and they enjoyed being able to apply their knowledge.

Students who reported that they enjoyed the first half of the course stated that they enjoyed the structure, knowing the answer, and felt the material was explained better. Students also expressed frustration about working in groups, the amount of time it took to get results, and not having a sense of direction to get results. The students felt that they learned more in the first half of the course and stated the amount of content, having access to the lab manual and teaching assistant, and the fact that no new material was covered in the second half as reasons. The students who felt they learned more in the second half stated participating in the research project forced them to think on their own and learn the content more in depth.

Statistical analysis using ANOVA determined that the students' attitudes and motivation toward inquiry did not change throughout the semester. Similar to other studies, students enjoy doing inquiry, but because it is different from their previous experiences with learning, in particular learning science, they do not view their experience using science inquiry skills as learning. The researchers attribute the lack of change to the students being science majors, but the more likely reason is that it takes more than one course to change a student's beliefs about the nature of science (Henige, 2011).

Summary

Although research indicates lectures and labs are ineffective ways to get students to learn science, they still remain the dominant method of teaching science at the undergraduate level. Several studies indicate that instructors intend students to leave their classroom with problem-solving skills, knowledge of the nature of science, and an understanding of the course content, but instructors' beliefs about teaching and learning interfere with that ability. Instructors, like K-12 teachers, tend to teach the way they learn. If they were taught science through the lab and lecture, they will teach it that way. Instructors also do not have the pedagogical training in alternative methods to the lab and the lecture. Many of them may believe that the lecture is the best way to deliver course content and may also believe that problem-solving skills and other goals for student learning can be transmitted through lecturing.

In the study conducted by Southerland et al. (2003), one of the participants was leery of changing from a traditional method of teaching because he truly believed that students would only learn if you told them. Another participant was only willing to try methods that he had tried and had found to work in the past. In the study by Kreber (2005), instructors in the natural and physical sciences tended to mostly use content reflection when reflecting on their teaching. When they made changes to their course to help students learn better, these involved changing the content being taught. They thought about using new methods of teaching less than instructors in other fields, and thought about their own thought processes during teaching much less than instructors in other fields. Kreber suggested that instructors in the sciences (natural and physical) do not approach their teaching with the same scientific vigor with which they approach their research. Their beliefs about the nature of teaching may interfere with their doing so. Because some science instructors lack the knowledge of research in pedagogy, their pedagogical reasoning may be lessened. Their ability to transform knowledge in a way that will bring about the desired student learning, science literacy, problem-solving skills, etc. is lessened even if it is their desire to do so. When they do reflect, they use content reflection instead of process and premise reflection because they believe that students will learn if they tell them the content. Making the content easier, and more interesting when they tell it to them will help them to learn it (and therefore in their minds they are acting as a facilitator of learning). In order for reform to take place, we have to change the way science is being taught. The only way we can do so is changing the way instructors teach. In order to do this we must first begin to develop an understanding of how instructors think about teaching in a way that is scientific. That is, if we are going to draw conclusions from how a teacher's beliefs affect their classroom performance, their behavior has to be observed in the classroom.

Changing teaching methods in a course will change the way students interact with the course content. The goal is to get students to interact with the content in a way to achieve the desired educational goals. If the goal is to improve science literacy, the changes made in the pedagogy used in the classroom have to include methods that go beyond getting students to read the textbook more (Slunt & Giancarlo, 2004) to methods that show students that science is collaborative, scientific ideas change and not a set of facts to be memorized. If the efforts being made to change instruction in undergraduate science are going to have an impact, instructors need a way of knowing what that impact is. Evaluation of the changes made needs to occur in order to determine what more needs to be done or if the changes are working to increase the kind of learning we want to occur in the classroom. These evaluations need to be done in a methodological and scientific way.

CHAPTER 3

METHODS

Introduction

This chapter describes the methodology used in this mixed methods research study. This study addressed how variations in the level of reform implemented in the classroom impacted students' perceptions of the learning environment by addressing the following research questions:

1. At what level of implemented instructional reform do students notice the learning environment as being different?

2. Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?

3. What aspects of instructional reform are most associated with students perceiving the learning environment as different?

4. Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?

The sample, research design, instruments used, the reliability and validity of the instruments, and data collection and analysis procedures are detailed.

Population and Sample

This investigation used secondary archived data, data collected during a National Science Foundation funded study, National Study of Education in Undergraduate Science (NSEUS). This was a collaborative effort between researchers at the University of Alabama, Kansas State University, and San Diego State University. The primary goal of NSEUS was to investigate the short-term impact of undergraduate reformed science teaching on science learning of undergraduate students and long-term outcomes of in-service elementary science teacher (Sunal, Sunal, Mason, & Lardy, 2008). In addition to the primary research goal, the NSEUS project sought to investigate factors such as the level of reform that may have impacted the learning environment. These factors included pedagogical content knowledge, beliefs, and instructional methodologies (Sunal, Sunal, Mason, & Lardy, 2008). Each of these factors had the potential to affect how the learning environment was perceived by the students enrolled in the courses. The research reported in this study will focus on individual factors impacting the learning environment experienced by students.

The institutions participating in the NSEUS study were selected, in a stratified random sample, from 103 institutions involved in the National Aeronautics and Space Administration's NASA Opportunities for Visionary Academics (NOVA) faculty professional development program. The NSEUS study began in 2006. The initial phase of research started with e-mail and phone follow-up surveys of the population. Contacts were attempted with all institutions that participated in the NOVA program. The participants were first contacted via e-mail or phone to obtain information on the status of the course and the NOVA team. The e-mail informed the participants that they were being contacted to participate in a survey because of their participation in the NOVA program, and gave them a brief explanation of the NSEUS study and a link to the survey. In cases where the original NOVA team members were no longer at the institution, the department head was contacted to obtain information about the status of the course and contact information for the instructor(s) who were teaching the course at the time the NSEUS survey was being conducted. Participants were given 2 weeks to complete the survey before being sent reminders via e-mail. Participants who had not responded or completed the survey after 3 e-mails were contacted by phone as a reminder to fill out the survey. After the phone call was made, another e-mail containing the link to the survey was sent. The participants were given another 2-3 weeks to fill out the survey. Participants who had still not filled out the survey were contacted by phone, and a phone interview was set up obtain information in order to be used complete the survey by NSEUS graduate research assistants.

A second round of data collection was conducted to obtain information from the 72 institutions offering NOVA courses in 2006. The information obtained about the courses included: course structure, student demographics, funding to maintain NOVA course, scheduling, department support, and information about dissemination of NOVA reforms into other courses. A stratified random sample of 20 institutions was selected from the population of 72 institutions to participate in the NSEUS on science course reform at the undergraduate level based on the following criteria: (1) the course was currently being taught, (2) the content being taught was science, (3) the NOVA course still contained elements of the NOVA model, (4) the course was offered at least once a year or every other year, (5) the course was a science content course, not an education methods course, and (5) the course was required or an elective for elementary pre-service education majors.

The instructor teaching the NOVA course or an original NOVA team member was selected to act as the liaison to aid in NSEUS data collection at each institution. This person, helped arrange and coordinate NSEUS data collecting activities during the site visit to the institution. The NSEUS liaison identified and contacted the instructors teaching the undergraduate science courses. The liaison also arranged meetings with department heads, other team members and other institution faculty involved in the reform course.

The comparison courses were identified by the liaison, confirmed as appropriate by the NSEUS senior personnel, and were science courses whose instructors had not received professional development training through NASA/NOVA. Each comparison course was selected based on the following criteria (1) the course was currently being taught, (2) the content being taught was science, (3) the course was offered at least once a year or every other year, (4) was a science content and not a methods course that enrolled elementary education majors, and (5) the course was required or an elective for elementary pre-service education majors. The instructional strategies employed in the comparison classrooms were not known to NSEUS staff prior to the site visit.

Participants for the current study were selected to provide a selection of instructors with a range of *RTOP* scores, a variation in course content, and a variation in class size. Nine of the courses were NOVA courses and the remaining were comparison courses. The majority of the selected institutions were Master's granting institutions, but the sample did include one minority serving institution and two research institutions. The course content represented several fields of science including biology, chemistry, and space science. The classes varied in size from small courses with a limit of 18-20 students to large lecture courses.

Research Design

Quantitative and qualitative data were used to provide evidence that the type of instructional methods present in the classroom impacts the way students perceive the learning environment using Biggs' (1989) 3P model as the basis, q. One of the goals of Biggs' work was to provide a framework to allow instructors to improve their teaching through reflection. In Biggs' model presage factors that are found in the students and instructors participating in creating the learning environment and have the potential to influence the way learning occurs. Presage factors were the beliefs that students and instructors brought with them to the classroom. An instructor's beliefs about teaching and learning determined the kinds of instructional methods used in the classroom (Biggs, 1999). Teaching methods are described as being on a continuum from passive to active in Biggs theory of how teaching methods impact students' learning . The author described lecturing to be an example of passive learning and problem based learning to be active. In his paper (Biggs, 1999), gives examples of two types of students that may attend a course at a university. The first student, Suzan, is capable of attending a lecture, engaging in what the instructor said, and then relating, applying, and theorizing about the content using what she already knew. The other student, Robert, attempts to take notes and memorize the course content. Students like Robert would need a higher level of engagement and more active learning methods to learn the course materials. Good teaching was described helping as many students in the class learn as possible by Biggs. The author described good teaching as "getting most students to use the higher cognitive level processes that the more academic students use spontaneously. (pg. 58)" Good teaching, would involve employing several teaching methods in order to reach as many students as possible.

Process factors were the second set of factors in Biggs' (1989) model. Process factors were defined as the methods the instructor used to teach. The outcome of process factors was the product. The product was described as changes that occur in the student as a result of experiences in the learning environment. In the 3-P model, the more "good" the teaching is the better the product. In the framework for how teaching impacts student learning described by Biggs, student activities based on constructivist learning theories lead to enhanced student learning (Biggs, 1999).

The 3-P model was not linear, meaning the product factors could have impacted the presage and process factors for both the students and the instructor. The instructor should reflect on events occurring in the classroom and make adjustments to the way the course is taught to meet the needs of the students. The current study examined the three Biggs' model factors from the view point of both the instructor and the student. The intent of this study was to examine the relationship of the type of science teaching implemented in the classroom to the students' perception of the instructors' classroom learning environment. In this study, the level of instructional reform implemented in the classroom was viewed as a process factor. The level of instructional reform implemented was measured using the *Reformed Teaching Observation Protocol* (*RTOP)*. The *RTOP* allowed both quantitative and qualitative accounts of the learning environment to be measured and compared. The semi-structured instructor and student interviews were used to corroborate differences seen in scores on the *RTOP*. The interviews were used to explain the learning environment from the perspective of the instructor participants based on their beliefs about how people learn and how science should be taught. The students' perceptions of the learning environment were measured using the *Constructivist Learning Environment Survey* (*CLES*) and Student Focus Group interviews. The *CLES* provided data on student preferences for learning (presage) and how they perceive the learning environment after instruction (product). The Focus Group Interviews provided allowed the students' views of the learning environment to be explored by allowing the differences between how students who participated in science courses with varying levels of reform to be compared. Figure 2 depicts the relationship between the level of reform and students' perception of the learning environment. The relationship as depicted in Figure 2 is linear, although this is not the case. Students' responses to the learning environment often determine how an instructor teaches. For the purposes of this study, the emphasis was on instructional methods that impact students' perceptions. Differences in the way reform is implemented in the classroom may be impacted by presage factors held by the instructors such as their beliefs about teaching and learning and their beliefs about why their instructional methods are the best ways to teach the content. Science teaching reform implemented in the classroom may impact how students perceive the learning environment. Since students come to the classroom with preferences for learning and beliefs about the nature of teaching, however, presage factors impact how students perceive the learning environment. The examples described in Biggs' paper are of two students with very different approaches to learning science. One student has the motivation to learn without aid from the instructor and automatically engages in thinking critically about the science content. The other student in the example attempted to learn science be memorization and would need more active learning in order to begin to think critically about the science content. Learning style is inherent to the student, and occurs before coming to a course. A student may be more likely to perceive a learning environment more favorably if it matches his or her learning style. Understanding the relationship between these factors may help understand the difference between the successful and unsuccessful implementation of science teaching reform in the undergraduate science classroom.

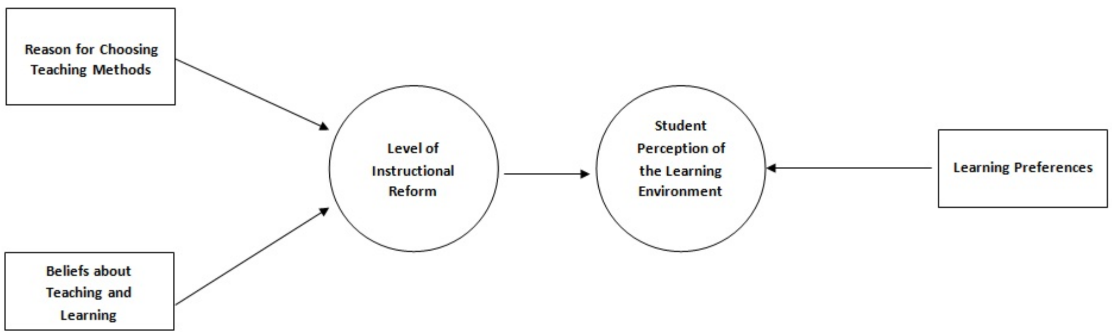

Figure 2: Model depicting the relationship between level of instructional reform and student perception of the learning environment.

Instruments

Data about the learning environment and the perceptions of the student and instructor participants were obtained from observations, interviews, and surveys. This study used the *Reformed Teaching Observation Protocol* (*RTOP*; Sawada et al, 2000)*,* instructor semi-structured interviews, *CLES,* and student focus group interviews, to determine the level of reform that an instructor used in the classroom and how this level affected student perception of the learning environment.

Reformed Teaching Observation Protocol (*RTOP*)

The level of pedagogical reform experienced by the undergraduate students in their science courses was determined using the quantitative portion of the *RTOP* (Sawada & Piburn, 2000). The *RTOP* was designed by the Arizona Collaborative for Excellence in the Preparation of Teachers to measure the degree to which a science classroom teaching reforms were being implemented in the classroom using national standards for science education (Sawada & Piburn, 2000). The instrument was divided into five subscales: (1) Lesson Design and Implementation, (2) Propositional Pedagogical Knowledge, (3) Procedural Pedagogical Knowledge, (4) Communicative Interactions, and (5) Student/Teacher Relationships. Included in the protocol were items such as "This lesson encouraged students to seek and value alternative modes of investigation or of problem solving" and "Students made predictions, estimations and/or hypotheses and devised means for testing them." The *RTOP* used a five point scale that is labeled: (0 point), never occurred (4 points) very descriptive. The observers choose the score for each scale based on classroom events (Sawada & Piburn, 2000).

The Lesson Planning and Implementation subscale was designed to document the ACEPT model of reformed teaching. The ACEPT model of teaching considered students' prior knowledge and misconceptions, engaged students as members of a learning community, and much of student learning was determined by student ideas. The Propositional Pedagogical Knowledge scale assessed the quality of the content of the lesson and how well the instructor understood the content presented in the classroom. The Procedural Knowledge scale measured the inquiry processes used to teach the lesson or how well the instructor was able to transfer their own content knowledge for student learning. The Communicative Interaction Scale measured how well the classroom environment allowed the students to communicate their ideas with each other. The Student/Teacher Relationship Scale represented the kind of relationship the instructor had with the student. The *RTOP* is included in Appendix A.

Construct validity for the *RTOP* was established using a correlational analysis where each subscale was used to predict the total score (Sawada & Piburn, 2000). Each of the five subscales was found to be strong predictors of the total score indicating good construct validity. The validity of the subscales was as follows: (1) Lesson Design and Implementation, α = .956, (2) Propositional Pedagogical Knowledge, α = .769, (3) Procedural Pedagogical Knowledge, α = .971, (4) Communicative Interactions, α =.967, and (5) Student/Teacher Relationships, α = .941 (Sawada & Piburn, 2000). Validity of the instrument was determined to be .954 using best fit linear regression of one set of observations on the other (Sawada & Piburn, 2000). Reliability for each of the subscales were determined to be (1) lesson planning and implementation, α = .915, (2) propositional pedagogical knowledge α = .670, (3) procedural pedagogical knowledge α = .946, (4) communicative interaction, α = .907, and (5) student/teacher relationships, α = .872 (Sawada & Piburn, 2000).

Semi-structured Interviews

The course instructors participating in the NSEUS study were interviewed to explore the rationale for making decisions on using the teaching methods to teach the lessons observed. The interview questions were based on an instrument to determine the pedagogical content knowledge instructors, *Content Representation* (CoRe) charts (Loughran, Mulhall, & Berry, 2004). The CoRe was developed to assess science teachers' understanding of content and methods of representing the content for student learning. Interview questions included the following, "What were the important knowledge and skills you needed to develop and teach this course?" and "What are the main goals that you wish your students to learn from this course?" Responses to the interview questions were used to develop an understanding of how instructors view the learning environment that they create and their rationale for choosing the instructional methods for teaching the course content.

The Constructivist Learning Environment Survey (*CLES*)

The *CLES* was used to determine if there were differences in students' perceptions of the learning environment between courses with different levels of reform implemented in the classroom. The *CLES* was developed by Peter C. Taylor and Barry J. Fraser (1997) to be used by high school teachers to monitor how well their constructivist approaches to teaching had been implemented. It was intended to allow teachers to understand their students' perceptions of the extent to which the classroom-learning environment enabled them to reflect on their prior knowledge, develop as autonomous learners, and negotiate their understandings with other students. The *CLES* contained five scales: (1) the Personal Relevance Scale measured how relevant students feel the course content is to their lives outside of the classroom, (2) the Uncertainty Scale measured the students' perception of the level of inquiry based science knowledge in the classroom (3) the Critical Voice Scale measured students' perceptions of their ability to question the teacher's pedagogy, (4) the Shared Control Scale measured students' perceptions of their control over classroom learning, and (5) the Student Negotiation Scale measured students' perceptions of their ability to share their ideas with other students in the classroom. Possible responses to the items on the *CLES* were as follows: *Almost Always* (5), *Often* (4), *Sometimes* (3), *Seldom* (2), and *Almost Never* (1).

The original version of the *CLES* contained 35 items which was reduced to 30 (Taylor, Fraser, & Fisher, 1997). On previous versions of the instrument, the items were placed in random order. In order to improve reliability and validity, the authors changed the order of the items of the *CLES* so that they were grouped based on scale in (Taylor et al., 1997). The reliability of the scales was above .60 and considered to be indicative of good internal consistency using Cronbach's alpha (Taylor et al., 1997. The reliability values were as follows: (1) the Personal Relevance Scale $\alpha = .82$, (2) the Uncertainty Scale $\alpha = .64$, (3) the Critical Voice Scale $\alpha = .88$, (4) the Shared Control Scale measures $\alpha = .95$, and (5) the Student Negotiation Scale $\alpha = .94$.

Participants in this study were given the revised version of the instrument (Taylor et al., 1997) that can be found on line at: http://surveylearning.moodle.com/*CLES*. This version of the *CLES* contained 25 items with 5 items on each scale. An item reading, "In this class the teacher asked me questions." was added to the survey and placed on the Relevance scale.

Two versions of the instrument were given to the students during the year, the pre-test or preferred version of the instrument was given during the beginning of the semester, and the post-test or perceived version of the survey was given at the end of the semester. This was done to measure student perception of the degree to which their preferences for the classroom environment occurred during the year. When the comparing the perceived version of the *CLES* to the preferred version of the *CLES*, a significantly negative score could indicate that the students' perceived that their preferences for their learning environment had occurred in the classroom. A significantly positive score would indicate that students did not perceive their preferences of what should be occurring in the classroom. Scores for each scale were determined by totaling each item for that scale. The total score was determined by summing all items on the instrument.

Student Focus Groups

Student focus group interviews were used to provide insight into the students' perceptions of the classroom environment, understanding of science, and in the case of elementary education majors; their science teaching efficacy examined. The interviews were used to develop a description of the students' experiences of university science classrooms with various level of reform. Sample focus-group questions include (1) How would you define science or the nature of science? and (2) Describe how has your understanding of science content changed as a result of taking this course?

Data Collection Procedures

The NSEUS national study consisted of four co-principal investigators, four graduate research assistants, and a post-doctoral fellow in three teams located in three parts of the United States. Each team was responsible for visiting the institutions located in their region. The collaborative team members were experts in the fields of physics, chemistry and biology and science education research at the K-12 as well as the undergraduate level.

The data were collected from 9 of the 20 sampled institutions by the NSEUS collaborative teams between 2006 and 2011. The data collection occurred in three phases over a full semester. At the beginning of the semester, demographic data were collected from the students. In addition the students were given the preferred *Constructivist Learning Environment Survey* (*CLES) during the first 1 ½ weeks of the semester*. The demographic data included: (1) academic major, (2) university or college level science courses, (3) year-level, (4) gender, and (5) interest level in taking science courses. The demographic preferred *CLES* were administered and collected on-line by the NSEUS teams. During the middle of the semester, a weeklong site visit to each institution was conducted. The data collected was both qualitative and quantitative in nature allowing for data triangulation and a more complete picture than quantitative or qualitative could have provided alone. During these visitations, the NOVA and comparison courses were observed. Observations were made on all activities associated with the courses during this time in order to develop a more complete picture of the student learning experience. *RTOP* was used to collect data from the undergraduate science classroom lessons presented by participating instructors. For every instructor whose classroom was visited, an interview was conducted, and course artifacts were collected from participants. Semi-structured interviews, course artifacts, and observation field notes from the *RTOP* narrative were used to create a profile of beliefs and teaching rationale for each instructor. Students enrolled in the NOVA and comparison courses were invited to participate in focus group interviews.

At the semester's end, post-test data were collected from the students. The students completed the *perceived CLES* on-line. The perceived *CLES* differs from the preferred *CLES* in that the questions are worded to capture the level of constructivist learning the student experienced in class. Table 1 outlines the data collected during the semester including data not used in this study.

The Reformed Teaching Observation Protocol (RTOP)

The undergraduate students and instructors were observed in their classrooms for a week. Each lecture, laboratory, and discussion course sections was observed by NSEUS team members. Typically, two or more observers attended the lecture, lab, discussion sections, or any other instructional time experienced by the students. Each observer took notes and gave the instructor a score on each of the *RTOP* scales. After the instruction; the observers who attended the session came to a consensus score. If more than one lecture, laboratory, discussion group or other course activity was observed, the scores were averaged to come up with a composite instructional score for the instructor. Each instructor received six scores on the *RTOP*, one overall score which is the summation of all items on the instrument, and a score for each of the subscales. The *RTOP* narrative notes were detailed accounts of the environment that the learning took plan in and occurrences that happened in the classroom. Student engagement in the lesson, and the ways in which the students and teacher interacted with each other and the course content were recorded. Observers recorded thoughts about the quality of the lesson being presented, science misconceptions in the lesson, and the methodology used to engage the students in learning.

Semi-structured Interviews

The semi-structured interviews were conducted mid-semester during the site visit. The participants, faculty instructors, arranged a day and a time that they would be available to be interviewed. One or more of the visiting team were present when the interviews were conducted. The interviewers took notes of the interview, and in some cases interviews, with a single interviewer, were recorded using a digital recorder. When the interviews were recorded, they were transcribed verbatim. The interviews were conducted in the instructors' offices or in another place selected by the interviewee. Interviews lasted between 30-45 minutes. The participants were not given the questions prior to beginning the interview. The interviewees were told they were going to be interviewed in regards to their beliefs about teaching with emphasis on the lesson that was observed. The interviewees were informed that they did not have to answer any question that they did not feel comfortable answering, and that the interview could be stopped at any time.

Interviewees were allowed to express themselves freely. In some cases, responses to the question were unexpected and relevant leading to the researcher conducting the interview to ask probing questions to get the interviewee to elaborate on their answer. For example, as a data collector in the NSEUS study one instructor who had extremely low expectations for students stated frustration when one of the students questioned her choice of pedagogy. The conversation with this instructor helped the interviewer to realize how strong an influence pedagogical beliefs about teaching and learning have on instructors' choices for classroom instruction. Probing questions were also asked in an effort to get the interviewee to elaborate on their answers.

The Constructivist Learning Environment Survey

The *CLES* survey was given to the undergraduate students at the beginning and the end of the semester through an online web connection. The instructor of each course was asked to briefly describe the NSEUS study and direct the students to the website containing the survey instruments used in the study. Reminders to participate were sent to the students via e-mail.

The students were given six sub-scores and a total score consisting of the summation of all items on the *CLES* instrument and a score for each of the scales.

Student Focus Groups

Undergraduate student focus group interviews were conducted mid-semester during the site visit. The faculty instructors were asked to encourage students to participate in the interviews. Several interview days and times were set up in an effort to increase student participation. Separate student focus group interviews for NOVA and comparison courses were held in conference rooms with up to five student participants. The students were asked questions dealing with their college science experience, and this specific science course experience. The students were asked about the science lesson that was observed during the site visit. Student participants were told that they could speak freely. When student responses lead to unexpected directions, the interviewer allowed them to continue in the direction they were going in effort to gain better insight into student perception of the learning environment.

Data Analysis

Concurrent triangulation of mixed methods design was used to determine which aspects of the learning environment had a significant impact on student perception. This study was considered to be concurrent triangulation because the qualitative and quantitative data were collected and analyzed at the same time. The qualitative data were not collected, analyzed, and then used to design the quantitative data or vice-versa (Rauscher & Greenfield, 2009; Wengraf, 2001). All data were collected during the same collection period. The quantitative instruments were not designed after analyzing the qualitative data were analyzed or vice-versa. Mixed method analysis has the advantage of allowing research problems to be explored more completely than quantitative or qualitative research alone (Gall, Gall, & Borg, 2007). Concurrent triangulation allows researchers to explore questions dealing with what, why, and how (Rauscher & Greenfield, 2009). Quantitative research could only be used to establish differences between groups, determine relationships between variables, and make predictions. The use of qualitative research in this study allowed differences to be described in detail from the viewpoint of the people who lived the experience, and provided evidence to support hypotheses in the literature that increased instructional student satisfaction with the learning environment. The weakness of qualitative research is that it cannot be used to determine whether these relationships are significant. Mixed method research takes advantage of both quantitative and qualitative research by providing triangulation between statistical and descriptive data (Creswell, Plano Clark, Guttman, & Hanson, 2003. The rationale for using mixed methods is that quantitative data can be used to identify statistical differences between groups and establish relationships between variables and qualitative data is used to refine, explain, and provide insight into differences that are not captured using the observation and survey instruments.

The research design used in this study was quasi-experimental with nonequivalent control groups because the participating instructors and students were not randomly assigned to NOVA or comparison groups (Gall et al., 2007). Random assignment of participants to groups would be ideal and to control for pre-existing variation in the groups.

The level of instructional reform implemented was used as a factor to determine differences in student perceptions of the learning environment. The level of reform used in the classroom was defined by score on the *RTOP*. Qualitative data derived from the semi-structured interviews were used provide a more in-depth analysis of what an instructor does in the classroom that cannot be measured using the quantitative portion of the *RTOP*. Student perception of the learning environment was measured using the *CLES*. Student focus group interviews were used to provide evidence as to how the students perceived the learning environment and determine how the students felt the learning environment impacted their ability to learn course content. The data analysis investigated the relationship between the level of reform implemented in the classroom and students' perception of the learning environment. In order to begin determining the relationship between instructional reform and how students' perceive the learning environment, the following questions were answered: (1) At what level of implemented instructional reform do students notice the learning environment as being different?

(2) Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform? (3) What aspects of instructional reform are most associated with students perceiving the learning environment as different? and (4) Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?

Table 1 summarizes the instruments that were used and the rationale for the use of each instrument to address each question.

Table 1

Research Questions and Instruments Used In the Study

Question	Instrument(s)	Rationale	Timeline
1. At what level of implemented instructional reform do students notice the learning environment as being different?	*RTOP* *CLES*	The quantitative portion of the *RTOP* was used to differentiate between instructors based on the level of reform used in the lesson observed during the visit. The *CLES* was used to measure students' perception of the learning environment.	The *RTOP* were conducted mid-semester. The pre- and post-instruction versions of the *CLES* were given at the beginning and end of the semester respectively.
2. Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?	*RTOP* *CLES*	The *RTOP* provided a measure of the level of reform in the classroom. The scales on the *CLES* measured how students perceived aspects of the learning environment.	

(*table continues*)

Question	Instrument(s)	Rationale	Timeline
3. What aspects of instructional reform are most associated with students perceiving the learning environment as different?	*RTOP* *CLES* Semi-structured interviews.	The scales of the *RTOP* were used to determine the relationship between aspects of reform and student perception of the learning environment as measured by the *CLES*. Semi-structured interviews provided insights into how instructors perceived the learning environment they created for their students.	
4. Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?	*RTOP* *CLES* Student Focus Group Interviews	Repeated measures analysis was used to determine the relationship between student satisfaction with the learning environment and the level of reformed used in the classroom. Student focus group interviews were used to provide insight into how students perceived the learning environment and their level of satisfaction with how they were able to learn science.	Student focus group interviews were conducted mid-semester.

Research Question 1: At what level of implemented instructional reform do students notice the learning environment as being different?

Undergraduate science education reform is intended to transform the learning environment into one that allows students to develop critical thinking and problem-solving skills (NRC, 2003; Siebert & McIntosh, 2001). Students will adapt their study habits to meet fit the teaching methodologies outlined by the instructor (Biggs, 1999; Martin, Prosser, Trigwell, &

Benjamin, 2000; Partin, 2008). The learning environments observed in the NSEUS study had various levels of instructional reform implemented (Sunal, Sunal, Sundberg, Mason, Lardy, Zollman, & Matloob 2007. In order to answer the question, "At what level of reform implementation do students notice the learning environment as being different?," Univariate Analysis of Covariance (UNIANCOVA) was used to determine how high or low the *RTOP* score has to be before a difference is seen on the total score on the perceived or post version of the *CLES*.

Research Question 2: Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?

Studies indicate that when students are more satisfied with their learning environment, they demonstrate increased learning outcomes (Biggs, 1999; Partin, 2008, Martin et al., 2000). This question will help determine which aspects of the learning environment are important for allowing students to feel that they can learn science. This analysis was used to examine this question to determine how various levels of reform impact how students perceive different aspects of reform related to a constructivist theory of learning. The subscales of the *CLES* were used to determine how constructivist students perceived their learning environment to be.

Univariate Analysis of Covariance was used to determine the impact of the level of reform on students perceptions of aspects of reform instructional methods implemented in the classroom. The independent variable, Level of Reform, had 3 levels, high, medium, and low. The scales of the *CLES* were used as the dependent variables. The total pre-*CLES* scores were used to control for differences on the *CLES* that existed prior to instruction.

Research Question3: What aspects of instructional reform are most associated with students perceiving the learning environment as different?

Question 3 was analyzed using Multivariate Analysis of Variance (MANOVA) with the total *RTOP* score and *RTOP* scales as the co-variables, and post-test scores of the *CLES* as the dependent variables to determine which aspects of science education reform impacted the students' perception of the learning environment. Question 3 was also analyzed qualitatively. The semi-structured interviews of the faculty participants were analyzed in to find common themes in the way the instructors felt their teaching methods impacted student learning. The interviews were also analyzed for themes dealing with how the instructors designed their lessons for student learning and reflections on teaching. The questions indicated in Appendix G were analyzed more closely than other questions because these questions directly asked the instructor to espouse upon their beliefs about student learning and designing a lesson for student learning. The interviews were analyzed three times. The first round of analysis was done to determine common themes found in all of the interviews regardless of the level of reform used in the classroom. For example, the interviews were analyzed for the instructors' beliefs about why it is important for students to learn the course content. The second round of analysis was used to determine if there were any commonalities between instructors in the high *RTOP* group, medium *RTOP* group, or low *RTOP* group. Finally, the three groups were compared with each other.

Research Question 4: Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?

Studies have shown that "good teaching" increases student learning in that the focus is no longer the content or what the teacher does, but the student (Biggs, 1999). Student collaboration with the instructor and their peers have positive outcomes for student learning as the students are able to voice their thoughts about the science content while building a more scientific understanding (Biggs, 1999; Martin et al., 2000; Partin, 2008). The *CLES* contained five subscales: (1) Personal Relevance, (2) Uncertainty, (3) Critical Voice, (4) Shared Control, and (5) Student Negotiation. The Personal Relevance and Uncertainty scales both deal with the nature of science in that the former deals with the application of scientific concepts to the world outside of the classroom and the latter deals with the idea that science is not a set of facts with no relationship to anything outside of the classroom. The other three scales deal with interactions between participants in the classroom. To determine whether higher levels of reform are associated with higher satisfaction with the learning environment, Repeated Measures analysis was used. The instructors were divided into groups based on their score on the *RTOP* and Repeated Measures analysis was used to determine if the level of reform impacted student satisfaction. Student satisfaction with the learning environment was determined by the change in *RTOP* score between the pre- and post-tests.

The student focus groups interviews were analyzed for the students' views of the learning environment in terms of how they felt they were able to learn science, their views about science in relationship to their lives, their roles as students, and the instructor's role as a teacher. Similar to the analysis of the semi-structured interviews, the focus groups interviews were analysis to develop themes found in the students' perceptions of the learning environment, to develop a description of students' views of the learning environment based on level of reform, and to compare the views of students from courses with varying levels of reform viewed their learning environment. These themes will be used to support differences in scores on the *CLES* based on level of reformed and student satisfaction in relationship to the level of reform implemented in the classroom.

All analyses were completed using SPSS PASW Statistics 18. All statistics were run at the 95% confidence level. The research questions, instruments, methodology, and analyses that were used to address each question are summarized in Table 2.

Table 2

Statistical Analyses Used to Address the Research Questions

Question	Instrument(s)	Methodology	Analysis
1. At what level of implemented instructional reform do students notice the learning environment as being different?	*RTOP* *CLES*	Statistical analysis was used to determine how high or how low the score on the *RTOP* has to be before a difference in student perception of the learning occurs as determined by score on the *CLES*.	General Linear Model: Univariate Analysis of Covariance
2. Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?	*RTOP* *CLES*	Statistical analysis was used to determine which scale on the *RTOP* has the biggest impact on student perception of the learning environment as determined by score on the *CLES*. Qualitative analysis was used to provide corroboration for and description of differences in the level of reform used by participants that may impact students' perceptions of the learning environment.	General Linear Model: Univariate Analysis of Covariance Qualitative analysis

(*table continues*)

Question	Instrument(s)	Methodology	Analysis
3. What aspects of instructional reform are most associated with students perceiving the learning environment as different?	*RTOP* *CLES*	MANOVA was used to determine which scale on the *CLES* is impacted the most by the total *RTOP* score.	MANOVA
4. Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?	*RTOP* *CLES* Student Focus Group Interviews	Statistical analysis was used to determine if higher level of reform being implemented in the classroom is related to higher satisfaction with learning environment. Qualitative analyses will be used to provide corroboration for and description of differences in the level of reform used by participants that may impact students' perceptions of the learning environment	Repeated measures Qualitative analysis.

Summary

Research into learning environments at the undergraduate level has identified "good teaching" as being associated with students perceiving the learning environment as positive. Having a positive view of the learning environment was shown to impact the approach students took to learning, and impact their content learning. The research in this dissertation explored aspects of the learning environment that impact student perception. Data from the NSEUS project was used to provide data about instructional reform at the university level as well as the perception of the students and instructors experiencing reformed science education. The *RTOP* was used to measure the amount of instructional reform observed during site visits and interviews from instructors and students provided corroboration of the observers' notes. The

CLES was used to provide a quantitative measure of the students' perception of the learning environment. First, the objective was to explore the degree to which a learning environment has to be reformed or traditional before students notice the difference. This objective was explored to determine of how much effort an instructor has to put into making methodological changes in the classroom that may be associated with students viewing the learning environment. After establishing the level of instructional reform that has to be present, or absent, before students notice the learning environment is different using the *CLES* and the *RTOP*, interviews from the students and instructors were analyzed for similarities and differences. The results from the analyses are discussed in Chapter 4 and the conclusions are discussed in Chapter 5.

CHAPTER 4

ANALYSIS OF DATA

Introduction

This chapter describes the analysis of data collected to determine the impact that science education reforms had on student perceptions of the learning environment in introductory level science courses from 20 institutions of higher education throughout the United States. The statistical and qualitative analysis procedures used to answer each study research question are described separately.

Research Question 1: At what level of implemented instructional reform do students notice the learning environment as being different? Analysis procedures included univariate analysis of covariance using the total score of the *RTOP* as the scale variable, perceived (post-test) version of the *CLES* as the dependent variable, and the preferred (pre-test) version of the *CLES* as a covariate.

Research Question 2: Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform? The question was analyzed using univariate analysis of variance with the total score of the *RTOP* as the scale variable, the scores from each scale on the perceived version of the *CLES*, and the preferred version of the *CLES* as the covariate. The total score on the *RTOP* was used to create three groups based on *RTOP* rating. The high group included professors with a rating of 71 or above. The low group included instructors with a rating of 45 or below. The medium group included instructors with a rating between 46 and 70.

Research Question 3: What aspects of instructional reform are most associated with students perceiving the learning environment as different? This question was analyzed using multivariate analysis of variance with the sub-scales of the *RTOP* rating as the independent variable and post-test scores of the *CLES* as the dependent variable. Semi-structured interviews of participants were used to provide greater understanding of how the instructors felt the teaching methods that were used in their classroom impacted their students' learning.

Research Question 4: At what level of implemented instructional reform do students notice the learning environment as being different? This was determined by using repeated measures analysis of variance using the *RTOP* rating, the total rating, and the ratings on each scale as the scale variables and pre- and post-test scores of the *CLES* as the dependent variable that changed over time. Research Question 4 was also analyzed qualitatively to provide a description of the learning environments as experienced by the students. Their interviews were analyzed for themes surrounding communication of ideas, the amount of control they have of their own learning, relevancy, and the nature of science.

Research Question 1

The first research question examined how reformed an entry-level undergraduate science course had to be before students perceived a difference in instruction. Univariate analysis of variance was used to determine at what level of reform students begin to perceive differences in instruction. The data used to analyze question 1 included the *RTOP* scores from 15 instructors that participated in the NSEUS study and the perceived *CLES* scores from 167 students enrolled in their courses. The sample of instructor and student participants was the same for all classes. The dependent variable was the total score on the perceived version of *CLES* and the independent variable was the total score on the *RTOP*. The sample course instructors' ratings on the *RTOP* ranged from 35 to 93. Both the *RTOP* and the *CLES* are based on constructivist teaching and learning methods.

RTOP ratings can range from 0-100. A rating of 50 on the *RTOP* is considered to be indicative of a course that contains a "considerable presence of reformed teaching" (McIssaac & Falconer, 2004). The authors also provided the following descriptions for courses based on their observations: >20 traditional university lecture (passive), >30 university lecture with demonstrations (some student participation), >45 traditional high school physics lecture (with student questions), >55 partial high school reform (some group work; most discourse still with teacher), 65-75 partial high school reform (some group work; most discourse still with teacher), 70-75 the author's modified (whiteboards, etc.) large (170 > n > 75) lectures, and 65-99 modeling curriculum (varied with amount and quality of discourse).

Using the last description, 65 was considered a high score on the *RTOP* and used as the score to begin determining how high the score on the *RTOP* had to be in order for the sample of students used in this study to perceive a difference in the way their course was taught as determined by the score on the perceived version of the *CLES*. A course with a score of 65 should contain some level of the model of reformed teaching as described by ACEPT. A score of 50 was used to begin making the determination of how low the *RTOP* score had to be before students in the sample began to notice a difference. Starting with a total score of 50, Univariate Analysis of Covariance was conducted by comparing instructors with a score of 50 or higher to instructors with a score of 50 or lower. The analysis was continued by increasing or decreasing the *RTOP* score until differences between the two groups were seen. The total rating on the preferred *CLES* was used as a covariate in order to control for differences in learning preferences that existed in students prior to discussion. Significant results and test assumptions are discussed below. The significant results are shown in Table 3.

Table 3

The Level of Instructional Reform Necessary to Impact Student Perception of the Learning Environment

Independent Variable	*F*	Sig.
RTOP Rating 71 or Above	4.49	.035
RTOP Rating 45 or Below	5.13	.024

Note. Dependent Variable: post *CLES* Total Rating.

Levene's test for homogeneity of variance was used to determine whether variance in the groups that were being compared were equal. Violations of the assumption that the variance in the group was equal indicated that statistical differences were unlikely to have occurred based on random sampling from a population with equal variances. The Levene's tests indicated the homogeneity of variance was met for one but not both comparisons. The assumption was met when comparing instructor's with an *RTOP* ranking below 45 to those with rankings above 45, F (1, 165) = .05, p = .82). The assumption was not met when comparing instructors who were rated 71 or above with instructors who were rated 70 or below F (1, 165) = 4.35, p = .04). The assumptions of normality of distribution were determined to be satisfied via examination of the residuals on the Q-Q plot shown in Figure 3. The Q-Q plot indicates a normal distribution. A review of the Shapiro-Wilk test for normality revealed a deviation from a normal distribution (SW (167) .98, p = .04). The statistics for skewness (-.37) and kurtosis (-.06) were acceptable.

Despite the violations of assumption, the researcher decided to retain the model and statistical results from this analysis should be viewed with caution.

It was determined that in order for the students who participated in this study to perceive differences in instructional methods using the *CLES*, a score of 71 or higher (F (3, 163) = 4.16, p = .04) or 45 or lower (F (3, 163) = 5.13, p = .02) had to be made on the *RTOP*. Similar to the descriptions given by McIssaac and Falconer (2004), a score of 45 indicated fewer reformed instructional methods were used in the observed lesson, the results from this study indicated that the students were able to perceive differences in courses with an *RTOP* score below 45 when compared to those with scores above 45. Students did not perceive a significantly higher level of reform in their courses until a score of 71 was reached.

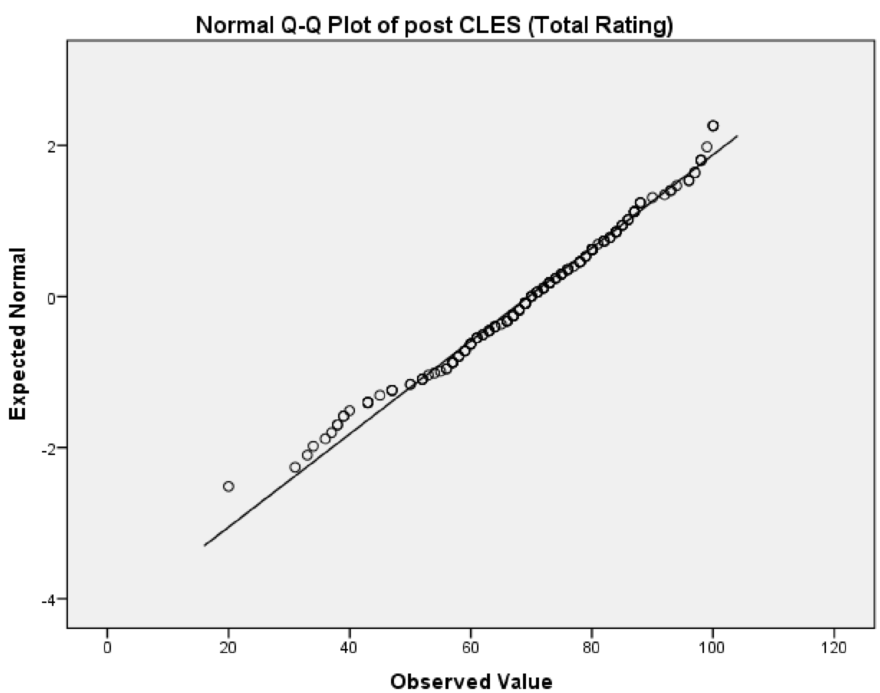

Figure 3. Q-Q plot for the normal distribution of the CLES post-test ratings.

The level of instructional reform implemented in the classroom has to be above 71 and below 45 before students noticed the difference in the learning environment. Using the descriptions provided by McIssac and Falconer (2004), students noticed the learning environment if it is completely teacher centered or if several aspects of science education reforms have been implemented. These results indicate that communication, especially communication between students, impacts student perception. These results also add to the observations made by McIssaac and Falconer (2004) in that a score of 45 and below on the *RTOP* is indicative of a traditional lecture course.

Research Question 2

Research Question 2 states, "Which aspects of the learning environment do students perceive as most different in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?" The aspects of the learning environment were defined using the sub-scales of the *CLES.* The *CLES* contained five sub-scales that measure how well the learning environment allowed students to construct their own learning of science concepts. The *CLES* contained five scales: (1) the Personal Relevance Scale (2) the Uncertainty Scale, (3) the Critical Voice Scale, (4) the Shared Control Scale, and (5) the Student Negotiation Scale. The five scales of the *CLES* focused on the relevance of the science content presented to the students' lives, the degree to which the students are allowed to use inquiry and critical thinking skills to learn science concepts, the level of control students have over how and which concepts are taught, and the interactions the students have with their peers and the instructor.

The level of reform was defined using the total score for the *RTOP*. Question 1 established that an instructor had to achieve a score of 71 on the high end and a score of 45 on the low end on the *RTOP* to make a difference in students' perception of the learning environment, as determined by mean score on *CLES*. To make this comparison, the course instructors were divided into three groups based on differences found in the analysis of Research Question 1. The high group was defined as instructors scoring 71 or higher. The medium group included instructors with a score between 46 and 70. The low group was comprised of instructors with a score of 45 and below. These groups were used to create the *RTOP* instructional Level of Reform variable.

Univariate Analysis of Covariance (UANCOVA) was used to determine the impact of the level of instructional reform on students' perceptions of aspects of learning environment implemented in the classroom. The independent variable, *RTOP* Instructional Level of Reform, had three levels: high, medium, and low. The sub-scales of the *CLES* were used as the dependent variables. The total pre-*CLES* scores were used to control for differences on the *CLES* that existed prior to instruction. The mean score for each level of *RTOP* instructional Level of Reform on each scale are shown in Table 4. The results for the Univariate Analysis are shown in Table 5. For brevity, only the statistically significant results are shown.

Table 4

Means, Standard Deviations, and Sample Size for Each Sub-scale on the CLES

Dependent Variable	Independent Variable	*M*	*SD*	*N*
Relevance Post	High	24.18	4.39	55
	Medium	22.16	6.53	63
	Low	23.24	5.20	46
Uncertainty Post	High	17.85	4.42	55
	Medium	17.57	5.52	63
	Low	17.87	4.92	46
Critical Voice Post	High	16.13	3.82	55
	Medium	15.65	4.30	63
	Low	13.83	4.54	46
Shared Control Post	High	14.89	5.45	55
	Medium	13.33	5.55	63
	Low	11.63	5.71	46
Student Negotiations Post	High	22.93	2.96	55
	Medium	22.59	3.78	63
	Low	16.65	6.05	46

Table 5

Results from Univariate Analysis

Dependent Variable	*F*	Sig.
Critical Voice Subscale Posttest	4.246	.006
Shared Control Subscale Post	3.444	.018
Student Negotiations Subscale	22.435	.000

Assumption testing was performed when significant results were found. Levene's test for homogeneity of variance was not statistical significant for the three groups (F (2, 164) = 1.39, p = .25), indicating that the assumption was satisfied for the variance in the Critical Voice subscale on the *CLES* post-tests. The Shapiro-Wilk test for normality revealed a deviation from a normal distribution for the Critical Voice subscale (SW (167) .90, $p < .001$). The statistics for skewness(-.77) and kurtosis (-.17) were acceptable. The distribution was normal as indicated in the Q-Q charts shown in Figure 4. For the Shared Control Rating on the *CLES* post-test, Levene's test for homogeneity of variance was not statistically significant for the three groups (F (2, 164) = .29, p = .750), indicating that the assumption was satisfied for the variance. Using the Shapiro Wilk test, a deviation from normal was found for the Shared Control subscale of the *CLES* post-test (SW (167) .90, p < .001). The skewness (.30) and kurtosis (.79) were found to be acceptable. The Q-Q chart indicating a normal distribution for the Shared Control post-test is shown in Figure 5. The Levene's test was statistically significant for the Student Negotiations subscale on the *CLES* posttest F (2, 164) = 18.03, p < .001). The skewness (-1.24) and kurtosis (.65) were found to be acceptable. The Q-Q chart indicating a normal distribution for the Shared Control post-test is shown in Figure 6. Despite the violations of assumption, the researcher decided to retain the model, and statistical results from this analysis should be viewed with caution.

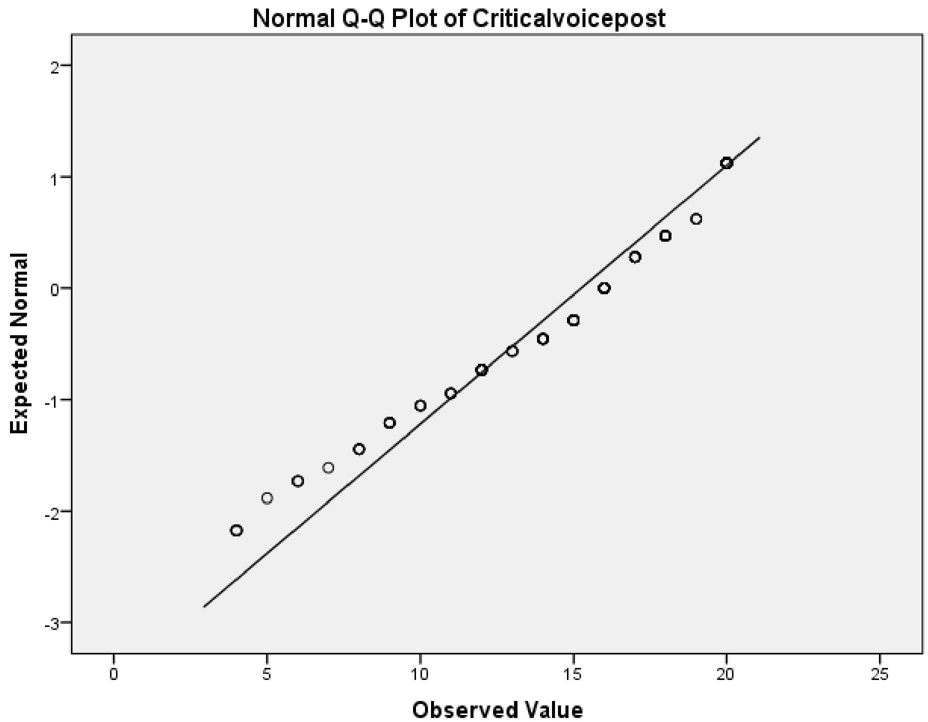

Figure 4. Q-Q plot for the normal distribution of the critical voice subscale post-test ratings.

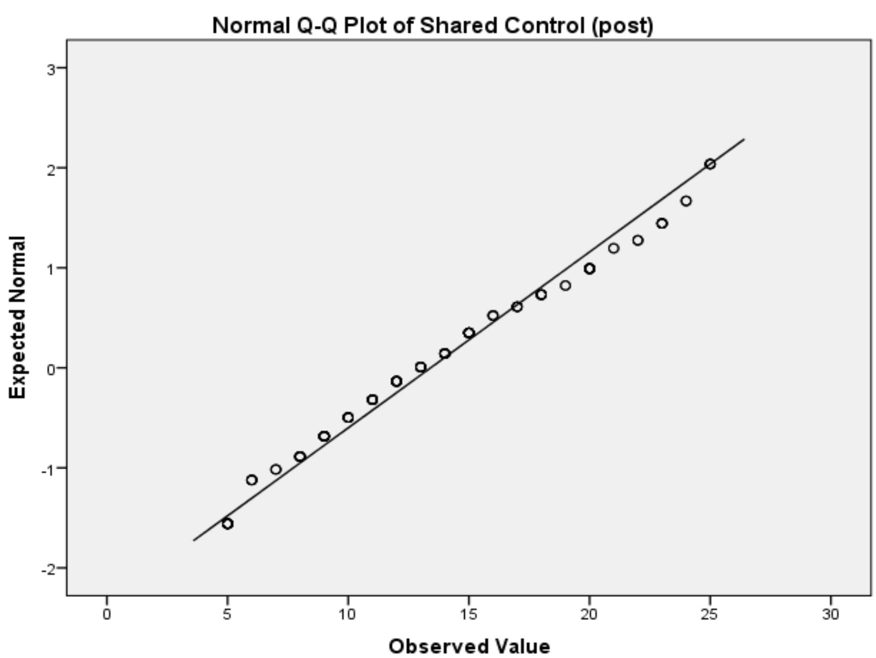

Figure 5. Q-Q plot for the normal distribution of the shared subscale post-test ratings.

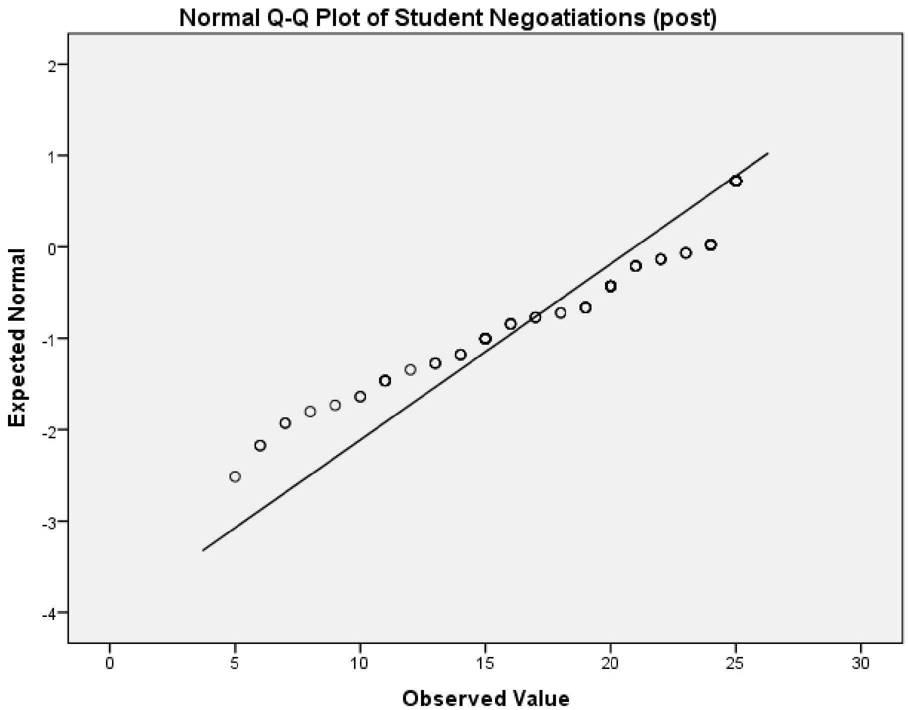

Figure 6. Q-Q plot for the normal distribution of the shared control subscale post-test ratings.

The UANCOVA analysis was found to be significant for three of the five sub-scales on the *CLES*, indicating that the level of reform implemented in the course impacted the student scores on those three scales. The Critical Voice Post (F (3,163) = 4.27, p = .006), Shared Control (F (3,163) = 3.76, p = .02), and Student Negotiations (F = 18.30, p < .001) sub-scales were significantly different between the high, medium, and low *RTOP* groups. The higher the *RTOP* score, the higher the score was on each of these scales. Eta-Squared is the portion of variance explained by the main effects, interactions, and error associated with an analysis of variance or co-variance study. Eta-Squared can be used to determine the degree to which each main effect contributed to the variance in the model. In this model, the pre-test *CLES* scores were used to control for any variation in students' preferences for learning that may have impacted how they perceived the learning environment. Together, the Critical Voice, Shared Control, and Student

Negotiations subscales explained 37% of the variance in the model. These results indicated that the majority of the differences in the way students perceived the learning environment between the three groups lies within the ability of students to communicate their ideas to each other and their instructors. Even controlling for differences in how students preferred to learn, these sub-scales played a significant role in how students perceived the learning environment.

Bonnferroni post hoc procedure for multiple analyses was performed to determine where the differences between the three groups occurred. The Bonferroni test for the Critical Voice Scale showed that the high group was significantly different than the low group ($p = .045$). The high group was significantly different from the low group on the Shared Control Scale ($p = .02$). The high ($p < .001$) and medium ($p < .001$) groups were both significantly different from the low group on the Student Negotiations Scale. The Bonnferroni results further emphasized the idea that student negotiations in the classroom were a key factor in the perceptions that students have regarding the learning environment. Differences were between all three levels of the independent variable. The results indicate the instructional methods that the students perceive are the ones that allow them to be more active participants in their learning. The Shared Control, Student Negotiations, and Critical Voice scales are all measures of how much of the communication about science in the classroom was done by the students. The level of satisfaction that the students felt about the learning environment is addressed in Question 4.   The poc hoc analysis of the data revealed that the biggest differences between the three groups lied between the low and high *RTOP* groups.

Research Question 3

Research Question 3 asked, "What aspects of instructional reform are most associated with students perceiving the learning environment as different?" Question 3 data were analyzed using Multivariate Analysis of Covariance (MANCOVA) with the total *RTOP* score and *RTOP* sub-scales as the covariables, and post-test scores of the *CLES*, the total score, and the sub-scales, as the dependent variables. The post-test scores of the *CLES* included both the total score and the sub-scale scores. Multivariate analyses allows for the interpretation of the main effects and interactions of multiple variables. In this study, it was used to determine the impact of how an instructors' methodologies impacts students' perception of the learning environment. Both the behavior of instructors and students' perceptions of the learning environment are multifaceted. This study used the *RTOP* and its sub-scales as a measure of what an instructor does and the *CLES* and its subscales as a determination of how students perceive the learning environment. MANCOVA allowed for the interpretation of how several aspects of an instructor's behavior impacted the ways in which their students perceived the learning environment while controlling for differences that existed between the students prior to instruction.

The univariate effects of the MANCOVA were examined to determine the impact of the variation of rating on the *RTOP* and its subscales on the ratings on the *CLES* and its subscales. The univariate effects were examined to determine which of the subscales the *CLES* were impacted by the different scales of the *RTOP*. The results are shown in Table 6. Test for normality indicate that the scores on the significant subscale on the *CLES*, the Student Negotiation scale, were not normally distributed (SW (163) = .78, $p < .001$). The kurtosis (.60) and skewness (-1.22) of the distribution were within an acceptable range. The Total *RTOP* score was significant for the Student Negotiations subscale (F (1, 163) = 9.95, $p = .001$). When examining the impact of the sub-scales of the *RTOP*, each of the sub-scales impacted aspects of the *CLES.* The Lesson Planning and Implementation sub-scale was significant for the Student Negotiations Scale (F (1, 163) = 9.03*,* p = .002). The Procedural Knowledge sub-scale had a significant impact on the Student Negotiations Scale (F = 12.301*,* p = .001). The Communicative Interactions sub-scale had a significant impact on the Student Negotiations subscale of the *CLES* (F = 11.53, p = .001).

Similar to the findings in Research Questions 1 and 2, Student Negotiations in the learning environment was a significant factor that the student participants in the study noticed. The Student Negotiations sub-scale of the *CLES* was impacted by the Total Score and four of the sub-scales of the *RTOP* indicating the way that ideas are communicated in the classroom may be important to the way students perceive the learning environment. The higher the rating on the *RTOP* or its subscales, the higher the rating on the Student Negotiation subscale of the *CLES.*

Table 6

Univariate Results from MANCOVA

Variable	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
RTOP Total	*CLES* Student Negotiations (Post)	182.004	1	182.004	9.948	.002
RTOP Lesson Design and Implementation	*CLES* Student Negotiations (Post)	181.169	1	181.169	9.903	.002
RTOP Procedural Knowledge	*CLES* Student Negotiations (Post)	225.052	1	225.052	12.301	.001
RTOP Communicative Interactions	*CLES* Student Negotiations (Post)	184.477	1	184.477	10.084	.002

The total rating and each of the sub-scales on the *RTOP* impacted the students' perspective of aspects of the learning environment involved in the way they were able to communicate their own scientific ideas. Good teachers are able to pick instructional methods to reach the most students and suggested that the incorporation of instructional methods involving more active roles for the students as the way to improve teaching (Biggs, 1999). The results indicate that students notice when they have more active roles in the learning environment.

Common Themes in Reasons for Selecting Teaching Methods

The semi-structured interview data from the participant faculty instructors were analyzed to find common themes in the way the instructors felt their teaching methods impacted student learning. The interview data were also analyzed for themes dealing with how the instructors designed their lessons for student learning and why they chose to teach the lesson the way it was taught. The planned instructor questions, reported in Appendix G, were analyzed more closely than other questions because these questions directly asked the instructor to reflect and discuss their beliefs about student learning and how this impacted their designs for a lesson. The interviews were analyzed to find (1) common categories, (2) themes that were common between all instructors that participated in the study in each of the categories were found, and (3) finally these themes were analyzed for differences and commonalities between instructors receiving a high, medium, or low score on the *RTOP*. The high, medium, and low groups were defined in the same way that they were defined in Research Question 2. The aims of this study were to examine the impact that reformed teaching has on student perception of the learning environment. Appendix F was created after analyzing the literature for descriptions of reformed and traditional teaching practices dealing with science education at the university or secondary level. The appendix was used as a guide to help develop ideas for how instructors may feel about their teaching, but not as a blueprint. The major categories into which the responses from the semi-structured interviews were analyzed were developed from Appendix F. The themes included in Appendix F could either be categorized as focusing on student learning, lesson design, or the role that students and instructors have in the classroom or a combination of the ideas. For example, Just in Time Teaching was considered to be an aspect of reformed science teaching. Just in Time teaching involves catering a lesson to the needs of the students while in the moment of teaching. Use the technique would involve having knowledge of how students learned, how a lesson should be designed for student learning, and the role that both the instructor and students should play in learning science (Garvin, 2006; Luo, 2008; Novak, 1999; NRC, 2003; Seibert & McIntosh, 2001). Also included in Appendix F under traditional science teaching is the idea that knowledge can be transmitted to students. The belief that students can learn through the transmission of knowledge still requires an instructor to hold ideas about how students learn, how a lesson should be designed, and the roles that students and instructors have in the classroom (Martin et al., 2000, Seibert & McIntosh, 2001). Thus, three categories were formed: (1) Student Learning, (2) Lesson Design, and (3) Reflections on Teaching. The third category emerged because question 3 deals specifically with which aspects of the learning environment students noticed based on the level of reform used in the classroom. It was believed that instructors who reflected on aspects of the learning environment based their beliefs about teaching and learning from personal experiences, collaboration with others, or science education research (Biggs, 2001; Martin et al., 2000). After analyzing the responses from the instructors' interviews to create categories dealing with the instructors' beliefs about teaching and learning, the interviews were further analyzed for common themes within those categories. The complete results of the analysis for common themes found in the categories are included in Appendix G. Appendix G contains the answers to each of the questions given by each of the participants in the studies. The themes found in the interviews are shown in Table 7. The themes are categorized by initials and order of appearance in the table. For example Gain an appreciation/ A better understanding of science was labeled SL1 because it is the first subtheme under Student Learning. The subthemes are not ranked in any order in the table. Chapter 5 will provide a more in-depth analysis of which themes were more important in determining how students perceived the learning environment. Finally, the themes were analyzed for differences found between instructors in the high, medium, and low categories. The results are shown in Table 7.

Table 7

Themes Dealing with Beliefs about Teaching and Learning Held by Instructors

Student Learning	Lesson Design	Reflection on Teaching
Gain an appreciation/ A better understanding of science (SL1)	Engage Students in Learning/Content (LD1)	Reflections on Students (RT1)
Problem solving (SL2)	Understand (LD2)	Reflections on Teaching Methods (RT2)
Relevance (SL3)	Activities/Experiments/Hands-on/Inquiry (LD3)	Reflections on Teaching Ability (RT3)
Concepts (SL4)	Explain/Lecture/Provide Examples (LD4)	
Knowledge about Students and how people learn. (SL5)	Depth vs. Breadth (LD5)	
Think Like Scientist (SL6)	Descriptions of how to teach concepts (LD6)	
Learn to Teach Science (SL7)	Model/“Building” (LD7)	

Student Learning

The Student Learning theme contained eight subthemes. Statements under the Student Learning category included statements about the purpose of student learning and how students learn. Every statement given in the table in the appendix was copied directly from the observers' notes. Changes were only made to correct spelling. A statement given by an instructor can fall under more than one of the themes. The majority, 11 out of 15, of the instructors mentioned the desire for students to gain an appreciation for or a better understanding of science (the course content). Examples of these statements include, “An understanding and appreciation for the physical factors in our world,” “lifelong skills for voting, etc., enthusiasm for science, respect for science diversity and difficulty,” and “hope they take away the process--the process is quite useful for buying an auto or transcription of DNA to proteins.”

The development of problem-solving skills is a common goal of reformed science teaching at the university level; however, only 2 out of 15 instructors in the sample in this study used the term problem-solving skills as a goal for student learning in their courses. Other instructors mentioned problem-solving skills in a more abstract way; for example, they may have hinted that they wanted their students to develop the skills to be able to go out and research a problem further if they needed more information to teach or solve a problem. An abstract example of wanting the students to develop problem-solving skills included, “the process is quite useful for buying an auto or transcription of DNA to proteins.”

A few, 4 out of 15, of the instructors stated that they wanted the students to realize the importance of science to their lives and/or their careers. Statements relating to students realizing the role that science/science content plays in their lives was coded as “Relevance.” Statements dealing with relevance included “make it interesting and enjoyable so they want to come to class" and "in most cases have to lead them through, give examples, and then they're able to pick up on it ask them to also make connection to the relation of science."

Learning science concepts was viewed as an important outcome of student learning. Many, 7 out of 15, of the instructors discussed the importance of students to learn the concept discussed in the courses. The answers varied from simply stating the concept that was observed in the course to explaining how and why students should learn the course content. A typical answer stating that the students should learn the course content observed during the visit included, "Overhead, use example, refer to Chernobyl, cause cancer and cure cancer." An example of an instructor beginning to explain why students should learn the course content included, "If students are comfortable seeing chemical structures, for example, they won't completely ignore them or turn off when they see them later."

Knowledge about students and how people learn included statements about how the instructor believed the course content is learned. The majority of the instructors, 9 out of 15, made statements about how people learn. Most of the statements made were statements made by the instructor to describe the typical student in their courses, and the perceived ability for students to learn. Typical statements included, "Self-confidence and expertise. Student says you expect way too much from us, after all we are not scholars." "We are only teachers" and "Unfamiliarity of students with this type of course--they don't know the expectations, how to prep for exams, or how to take notes." Other statements included knowledge about how people learn science: "Good teaching is situationally specific. Learning is personal and you need to teach to your audience. Know your students. Know who they are and what they want" and "Assume that they have different learning styles although I mainly lecture and they memorize."

Learning to "Think Like a Scientist" was also a theme found in the instructors' responses, when they were discussing goals for student learning. Only 3 out of 15 instructors included in this sample stated that they wanted their students to be able to think scientifically. The instructors who made these statements wanted their students to understand the scientific method, to be able to use evidence to solve a problem, answer a question, or explain a phenomenon. An example of a statement made by one of the instructors included, "Problem solving is a skill that they can use and apply to their everyday lives. People trained in science think this way all the time. Scientists sometimes don't realize that we don't all think this way."

The sample of instructors and students came from a subset of data taken from the NSEUS project which investigated the short- and long-term impact of reformed teaching pre-service teachers. Many of the courses investigated were specifically designed for education majors, and many, 7 out of 15, of the instructors indicated that they considered how students would use the knowledge gained in their courses. Examples of instructors using statements that were classed as Learning to Teach Science included: (1) I expect that students will not be able to grasp fact that rocks aren't always hard; I will use gum pull & break & stretch, I can't show imagine conditions under surface of earth, and (2) tomorrow's lesson the main activity will be phases of the moon – they've supposed to have taken observation. I will give names to phases, and they model the phases, and it will helpfully allow them to arrive at the conclusion.

Lesson Design

The Lesson Design theme had six subthemes. The Lesson Design category was used to determine how the participants in the study designed their lessons for student learning, and to compare differences between instructors who have implemented higher levels of reform with those who have implemented a lower level of reform. It was believed that instructors may have similar goals for student learning, but those instructors with higher levels of reform implemented would have lessons designed to accomplish those goals. The six categories investigated included, (1) Engage, (2) Understand, (3) Activities/Experiments/Hands-on/Inquiry (4) Explain/Lecture/ Provide Examples, (5) Depth vs. Breadth, and (6) Model/"Building."

Statements were labeled as falling under the engage theme if the instructor used the word engage or if they indicated there was an attempt to get the students to participate in the lesson. Most of the instructors, 9 out of 15, indicated that they designed their lessons to engage students in the lesson. Examples of instructors discussing how they engaged their students in learning included, "I try to engage students as much as I can. I use Blackboard to post my notes so that they can spend class time concentrating on what I am saying rather than copying down information." "Since the students are coming in without much background on the subject, I'll start out with an introduction to give them some background." "They don't enjoy it. I'm trying to get them interested and engaged. Using hands-on seems to be able to help a lot with that. They're also a little more relaxed and so they tend to interact more with me." Each of these statements involved the instructors' beliefs on how students should be engaged to learn the material.

The instructors participating in the study stated that they designed their lessons to help students understand the concepts taught in their courses. Less than half, 4 out of 15, of the instructors emphasized the development of student understanding when they designed their lessons. An example of an instructor making a statement about designing a lesson to foster student understanding included, "tomorrow's lesson's main activity will be phases of the moon--they're supposed to have taken observation, give names to phases, model will helpfully allow them to arrive at the conclusion that phases is caused by the sun earth moon angle-- couple aspects that associate with eclipses."

Activities/Experiments/Hands-on/Inquiry

The activities that the students participated in during the course were seen as important in designing a lesson for student learning. The theme Activities/Experiments/Hands-on/Inquiry was developed to describe the various ways that the participants described student activities in the classroom. Many of the instructors in the study, 6 out of 15, described activities used in the classroom. An example of an instructor describing the use of activities to help students learn included, "Don't negate that people can have other belief systems, but this is how science works. Integrate a lot of different types of activities like debate. (They come up with debate ideas and vote on them.) Regardless of skill set, there's always a way for each student to shine. Uses website from University of Buffalo for case studies."

The instructors in the study also discussed the value of lecturing or explaining science concepts to the students in the course. Statements that the participants made about how they used lecture to design lessons were classed under the category, "Explain/Lecture/Provide Examples." The majority of the instructors, 9 out of 15, used lecture, explanations, and examples to design lessons to teach students. Statements made by instructors that fell under the Explain/Lecture/ Provide Examples category included, "tell them about the limitations of the model--leaves out the tilt of the moon's orbital plane" and "I use Blackboard to post my notes so that they can spend class time concentrating on what I am saying rather than copying down information. I attempt to incorporate real world examples for the concepts that I teach."

Concern about depth of coverage may be an issue when considering course reform (Siebert & McIntosh, 2001); however, only 3 out of 15 of the participants voiced concerns about depth or breadth when designing lessons for their courses. One instructor was more concerned with the breadth of the course and stated, "Molecules are hard for them, assign fewer pages in reading, uses Campbell. Uses it because of the organization, can use it as a reference book." Another was more concerned that the students understood the concepts of the course and stated, "Key ideas of the course content . . .," indicating that this instructor may have desired for the students to understand a few fundamental key concepts.

Some of the instructors indicated that they used models or other materials to allow students to build an understanding of the course concepts. Most of the instructors, 7 out 15, stated that modeling was an important consideration when they were designing lessons for student learning. An example of a statement where an instructed discussed using modeling included, "give them pre- and post-tests. I also give them various items (piece of paper, light bulb, battery and wire) to test their conceptual knowledge."

Themes Pertaining to Reflections on Teaching

Three subthemes pertaining to reflections on teaching were found. These themes were related to teacher efficacy: (1) Reflections on Learning, (2) Reflections on Teaching Methods, and (3) Reflections on Teaching Ability. These themes were related to the two types of teaching efficacy as defined by Riggs and Enochs (1990): (1) Personal Science Teaching Efficacy and (2) Science Teaching Outcome Expectancy. Personal Science Teaching Efficacy dealt with teachers' beliefs about their ability to teach science, and Science Teaching Outcome Expectancy dealt with the beliefs that an instructor holds that if effective science teaching is provided for students, the students will learn science. Because the focus of this study was to determine how students perceive the learning environment, two of the themes pertained to instructors' beliefs that if they provided appropriate lessons, students would learn and the other dealt with an instructor's belief that they are able to teach science.

Reflections on teaching ability were statements where the instructor focused on thought about how events in the classroom, including their own, impacted their teaching. It was believed that instructors that implemented more reformed teaching practices would be more aware of how events in the classroom can be used to inform their teaching. Reflections on how students learn were statements where the instructor focused on how feedback from students impacted their teaching. Most of the instructors, 7 out of 15, reflected on how evidence of student learning was used to inform their teaching. Such statements included, "I gained a lot from the National Research Council book How Students Learn. I understand the importance of relevancy, connectedness and prior knowledge" and "first time teaching by inquiry--needed to learn methods and knowledge. Gain ability to ask students to figure out the answer and tell me [him], Develop ability to pull out questions and ideas. Ordering of materials and modules. Now is my [his] favorite course."

Reflections on teaching methods were statements focused on the instructor's teaching methods. Only 3 out of the 15 instructors participating in the study made statements indicative of their thoughts about their own teaching. An example of a statement made by an instructor that was indicative of reflecting on teaching methods is, "I continually revise--look for new ways, new approaches. Challenge--some of the material is abstract." Reflections on teaching ability were statements where instructors shared their thoughts on how able they were to teach the course content. Many of the instructors reflected on their ability to teach the course content whether they were using a more traditional approach to teaching the course or their course had a high level of reform implemented. One instructor who had a more traditional approach to teaching made the statement, “This (course) is much more challenging due to my background expertise and the lack of interest of the students” to describe how he felt teaching non-science majors in a subject that is out of his field. Another instructor described the struggle of moving from being more traditional to embracing a more reformed approach to teaching science: “The hardest part was to make the transition from lecturing to not lecturing. One you’re used to it and that’s what you do.”

Although the instructors described their goals for teaching similarly, the ways in which they described the implementation of those goals differed. The instructors were compared based on their *RTOP* score using the classification previously described. Even when the instructors’ statements indicated that they used similar methodologies in the classroom, the definition of the methodologies, and reasons for using the methodologies differed. Finally, instructors differed in the ways in which they reflected on their teaching. The results summarized in Table 8 are generalizations derived from reading all of the statements made by the instructors for each category and theme. The results from statements made by individual instructors can be found in the Appendix G. Once the general statements were made, differences between them were compared across all groups.

The instructors in the low *RTOP* group, a score between 0 and 45, believed that students could learn science by being told science and their roles as instructors was to interpret the science content in a way that the students could understand. Instructors with low *RTOP* scores simply stated that they wanted students to gain an appreciation of science or the course contents. They did not elaborate on how to help students appreciate science. The instructor with the lowest score (22) stated, “An understanding and appreciation for the physical factors in our world.” He never stated how students would gain an appreciation of the natural world from his lectures. As the *RTOP* scores in this group increased, the instructors considered more than just lecture and notes when discussing the information they give the students to aid them in their learning. However, the statements were still based on the premise that students need to be given information to learn. For example, one instructor who received a 37.5 on the *RTOP* stated, “Go through details, give enough information to [make them] aware [or how science is relevant to their lives] and [to make them] interested.” This instructor stated how he believed he could get students to be interested in the course content, but not why the students should be interested.

Table 8

Summary of Common Themes about Teaching Beliefs by Level of Reform

	Student Learning	Lesson Design	Reflection on Teaching
Low	Simply stated that wanted students to appreciate science (course content) Only one instructor mentioned problem-solving skills, but did not state how the students will develop problem-solving skills. The information that the instructors give to the students should be interesting and relevant to the students. One instructor stated that the students should have the facts to understand the science they hear about in the news. If described, the course concepts are described as a set of facts that the instructor tells the students about (even when the instructor is attempting to make the concepts relevant to the students) The instructors did not mention knowledge of students when considering student learning even when they wanted the students to develop problem-solving skills or for the content to be relevant. One instructor mentioned that the students felt he expected to much of them. Some instructors that mentioned how people learned, stated that they had to give students the information. One instructor	Engaging students meant giving them information; especially if the instructor thought the students would find it relevant or interesting. It also meant "starting slow" or giving the students the information they may need to understand more difficult concepts. Only one instructor mentioned student understanding. His goal was for his students not to memorize, but understand the course material. They do not mention what the students are supposed to gain from the experiments, demos, or hands-on experiences. Many instructors felt that if they gave the students the information they will learn it. One instructor stated that he gave the students his lecture notes ahead of time so they can concentrate on what he is saying during the lecture. Two instructors mentioned that they do not go into much depth with some concepts because students struggle with it. No mention of how to teach concepts was made. No mention of modeling was made.	Only one instructor made statements that were indicative of reflections on teaching. His choices on content and how he taught were influenced by his belief that the students were not interested and also by his feelings that he lacked the expertise.

	mentioned they had to reorganize the knowledge that the students came in with, this instructor also believed they had to build the knowledge up for the students. No mention of thinking like scientist. One instructor stated that they wanted to give the students information to help them feel comfortable teaching the content in the future. Another instructor felt the students would pick up the skills they need to teach science somewhere else.	The instructor who mentioned building and reconstructing believed he was the one that had to reconstruct the students understanding.	
Medium	Instructors who said that they wanted students to gain an appreciation for science, wanted the students to see that science was relative to their lives, and can be used to make everyday decisions. Problem-solving skills were not mentioned. One instructor stated that they show the students how the content is related to their lives (using activities), the other stated they lead the students so they can see the relationship or the students are asked to make a connection. Concepts were mentioned in terms of their relevancy to students or in terms of misconceptions students have about those concepts. Mentioned students' prior knowledge as being something that affects the way they learn.	One instructor mentioned engaging the students in science by allowing them to do science; the other mentioned engaging them by giving them the background information that they needed. Instructors sought to have students develop understanding through observations and modeling of scientific concepts. Activities are used to allow students to observe science, and learn to make conclusions based on observations. One instructor mentioned using analogies to allow students to connect simpler concepts to more complex ones. Students are given more control over the lesson. One instructor allowed the students to pick the topics to be debated. Students are told information the instructor feels is important, or that the	The instructor that reflected on student learning mentioned that they attended conferences for constructivist teaching methods and that they consider student prior knowledge and misconceptions when creating their lessons. This instructor mentioned using clickers, homework, and modeling to gather information about student learning in order to determine which method(s) may help the students the most. This instructor also mentioned attending conferences to improve their knowledge of how people learn and their science knowledge. Changed focus on content to student learning. No longer presented science as a set of facts

	Consider prior knowledge when choosing activities to help students learn. One instructor considered alternative assessment as a way to measure student learning. One instructor tailors the way he/she teaches based on students questions and student performance. Different learning styles are considered. One instructor mentioned using different methods because students have different ways of learning. One instructor mentioned that they wanted their students to see that science is a way of thinking and doing things. They wanted them to see that it is a way of questioning evidence to find an answer. One instructor felt that the information and the way the information was presented would help the students become better science teachers.	instructor thinks they will struggle to figure out on their own. Instructors emphasized that the key ideas should be covered. Activities, conversations between students, discussions are used to help students learn through observation of scientific concepts. One instructor mentioned that s/he monitors students' reactions to determine the direction the activities should go. The instructor that mentioned homework used it to monitor how well students were learning Models were used to help students reach conclusions and observe how their understandings of scientific concepts change over time. The instructor that mentioned "building" stated that the course was designed to tell the story of how we arrived at our understanding of the scientific concepts in the course	
High	Wanted students to appreciate science to apply it to their daily lives, teaching, and as a way to go about answering questions. Wanted students to appreciate that scientific thinking is not just applicable to science, but to other situations that require making a decision. One instructor mentioned problem-solving skills. He wanted students to be able to use information they have to	Engage the students in science through hands-on activities. One instructor stated that they used guided inquiry in order to keep the students thinking and engaged. One instructor keeps the students engaged by showing them how chemistry is related to things they see every day like pollution and the air in their bodies. Another instructor begins each topic with a short lecture. The lecture is used to	Reflected on what should be taught and how it should be taught. One instructor realized you had to be comfortable with the content in order to change how to teach it. Collaborated with colleagues and attended meeting on science education to improve teaching and science education research. In order to teach through inquiry you have to gain the ability to teach the students to think through things by asking the

	solve problems. One instructor mentioned that students should be able to understand the articles they read in Newsweek or time. The instructors in the high group seemed less concerned that their course would be relevant to the students than instructors in the other two groups. One instructor mentioned that they wanted the students to understand and apply concepts of the course (bio). The other mentioned that they wanted the students to be able to build circuits (the observed concept), be able to explain what's going on at the molecular level, and troubleshoot problems should they arise. The concepts should not be understood just to come to the right answer for the course, but to be understood so that they can apply them in a situation where it is necessary to understand them. The instructors had mixed feelings about how their students felt about science. Most felt that elementary education majors either did not like science, had low confidence in their abilities to do science, or were afraid of science. One instructor felt that students like science and are curious about it but their past experiences left them afraid of science by focusing on science facts instead of science inquiry skills. Discussed the idea of conceptual change; getting to	engage the students. The students remain engaged with the topic because they aren't just reading about how science works, they are doing it. The instructors that mentioned understanding stated that they wanted the students to understand aspects of the content that are related to their lives or to content they will have to teach. (Hands-on) activities are used to engage students and keep them interested. To bring together lab and lecture. Hands-on activities are used to solve problems, work on solutions in a group and share ideas. One instructor saw student learning as a little bit of memorization, and a little bit of hands-on activities. The hands-on activities reinforce the lecture. She tries to link everything in the course through lecture. Did not mention depth/breadth of the content One instructor was made sure that she made all parts of the lesson linked. Carefully choose activities, films, learning. Makes sure all things in the class are connected. The instructors focused more on what the students did or what the students should gain than they did on how they taught particular content in their responses. They focused more on why students should	right questions, getting them to think about their prior knowledge. Reflected on the fact that the way they teach their science course is not only going to impact the way the students learn the content, but also the way they teach the content Reflected on why they taught the way they did. Reflected on the methods they chose and why they chose them. Considered what the students should gain. Talked about assessment in terms of teaching a lesson and their reflection. Assessment was not only to see what the students knew, but to improve their teaching. Two instructors reflected on the difficulty of transitioning from lecturing to inquiry. One instructor elaborated on this, and stated that he had to learn to teach inquiry and not the way he was taught. He discussed his experiences with group work and why he was reluctant to use them until he learned how to teach using groups properly. Realize that content is not the only thing that is important in a science course. Interested in improving teaching through attending conferences, collaborating with other to improve their teaching. Student assessment was also used to develop teaching.

	know what the students think about the concept and monitoring how their thinking changes during the lesson. Hands-on activities should be used to demonstrate how scientists do science. Concerned that the students understand the content. Less is more. Recognize they learning is situational and personal and that the students always have to be considered, their job is to help students learn how to learn. Learning is not about memorizing facts, but gaining tools to become lifelong learners. Wanted students to be able to build a hypothesis, use data to support an argument. Wanted students to understand the process of science, asking a question, collecting data, making observations, making an argument, and drawing conclusions. Feels it is their duty to help students think like scientist and understand that it is something they do every day. Realized the value of having to teach science for the students both in terms of their own learning, and for them to feel confident in their abilities as a teacher in the future. Although other instructors mentioned the NSES, the instructors in the high group used the NSES so that students could see different approaches to teach science content.	learn the content than they did on how they would present the content to the students. Homework was not mentioned. Modeling was used to present science concepts and give students an idea of how science works, but the instructors emphasized that they used modeling to show how to teach science/ Builds the lecture to lead into paper that will be discussed. One instructor specified that they used the 5E learning cycle (Eisenkraft, 2003).	

Unlike instructors in the high and medium groups, discussed below, these instructors do not mention considering learning style, student thinking, or anything other than the distribution of information when they are attempting to get students to appreciate science. Similar results were seen with the other seven categories listed under Student Learning. The instructors believed that you could tell the students what they needed to know and learning would occur. For example, the instructors viewed the concepts in the class as information that they had to give or present to the students. They also felt that the students could be told how problems should be solved, how science is relative to their lives, and how to teach science. As will be discussed in more detail, when compared to instructors in the other two groups, the instructors in the low *RTOP* group did not consider the students when planning their lessons. The instructor remained in control of what the students learned, what was considered relevant, and how problems should be solved. For example, when describing how they made lessons relevant to students, one instructor stated, "Be knowledge[able], try to remember to be[ing] student, make it interesting and enjoyable so they want to come to class." Although they were considering their students when trying to make their lessons relevant, there was no indication that they invited their students to actively participate in the content of the lessons.

The lessons designed by instructors in the low *RTOP* group were intended to give students the information that they needed. Whether the lesson was designed to engage students in learning, aid in student understanding, provide students with activities, or explain a science concept, the provision of information was the way in which this was done. This was different from the medium and high groups in which the lesson was at least partially designed to have students actively participate. In order to engage the students in learning, get them interested in the course, or have the students find the science concepts to be relevant to their lives, the concepts had to be introduced and presented in a more dynamic and interesting way. One instructor stated, “Engage your students, don’t make them memorize but understand instead and provide real-world examples of the concepts that you are teaching.” This statement sums up the belief that the instructor could provide all of the information the students needed in order to learn the material shared by the instructors in the low *RTOP* group. For instructors in the low group, engaging the students meant starting slow, but only giving them the basics so they will be able to understand the more complex concepts when they are presented. This belief was summarized by this statement, “Explain to class situation--start slow, get basics, and then accelerate getting more complex as students proceed.” This is in contrast to instructors whose course received a score above 45. Instructors with higher *RTOP* scores understood that knowledge was constructed, but that it could not be constructed by the instructor alone. One instructor mentioned that he wanted students to be able to solve problems, but he did not mention how he would help students learn to solve problems. All of the instructors in the low group primarily relied on lecture and stated that their lectures were meant to engage the students in learning by giving them the information they needed in an interesting way. They described doing hands-on activities or demonstrations, but did not explain the reason for having their students do the activities. Only one instructor mentioned that he wanted the students to understand the concepts in the course, not just memorize them. There was no mention of how the students were to develop their understanding of the course content. Only one instructor made statements that indicated the types of reflections that they made.

Only one of the instructors in the low *RTOP* group made statements that indicated reflections on teaching. His teaching was influenced by the fact that he perceived that the students were not interested and he felt he lacked the expertise to teach the course. This instructor was the only instructor in the low group to give any statements reflecting on his teaching. His teaching was influenced by the fact that he perceived that the students were not interested and he felt he lacked the expertise to teach the course. The statements that the instructor made were indicative that his Personal Efficacy to Teach Science was low. He doubted his ability to teach the content and, moreover, he doubted his ability to teach the concept to the students in his class.

Instructors in the medium *RTOP* group, an *RTOP* score ranging from 46-71, also stated that they wanted their students to gain an appreciation for science. Unlike the instructors in the low *RTOP* group, instructors in the medium *RTOP* group provided a rationale for their desires for students to appreciate science. They wanted students to appreciate science as a subject that was relevant to their everyday lives and future careers. For example, an instructor who received a score of 62.4 stated, "Hope--more than anything, they gain an appreciation of science as way of knowing--approach for understanding the world that other approaches don't provide. Given its limitations, they need to know about it and take seriously in teaching." The majority of the instructors in the medium *RTOP* group believed that students had to be led to see that there was a relationship between the science content and their lives, which is a different view from both the low group and the high group. An instructor who received a score of 70 felt the students had to be shown that science was related to their lives. She stated, "Show them how it relates to their everyday lives. Everyone wants something that relates to them personally." In this statement, she was stating that she has to give the students the information to be aware of the relevance of science and to help them become interested. When describing how she engaged the students' interest she stated,

> Since the students are coming in without much background on the subject, I'll start out with an introduction to give them some background. Normally I use the Internet and

> PowerPoint for that in the discussion section of the course, but since lab is not in a "smart" classroom, I'll use overheads to give them the visuals.

As discussed previously, instructors in the low group believed students can be told how science is relevant to them. Instructors in the medium group seemed to understand that students were not going to learn from just being told the information, but they had to be led away from information that was not correct. Their role as instructors was to provide them with correct information. Typical statements made by instructors in the medium group dealing with students gaining an appreciation for science included, "I want them to not be afraid of teaching science. Get students engaged in inquiry. Projects--get them to have comfort with the process of science and then take it to their own classroom," and "I try to incorporate different learning styles (audio, visual, tactile) because not all students learn the same way." The first statement is representative of why instructors in this group felt students should appreciate science. All of the instructors felt that the students should appreciate science as a part of their daily lives and feel comfortable enough to teach it in the classroom. The second represents how they felt that they learn science and that was that they can be shown the relevancy of science in their lives. Instructors in the medium level *RTOP* group also felt that the students could be shown or led to be able to use problem-solving skills, develop scientific understanding of course content, and to apply the knowledge gained in the course to their future careers. A few instructors said that the students were asked to make the connections and one stated that he had to show the students how the science content was connected to their lives. A few also mentioned that students' prior knowledge and misconceptions were used to make decisions when choosing lessons to aid in student learning. Most of the instructors realized that students have different styles of learning, and some of them incorporated different methods in order to ensure all students could learn. Despite being aware of impact that students have prior knowledge, the instructors felt that the students could be given correct information and that it was their job as instructors to change students' misconceptions. For example, one instructor stated, "in most cases have to lead them through, give examples, and then they're able to pick up on it ask them to also make connection to the relation of science activity oriented approach that covers variety of topics." This instructor seemed to feel that the students have to be led through and given examples by him in order to come to the conclusion of the lesson. Another instructor stated,

> I try to incorporate different learning styles (audio, visual, tactile) because not all students learn the same way. I try to be responsive to the students. I will switch the way I'm teaching something depending of the questions that the students have.

Unlike an instructor in the low level *RTOP* group, the instructor does consider students in how she designs her lessons to help students learn, however she maintained control of how the information would be presented. The instructors in the medium *RTOP* group felt that they were able to teach science to all of their students. They believed that the ideas that students had about science could be changed by showing them through hands-on activities or through providing them with information. The instructors in this group may have had higher teacher efficacy, and may have had a better understanding of how students learn than the instructors in the low *RTOP* group, but they struggled with implementing reformed teaching practices in their classroom. Hurd (2001) discussed this phenomenon as being one of the reasons that science education reform is slow moving at the university level. Using reformed teaching practices in order to give students information is no more likely to help students learn than giving them information through traditional lectures.

Instructors in the medium level *RTOP* group designed their lessons to engage students in learning. One instructor stated that they engaged the students in the learning by allowing them to do science through hands-on experiences. He stated, "I use a hands-on experimental approach.

Use analogies to simpler systems." The instructor only described his role, and not the role of the students. His role was to give the students the experiences, and the students' role was to learn from it. Instructors in the medium group still maintained control over the lesson, but students were given more opportunities to do science. The students in these courses were given the chance to observe science through science activities or through demonstrations done by the instructor.

Three of the instructors in the medium level *RTOP* group participated in teacher reflection as well. Their reflections varied and each will be discussed. One instructor, Tim, reflected on feeling as if he did not have the science background necessary to teach the course. He felt he needed to have a broad background in the physical sciences in order to teach the course. He stated, "helpful to have broad background in sciences. Some of the people who have taught the course have more specialized backgrounds and I tend to think of the course that is intended to provide some background across the physical sciences." Another instructor, Connie, also felt her background was limited, but she was able to relearn chemistry by watching and learning from other instructors. Similarly, she stated "I needed to relearn chemistry. I watched how other instructors taught these concepts and I picked up on ways to make the teaching of chemistry concepts more successful." Both of these instructors received a 48 on the *RTOP*, which is near the low end of the medium level *RTOP* score. These two instructors seemed to be focusing on the course content in their reflections. Both instructors offered responses suggesting the method in which they make decisions to change their teaching. Tim simply stated he struggled to decide on what content to use in his course, while Connie seemed to reflect more deeply. She stated, "[I] picked up on ways to make the teaching of chemistry concepts more successful Eye contact and the pacing of the lessons Conceptual Learning Educational courses helped." This statement indicated that she used the ideas of others, either from watching others teach or from courses on how people learn. The third instructor, who received a 62.49, also emphasized the importance of knowing the course content, but he also felt that his teaching skills needed to be developed. Participating in workshops and professional development such as NASA/NOVA helped develop his skills as a teacher. He stated, "Skills--been developing for 27 years through workshops including NASA-NOVA and conferences. I knew of active learning, multiple learning styles, and constructivist approaches through a gradual development of skills. NASA-NOVA allowed me to focus these skills on a population." Though these instructors differed in their reflection, it was concluded that the instructors that interacted with others were more likely to make changes in their teaching. Tim did not mention his interaction with other people and only discussed what he did to change the content. The other two instructors focused on changing their actions in the classroom.

Instructors with *RTOP* scores over 72 stated that they wanted their students to develop an appreciation for science in terms of their lives and careers. They also stated that their students should be able to appreciate the idea that scientific thinking can be applicable to all aspects of their lives that require them to make a decision. One instructor felt that engaging students in a discussion about a subject that they saw as relevant could lead into the discussion of science concepts that would help them understand the subject better. On the subject of pollution, the instructor stated, "It relates to their lives (pollutants, chemicals, their own bodies) and it will lead into functional groups and amino acids. It's important for them to understand what life is based on." Like some of the instructors in the low and medium-level groups, this instructor realized that the molecular structure of chemicals was something the students struggled to learn. Discussing the role that molecular structure plays in how a molecule functions, whether inside the body or in the environment, gave it an application that the students could use to develop a further understanding of a subject that they are interested in. Also, unlike instructors in the other *RTOP* levels, instructors in the high level *RTOP* group focused on the students and how people learned. The students had a role beyond taking notes. The instructors in the high level *RTOP* group provided examples of how they made science relevant or appreciable to the students. For example, one instructor stated, “Try to integrate lots of experiences into the class where they aren’t just reading about how science works, or participating in it, but they get to see how science works.” The instructor continued on to explain how the activities that she gave are not just to confirm science facts, but to help the students learn to use their knowledge. When describing how he knew students were learning, another instructor stated, “I also give them various items (piece of paper, light bulb, battery, and wire) to test their conceptual knowledge.”

The instructors in the high *RTOP* group did not focus on science content in the same way the other instructors focused on them. There was less concern with the memorization of facts, than in the other groups. The instructors in the high level *RTOP* group seemed more concerned that the students learn to apply the concepts than just memorize them. They described giving the students experiences through activities, discussions, and explanations to help the students learn in a way that worked for them. Their statements instead indicated that they wished their students to develop an understanding of the content. One instructor explained that the students should be able to “troubleshoot” circuits so that in the future, they can better help their students in case something goes wrong. As discussed previously, another discussed activities that allowed students to begin to develop an understanding of why molecular structures of organic compounds were important. He engaged them in conversations about pollution and their bodies to allow them to begin to appreciate that carbon-based molecules. Their functional groups are something they observe the interactions of on a daily basis and something that they should understand. The hands-on activities used in their class were not only designed to help students "learn" science content as it was in the classes of instructors at other *RTOP* group levels, they were also designed to allow students to learn to collaborate, express their ideas, formulate hypotheses, and make conclusions based on observation and other aspects of scientific thinking. Instructors in the high level group used modeling in the classroom to demonstrate science concepts, allow students to develop and form a scientific understanding of science concepts, and to show how science concepts should be taught. Instructors in the high level *RTOP* group implied that factual learning is embedded in learning through doing scientific activities. When asked how she assessed student learning, one instructor stated, "My assessment is embedded in the teaching. I gauge how well they're getting it along the way. In the end, I'll draw a structure on the board and see if they can name the compound." Other instructors in this group expressed similar sentiments when describing how student learning was assessed. They discussed monitoring students' interactions, activities, and discussion in order to provide more effective learning opportunities.

Instructors in the high level *RTOP* group reflected on what should be taught, how it should be taught, and what they needed to do in order to continue being an effective teacher. The instructors in the high *RTOP* group seemed more confident about their teaching decisions, and they felt that they could teach science content to any student based on their understanding of the content, how students learn, and instructional methods. Based on their statements, their self-efficacy for science teaching was higher. They indicated that if they were struggling with teaching students, they could reflect on the problem and solve it. They focused on how the way they taught and designed the course would not only impact how the students in their courses learned, but also the way they would teach science in their own classrooms. They reflected on why they were choosing to teach what they were teaching and why they chose one method over another. Their use of informal assessment was done not only to determine how to improve student learning, but to improve the way in which they teach as well. When describing how teaching a reformed course influenced how she taught her other courses, one instructor responded,

> This [NOVA course] one works so well, that I am trying to change my other classes to not lecture so much because they get the totally glazed over look. They don't seem interested at all. And this class is completely different. You are taking people who have no interest in it at all in the first place and at the end of each unit I actually ask them to write a little reflection. And often they will say I've never liked science before in my whole life. This is class is so fun that I'm changing my attitude. This helps me assess what I'm doing to. If I know something is not working by reading these, I can change what I'm doing.

This quote sums up the sentiment that many of the instructors expressed about how teaching a reformed course changed their views on what a course should look like, but also how they felt about their roles as instructors. Many discussed having to change their understanding of teaching and learning in order to be able to teach inquiry properly. They had to learn that not everyone learns in the same way that they were able to learn. One instructor elaborated that he had to learn to not teach the same way he was taught. When describing the transition from lecturing to using inquiry, the instructor stated, "I had to learn new ways to teach. I thought I was a good lecturer, but I never did group work because I always hated working in groups when I was in college. I had to learn about groups and about teaching and learning. I still try to learn about that, which is why I go to workshops, conferences, and faculty development." Instructors in the high group also emphasized the importance in attending conferences and collaborating with others in order to improve their teaching. Instructors in both the medium and high group felt that science education literature and professional development were important, but the instructors in the high group also emphasized the importance of collaborations with others when developing a course.

One instructor described the importance of including all people, including the students, who will be impacted by the course. "In developing the course, we brought together former students, mentor teachers, and faculty from different areas to give input on a chemistry content course for teachers." He went on to describe how having the students go teach in schools helped the students learn the importance of learning the chemistry content of the course. The collaboration allowed a course to be developed that allowed the students to learn science through inquiry, but also to experience how they would apply the knowledge in their futures. Other instructors, especially in the other *RTOP* levels, discussed the idea that their students could not see the importance of why they had to understand the course content when they only wanted to be teachers. Teaching science lessons for elementary school children may have allowed students in this course to experience the idea that an instructor has to understand a concept in order to be able to teach it to others.

All of the instructors that participated in the study wanted their students to learn to appreciate science as being relevant to their lives and careers. They firmly believed that their teaching methods were effective. Those in the lower level *RTOP* group felt that lecturing was all that students needed to learn. Their efforts to improve student learning included giving students the notes ahead of time and decreasing the amount of reading. If the students did not learn, it was the fault of the students for not being interested or not understanding science. Instructors in the medium level *RTOP* group also depended on lecturing and giving students information. They were more aware that students had to play an active role in learning, however, they also seemed reluctant to let go of control in the classroom. The instructors in the high level *RTOP* group focused more on the students in the course than the content. They also viewed themselves as guides to learn instead of as resources of knowledge. Their courses were designed to allow students to learn to use scientific knowledge instead of just learning science facts.

Instructors with lower levels of instructional reform implemented in the class focused on the content and how to deliver the content to the students. They may have been concerned with the students feeling that the content was relevant and interesting, but they attempted to engage the students' interest not by involving the students in learning, but by giving the students examples of how the lessons were relevant. The instructors who implemented a medium level of instructional reform also focused on the content, but they also focused on how their actions impacted students' abilities to learn. Instructors who implemented a higher level of instructional reform focused on both their roles as an instructor and the students' roles as learners. They focused more on how and why one instructional method should be chosen over another in order to provide students with learning opportunities that would allow them to see the relevance of science and apply their scientific knowledge to novel situations.

Research Question 4

Research Question 4 investigated whether variation in the level of instructional reform implemented in the classroom impacted students' perceptions of the learning environment. The difference in score between the preferred (pre) and the perceived (post) versions of the *CLES* can be used to determine student satisfaction with the learning environment (Taylor, Fraser, & Fisher, 1997). This was done by comparing the students pre- and post-instructions scores. If the pre-test scores are statistically higher, this was an indication that the students' preferences for the learning environment were not meet. If the pre- and post-test scores were not significantly different, the students' desires for the learning environment had been met. If the post-test scores are significantly higher, the students' preferences for constructivist teaching and learning have been exceeded.

Repeated Measures was used to determine if the instructor *RTOP* score had a significant relationship with student level of satisfaction with the learning environment. A single factor with 2 levels was created to explore the differences between students pre- and post-test scores on the *CLES*, this measurement included the students' overall score and scores on each scale. Instructors were grouped based on their *RTOP* rating with three levels, as described earlier. The *RTOP* score, including the total score and the sub-scales, was used as covariates.

The univariate tests were used to examine the relationship between level of reform and each of the *RTOP* sub-scales on the *CLES*. The Levene's tests indicated the homogeneity of variance was met for the Critical Voice subscale on both the pre- (F (2, 161) = 2.51, p =.08) and post-test versions (F (2, 161) = 2.06, p =.13) of the *CLES*. Variation in the Communication subscale of the *RTOP* caused significant differences on the Uncertainty subscale of the *CLES* (F = 8.44, p = .004).

The Communicative Interactions scale of the *RTOP* measured how much of the communication occurring in the classroom came from the students. The Uncertainty subscale on the *CLES* was indicative of how students view science. The items within this subscale measure students' perceptions of the tentative nature of science. The subscale contains items such as "In this class I (wish that) I learned how science has changed over time." And "In this class I wish that I learned how science is influenced by people's values and opinions." The result indicated that the more students were allowed to communicate their ideas, the better their understanding of the nature of science.

Quantitative results indicated that the way science is communicated in the classroom was important to the students.

Students Discuss Their Perception of the Learning Environment

Student focus group interviews were analyzed for differences between the instructors with high, medium, or low scores on the *RTOP*. The analysis involved several steps. First interviews were analyzed to develop common themes in communication in the classroom, student learning, and the views that students held about science. The common themes found in each of these categories are listed in Table 9. After the common themes in each category were established the similarities or differences between the high, medium, and low *RTOP* groups were compared for similarities and differences.

Table 9

Common Themes from Student Focus Group Interviews

Communication Interactions in the Classroom	Learning Science	Views of Science
Speaking on their level	Hands-on	Positive
Feedback	Memorize facts	Negative
Interactions with other students	Understanding science	Relevance
Interactions with the instructor.	Applying facts	Teaching Ability
Interactions with the course content	Relevance	Definition of Science
	Feedback from /interactions with instructor	
	Interaction with other students	

Student Perception of the Learning Environment

The Learning Science category has seven themes that emerged from statements students made about how they felt they were helped to learn or hindered from learning science. The themes that arose when analyzing students' responses to how they felt about learning science included the following: (1) hands-on, (2) memorize facts, (3) understanding science, (4) applying facts, (5) relevance, (6) feedback from/interactions with instructor, and (7) interaction with other students. The desire to have a "hands-on"The students felt that being able to do activities in class made it easier for them to learn the material. As discussed below, the students defined learning differently based on the level of reform introduced into the course. A typical statement made by a student describing how hands-on activities made it easier for them to learn included "[The course is] entertaining. [I am] learning on own. [I learn] by doing activities retain better." The reasons why students preferred hands-on learning varied by level of reform and will be discussed below. Students in the low level *RTOP* group were more likely to view the ability to memorize facts while students in the medium and high level *RTOP* groups were likely to view the ability to understand and apply scientific facts as learning. The students in the low level *RTOP* and some students in the medium level groups stated that they needed the instructor to explain the material or provide hands-on activities so that they could memorize the course content better. The students whose instructors had low scores on the *RTOP* had very little to say about what they had learned in the course. They did not mention memorization, understanding science, or the ability to apply factual knowledge. However, they did mention the desire for their instructor to explain things on a level they could understand. Students in the low level *RTOP* group may not have stated directly that they wanted the instructor to help them memorize the science content, but they did make indication that they did. For example, one student stated, "He won't phrase a problem in more than one way. It is really frustrating." The student seemed to imply that the way the instructor phrased the problem made it easier to understand. Some students whose instructor received a medium score on the *RTOP* felt memorization of science facts helped them to learn science. A student in a course at the lower end of the medium level *RTOP* group stated, "She makes us memorize stuff, which is actually helpful. It gives us a good foundation. If we didn't have to memorize some of this stuff we wouldn't do as well in upper-division chemistry." The students in classes that were in the high level courses described learning science as the ability to understand and apply science facts. They tended to have a negative attitude toward the memorization of science facts. One student stated,

> We've had all this before, but we're relearning it again. You have to understand it to be prepared and be able to answer kid's questions in the lab. You can't let them down. You have to teach yourself more and actually do background research to be prepared to teach it to the kids. It makes you want to learn more content just in case. If something goes wrong with the experiment, you can supplement it with something else.

The students in the courses that received a high score on the *RTOP* seemed to be more aware of the importance of understanding science if they were going to apply that knowledge. The students also discussed relevancy when discussing factors that helped them learn science. The students felt that content that was interesting or that they can observe daily in their lives was relevant. They struggled to see the value of content that was more abstract or not interesting to them. For example, one student stated, "I'm just not too much into physical science. I know there is a need for science. I don't see the need for chemicals and all that stuff." The viewpoint that science is a set of facts held by students may lead to the inability to realize how those facts allow people to understand the world around us. Students in courses that received a higher score on the *RTOP* had a different view of learning science, they indicated that they often discussed feeling confident that they understood the science concepts well enough to teach them. One student stated, “I find science to be fun and interesting. My attitude has changed because I know that I will have to teach these concepts to others and can’t rely on just memorization.” The statement indicates that the students understand that in order to effectively teach science, they had to learn concepts and not just memorize them.

Communication in the classroom was another factor that the students identified as being important for them to be able to learn science. The students described interactions with the instructor and other students as being important. The students in the low *RTOP* group reported that their instructor spoke over their heads and did not explain the material so that they could understand it, while students in the high *RTOP* group felt that the instructor was able to explain the content so that they could understand it. A typical statement made by students in the low *RTOP* group regarding how science was communicated by their instructor was, “He can’t comprehend how we understand. It’s physical science. It’s one of the harder sciences.” The students in the medium *RTOP* group also reported that their instructors were able to bring the material down to their level, but they described learning differently than students in the high *RTOP* group. Students in the medium *RTOP* group stated that they were able to memorize the course content because of their instructors, while students in the high *RTOP* group stated that their instructors helped them develop their ideas about the course content. As discussed for the low *RTOP* group, students in the medium *RTOP* group also viewed memorization as learning. However, they discussed hands-on activities more than the students in the low *RTOP* group. When describing how their instructor communicated science ideas in the classroom, one student stated, “I feel like on his level. He’s not using big words and putting us down. Not overwhelmed. Lectures but also activities. Good at coming around to help. How he applies . . . really helps you to remember it.” The instructor is still maintaining control of how science is communicated in both the low and medium groups. Students in both the medium and high *RTOP* groups felt that interacting with their peers helped them to learn the most. The reasons varied from simply seeing another student solving a problem giving them the confidence to solve the problems themselves to interacting with other people allowed them to understand the concepts from different perspectives. Students in the low level *RTOP* expressed a desire to work with students in the class to learn science. However, they did not elaborate on why the desired to work in groups.

The interactions with the instructor was seen by the students as being important to help them learn. The students in the low *RTOP* group described the interactions with their instructors in a negative way. They believed that their instructor was available to help them, but they also felt judged for being wrong and did speak out in class. They also felt that the instructors spoke over their heads and only wanted the right answer. When discussing speaking out in class, one group of students stated, "He isn't looking for an answer? It's the answer. I think a lot of us are confused and we don't speak up." Students in the low *RTOP* group felt that their instructors only wanted them to solve problems in one way and attempted to learn to solve problems the way they were told to solve them. They felt they would be penalized for solving problems in a different way on the test. The students in the medium level *RTOP* group described mixed interactions with their peers and instructors. The students' descriptions of the ability to bring the material down to their level were not related to the *RTOP* score in the medium group. The instructor that received the highest score in the medium level *RTOP* group, 62.49, had the most dissatisfied students. They felt that their instructor was intelligent but could not explain the material so they could understand it as evidenced by this statement, "more engaging--Jim Lorman really intelligent--feels has hard time bringing material to her level doesn't feel try to engage as lecturer. I've had lecturers wow interesting. Tone of voice into subject." One instructor that had a score of 48 had students that were very satisfied with the communication in the classroom. They stated,

> I had a really bad experience in high school chemistry so I was really nervous about taking this class. I failed out of chem in high school so I was nervous. But this instructor makes me feel very comfortable. She's very approachable and she seems like she wants to help us learn. If I want to succeed, I can succeed. She'll give us the tools. This teacher wants you to learn. She wants us to go forward and be successful in other classes.

These results indicate two things: (1) it takes more than being just an effective communicator for students to notice differences in the classroom, and (2) implementing reformed teaching does not mean that the students will notice it in the learning environment. Students in the high level *RTOP* group were satisfied with the communication that occurred in the classroom. They indicated that the ability to share and communicate their ideas to their peers was extremely important to helping them learn science concepts. One student described the interactions in the classroom as such, "In my ed[ucation] classes being in class and work with other people made me think other people makes me aware of my strengths and weaknesses, what I need to do." This sentiment expressed how many of the students described what they gained in the course. They felt that working in groups allowed them to gain different perspectives on how to solve problems in the course or in their future careers as teachers.

Relevancy also played a role in students' attitudes toward science. Very few students stated that they did not like science; they felt as if science were too difficult to learn. Many of the students in courses taught by instructors that were rated low on the *RTOP* had a hard time seeing the relevance of the science content that they learned in their classes. If they could not see the science content of the course as being applicable or relevant to their lives, they voiced a negative view toward the course or science in general. If they were able to see the application and relevance of the science content, they expressed a more positive view of science. For example, students in the least reformed course had a negative attitude toward physical science, the topic of the course. They stated, “I really don’t think I need to know when you drop a bullet and [a feather] they hit the ground at the same.” However, the students felt that their biology course was interesting and relevant because they could see how the content is related to their lives. They stated, “I would say biology, because it has more to do with the real world, animals, and plants and stuff. I’m more into animals and plants.” Students whose instructors received a medium score on the *RTOP* were positive about their courses and science. They expressed that science was not a set of facts, especially when they were able to see how the content was relevant and applicable to their lives. Despite the fact the students stated that they could see that science was not a set of facts, they struggled with the idea of finding the right answer. They found the details of science intimidating and did not feel that they could teach science. For example, one student stated, “interested, environmental specifically--looking at how science answers questions about natural world. Intimidated by details like DNA. Not comfortable teaching to middle school or high school. The process of science. Everyday life, how it affects everyday life. ArtiCLES and conversations. Have a reference point.” Another student did not like science, but their experiences in the course allowed them to see that science is relevant to their lives, “not teach science. Not subject I like. Think it is important because--especially environmental and how things work. Don’t want to teach it.” Very few students whose instructor was rated high on the *RTOP* had negative experiences with the course. The students that expressed negative feelings toward the course felt there was too much work, or they preferred learning in a traditional setting and did not feel confident that they were learning. For example, one student stated,

> Some people like traditional better. Keep a balance. I like my own style, so far the experience good for one person. I am not used to this way. WE don’t go back to book, discussion not recorded. This class is harder because it is not traditional. Helpful if this

class was more balanced between instructional strategies. Nothing to refer back to for the exams.

The majority of the students in courses whose instructor was high on the *RTOP* felt that the hands-on experiences in their course helped them develop a better understanding of science and the work of scientist and they felt they were more capable of teaching science because of course experiences. The typical student in this group stated, “Before this class I was nervous and afraid of science, but now I have more fun learning and thinking about how to teach it. It’s more beneficial to me to see how I’m going to use it in my classroom.”

The students that participated in the study indicated that communication of ideas was important to how they learned and perceived science. When they perceived that it was safe for them to express their ideas to their instructors and peers, the students felt that they were able to learn better. Students in the low level *RTOP* group expressed a desire to communicate their ideas with peers and instructors. They also desired their instructor to communicate the course concepts in a way that they could understand. In courses where students were allowed to communicate, the students stated that they enjoyed learning to look at solving problems from different perspectives. The students interacted with the course content differently. Students who experienced courses where the course content was controlled by the instructor, viewed learning as memorization. This was even the case when students were given the opportunity to experience hands-on activities. Students who were given the opportunity to learn science through exploring their own ideas with their instructors and peers and develop their own understanding of the science concepts were more confident in their learning, described science as a process or a way of thinking, and had a higher belief in their abilities to teach science than students in courses with lower levels of reform.

Chapter Summary

Quantitative and qualitative analyses both revealed the importance of communication of science concepts in the classroom. A score of 71 or higher had to be reached in order for students to perceive differences in the learning environment ($F = 4.49$, $p = .035$). Instructors whose scores were above 71 designed learning environments to give students a chance to experience science, in order to develop a better understanding of the scientific method, course content, the nature of science, and to increase the students' abilities to apply scientific thinking and science concepts to their lives and careers. To do so, their students were provided with activities that allowed them to think about their prior knowledge and allow them to develop new understandings of the science concepts through their interactions with others in the classroom. Instructors who taught courses with scores above 71 viewed themselves as facilitators of learning with the job of providing learning opportunities for their students. They also realized that becoming an effective teacher involved more than having knowledge of the course content; they also used knowledge of how people learn and knowledge of instructional methodologies as well. They also viewed professional development as being extremely important in deciding how they designed their courses for learning and determining how they taught. The students that experienced these courses stated that they understood science better than they did before and felt confident in their ability to use scientific knowledge in their lives, in particular in their careers as teachers. Instructors with scores below 45 viewed providing knowledge of science facts to be their role as instructors. They stated that their ability to make a lecture interesting and to break the information down would help their students understand and view science as relatable to their lives. When they sought to improve student learning, they focused on the course content and their understanding of the course content. The students in their course viewed science as a set of facts to be memorized. They felt that their instructor's job was to present the information in a way that they could memorize it. Students in the low *RTOP* group also had little confidence in their ability to learn and did not feel they could teach science when this was applicable. The beliefs that instructors held about teaching and learning in the medium *RTOP* varied, but the variations were not necessarily based on score. Students in the class where the instructor was viewed as an effective communicator was not the instructor with the highest *RTOP* score, and the instructor with the highest *RTOP* score was viewed as an ineffective communicator. This suggested that communication and the implementation of reform alone are not enough for students to perceive differences in the *RTOP*. There may be interplay of both. The instructors in the medium level *RTOP* group used more hands-on activities than students in the low *RTOP* group, but those activities were still meant to give the students information to learn the course materials. The instructors in the medium *RTOP* group participated in science education seminars and collaborated with others about their teaching, but may have struggled to implement reform in their classroom. Many of the instructors in the medium *RTOP* group seemed to believe that the hands-on activities helped the students memorize the course content. The students in courses seemed to believe it was up to the instructor to provide the information for them. The analysis of the data in this study indicates that an instructor's perception of what it means to teach impacts their students' beliefs about learning.

CHAPTER 5

FINDINGS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Introduction

The purpose of this research was to determine the impact that variations in implementation of science instructional reform, instructors' beliefs about teaching and learning, on undergraduates' perceptions of the learning environment. Research indicates that the perception that students have of the learning environment impacts the approaches they take toward learning science (Biggs, 1999; Martin et al., 2000; Partin, 2008). Research also supports the idea that the approach that students take toward studying and learning science is dependent upon the learning environment (Biggs, 1999). Lectures and other teacher-centered methodologies lead to students taking a surface level approach to learning (Biggs, 1999; Martin et al., 2000; Partin, 2008). When classroom instruction is changed to a student-centered approach, students begin to take different approaches to learning science (Martin et al., 2000). This study investigated the learning environment as perceived by the instructors and students participating in them by investigating the relationship between science course reform in the classroom and how undergraduates perceive the learning environment. The first question of this study determined the amount of instructional reform that has to be implemented in the learning environment before students begin perceiving differences. After it was determined how much or how little instructional reforms have to be implemented in the classroom, differences in the perceptions of the students in the learning environment, and differences in the beliefs held by the instructors were compared for similarities in differences.

The findings and conclusions of the research questions are presented in this chapter. In addition, the implications for improving science course reform at the university level resulting from the research reported in this dissertation are discussed. Recommendations for further research in learning environments at the university level are included.

Summary of Findings

Research Question 1, "At what level of implemented instructional reform do students notice the learning environment as being different?" was investigated using covariate analysis of variance between ratings on the *RTOP* and the *CLES.* In order for the students to begin to perceive the learning environment as being more learner-centered as measured with as the *CLES* instrument, a rating of 71 had to be achieved by a course instructor on the *RTOP* instrument. Students do not begin to see the learning environment as being less learner-centered or more teacher-centered until a rating of 45 or below on the *RTOP* is reached. Ratings between 46 and 71 on the *RTOP* did not show significant differences on the *CLES.*

Research Question 2 asked, "Which aspects of the learning environment do students perceive the most difference in classrooms between instructors with a high level of instructional reform and those with a low or medium level of instructional reform?" This question was analyzed using multivariate analysis with the total rating of the *RTOP* as the independent variable, the ratings from each sub-scale on the post-test perceived version of the *CLES* the dependent variable, and the sub-scales on the pre-test preferred version of the *CLES* as the covariate. The instructors were divided into three groups based on the total rating they received on the *RTOP*. Instructor ratings of 71 or above were included in the high *RTOP* group, between 46 and 70 the medium *RTOP* group, and below 45 the low *RTOP* group. The UANCOVA was significant for three of the five sub-scales on the *CLES*: Critical Voice Post, Shared Control, and Student Negotiations. Level of reform explained a small percentage of the variance seen in two of the scales: Critical Voice (η^2 = .040) and Shared Control (η^2 = .045). Level of reform explained 28.2% of the variance seen on Student Negotiations (η^2 = .282).

Research Question 3 asked, "What aspects of instructional reform are most associated with students perceiving the learning environment as different?" This question was analyzed quantitatively using MANCOVA, and qualitative analysis was used to provide triangulation for the quantitative data and descriptions of aspects of the learning environment as described by the instructors who created them. A MANCOVA was conducted using the total *RTOP* score and the scales of the *RTOP* as the independent variables and the total score and scales on the perceived *CLES* as the dependent variable. MANCOVA revealed significant differences between the Total *RTOP* rating, The Lesson Planning and Implementation, Procedural Knowledge, and Communicative Interactions subscales had a significant impact on the Student Negotiations subscale on the *CLES*.

Qualitative analysis using the faculty semi-structured interviews revealed that the instructors participating in the study espoused many of the same goals for student learning, but used different methodologies to reach those goals and held different beliefs behind choosing the teaching strategies used in the classroom. Instructors whose course was rated low on the *RTOP* believed they learned from being told information and designed their courses so that information was delivered in a way that made the course material relevant, interesting, and applicable to students' lives. Instructors that had a medium level of instructional reforms implemented in the classroom also believed that students had to be told the information in order to learn, but they also believed that hands-on experiences had to be provided in order for students to learn the course content or to find the science discussed in class relevant or applicable to the students' lives. Instructors whose course received a high rating on the *RTOP* allowed students to develop their own ideas through hands-on instructional methods, interacting with their peers, and applying scientific facts to novel situations. Key differences between instructors at various levels of instructional reform are highlighted in Figure 7.

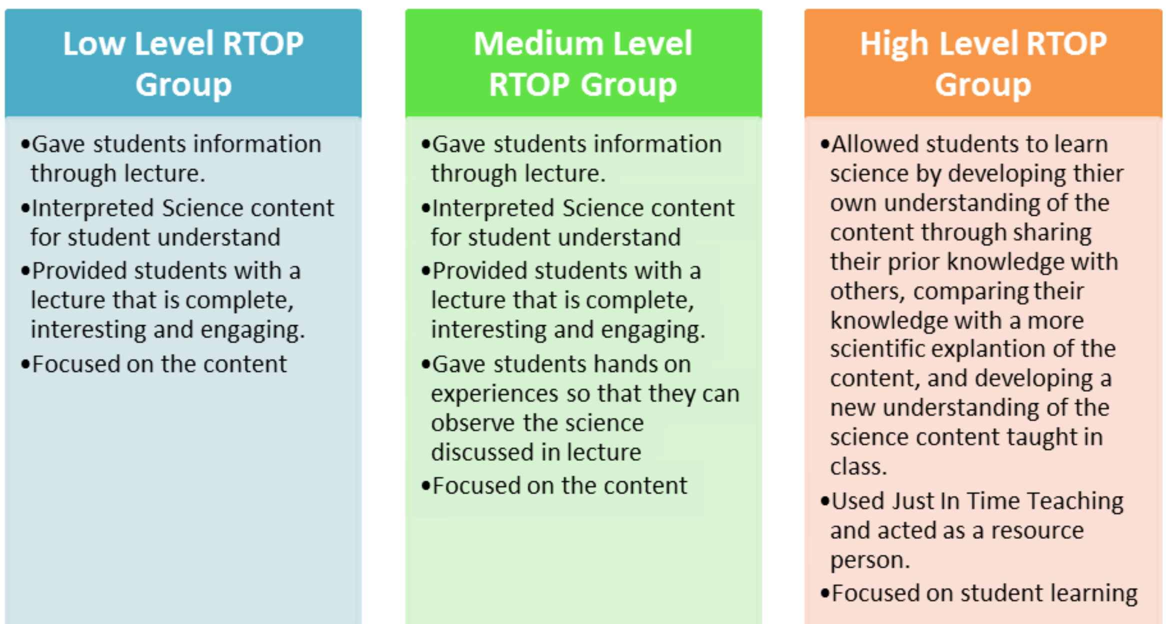

Figure 7. Summary of descriptions of teaching methods of instructors at each level of reform.

Question 4 asked, "Which differences in level of instructional reform implemented in the classroom lead to a variation in student satisfaction with the learning environment?" This question was analyzed both qualitatively and quantitatively. The quantitative analysis used repeated measures analysis of variance using the *RTOP* rating, the total rating, and the ratings on each *RTOP* subscale, as the independent variables and pre- and post-test ratings of the *CLES* as the dependent variable that changes over time was used to determine how the variation in the level of reform impacted student satisfaction with the learning environment. The difference between the pre- and post-test ratings on the *CLES* was indicative of student satisfaction with the learning environment. If the post-test ratings were significantly lower than the pre-test ratings, the students preferred methods of constructivist teaching and learning were not experienced in the learning environment. The Communicative Interactions scale of the *RTOP* made a significant difference between the students pre- and post-tests rating on the Uncertainty. This indicated that students who developed their own ideas about science content were more likely to see science as evolving and changing over time as a set of facts.

Analysis of the student focus group interviews indicated the type of instructional methods used in the classroom impacted the way students viewed the learning environment and their ability to learn science. Students in courses with a lower level of instructional reform expressed dissatisfaction with the learning environment and their ability to learn science. The higher the level of instructional reform was implemented in the classroom, the more satisfied the students were with the learning environment and the better they felt about their ability to learn science. In particular, students expressed that the ability to communicate their ideas with others was important in helping them feel comfortable and learn science. The key points from the analysis of the student focus group interviews are shown in Figure 8.

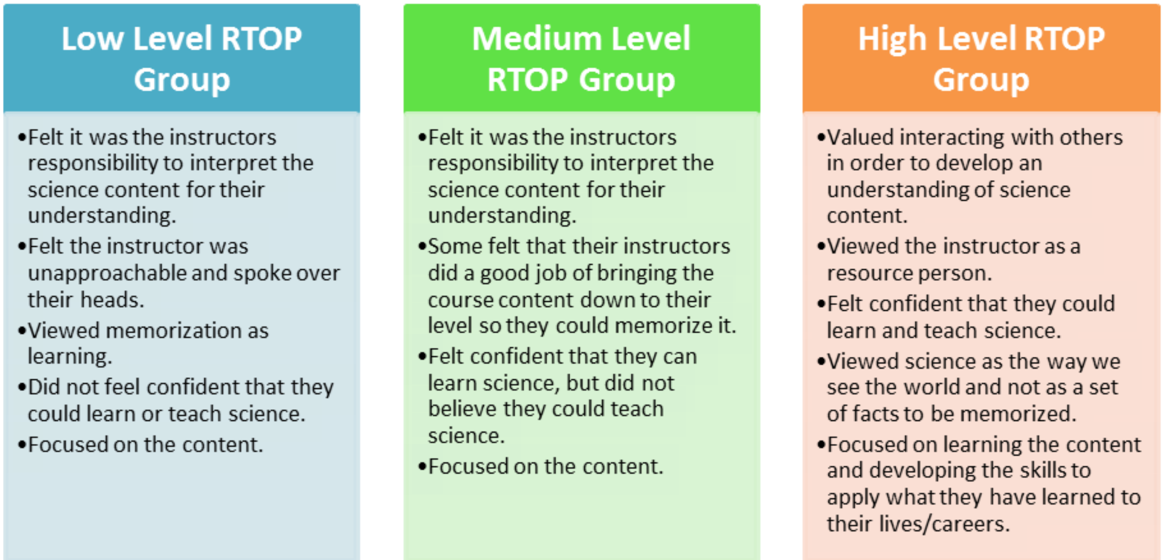

Figure 8. Differences in perception of the learning environment of students in courses with various levels of instructional reform.

Conclusions

The results of this study support the conclusion that undergraduate science classroom communicative interactions are important in order for students to perceive the learning environment favorably. The quantitative and qualitative analyses conducted in this study indicated that the way science is communicated in the classroom determined the way students viewed the learning environment, science, and learning. Instructors who gave their students the opportunity to share their ideas with others in the classroom had students who were more confident in their understanding of the science concepts. The focus group interviews indicated that the students enrolled in classes where a high level of instructional reform had been implemented felt the content was more relevant, felt they could understand the content, and felt they could use the content in their careers as teachers. Instructors who relied upon teacher-centered methodologies had students who expressed more dissatisfaction with the learning environment.

Based on results for Research Question 1, students do not begin to difference in course environment unless a rating of 71 or higher is achieved on the *RTOP*. A rating of 71 or above indicates that instructors have implemented a significant level of reform in their classroom. In order to achieve a rating of 71 or higher on the *RTOP*, nearly all of the items on the *RTOP* would have to be rated 3 or above. This finding indicates that in order to make a difference in the way students perceive the learning environment, science education reforms have to be planned, purposeful, and used throughout the entire course and not just for some concepts or some activities.

Statistical analyses indicated that the higher the level of reform, the higher the students' perception of their ability to share and communicate their ideas in the classroom. Research Question 2, using Univariate Analysis of Covariance, revealed that the level of reform used in the learning environment had an impact on three of the scales of the *CLES*. The level of reform was defined by total rating on the *RTOP*. Instructors who were rated as 71 or above on the *RTOP* were considered high, an *RTOP* rating between 46 and 70 was considered medium, and a rating below 45 was considered low.

Each of these subscales was related to how much control the students have over the way they learn in the classroom. The *CLES* Critical Voice and Shared Control scales deal with how comfortable the students feel about questioning the instructor about the methodology used and content taught, respectively. The *CLES* Student Negotiations scale was also significant. The Student Negotiations Scale measures the students' perceptions of their ability to communicate their ideas with others in the classroom. The level of reform observed explained 37% of the variance seen on the *CLES* sub-scales. Biggs (1999) suggested that the best teachers used methodologies that would reach the most students possible.

The instructor participants in this study who were given ratings of 71 or above seemed to fit this description. Their focus of their decisions to select their teaching methodologies was how students learned science. Their courses were designed to give students the opportunity to communicate their ideas about science in order to compare their knowledge to more scientific understandings of scientific concepts so that they can begin developing more scientific understandings of science. Beyond developing an understanding of the science concepts, instructors who were rated high on the *RTOP* gave their students the opportunity to apply their science to novel situations, in particular science teaching.

These instructors set goals for their courses, and used researched instructional methodologies to determine the best way to reach them. These instructors stated that professional development and collaboration with others was helping them change the way they teach in order to achieve their goals. Instructors who received a rating between 46-70 on the *RTOP* understood that students had to be engaged in the learning activity, but still maintained control of the learning in the classroom. In addition to describing what good teaching should be, Biggs' (1999) described three types of instructors and their behaviors. Using the author's descriptions, instructors who were rated high on the *RTOP* would focus on what the student does. Instructors who received a medium rating on the *RTOP* would focus on what the teacher does. This is distinguished from focusing on the student in that the teacher still acts to transmit information to the student, but they are more aware that they have a role in the way the student learns. Many of the instructors in this group were aware of active learning techniques, but seemed to be reluctant to not use lecture or not explain to the students what they should be observing before allowing them to do the experiments. Their use of hands-on experiences was to aid in the transmission of information. Though some of them admitted to attending professional development for teaching, few mentioned collaborating with others beyond content, in class wait time, etc. Professional development seminars for aiding college instructors to develop their teaching skills should provide the support and collaboration interested instructors need to develop their teaching. Instructors in the low *RTOP* group focused on delivering the course content to the students. They believed students could learn through listening and note-taking alone. If students did not learn the course content, it was the students' fault for not liking science or other reasons not given. In order to improve science instruction at the undergraduate level, more needs to be done to encourage instructors to rely less on traditional teaching whether through collaborating with others, professional development, or rewards for teaching (Siebert & McIntosh, 2001).

Question 3 of this study used MANCOVA to determine how variations in behaviors that an instructor demonstrates in the classroom and the various aspects students may perceive. Qualitative analysis was used to provide descriptions of how students perceived the learning environment and corroboration for quantitative results. The Student Negotiations Scale of the *CLES* showed significant difference when compared to the to the total rating on the *RTOP* as well as all of the sub-scales of the *RTOP* indicating that the way science is communicated in the classroom is important to students. The students in courses that received a high *RTOP* score valued being able to share their thoughts with the other students in the classroom. They viewed their instructors as a resource person who acted as a guide for their learning instead of being the person who is responsible for their learning. They stated that being able to share their own ideas helped them learn. In addition, these students were more confident in their ability to learn science, apply science to problem-solving skills, and their future careers. The students in courses whose instructor received a medium rating on the *RTOP* valued the hands-on opportunities they were given in class. However, they viewed these experiences as helping to better memorize the course content. The instructor was still viewed as being the source of knowledge. The students described their instructor as being good or bad based on their ability to interpret and present the science content on their levels. The students in courses with a medium level of instructional reform felt confident about science content that they could see as being relevant to their lives or that they found interesting. They did not feel confident that they could apply their scientific knowledge to their careers; this was especially true for the elementary education majors. Students whose instructor received a low rating on the *RTOP* had a negative view of the communication that occurred in the learning environment. Many spoke of being afraid to speak in class for fear of being wrong or being judged by their instructor. They also described their instructor as being good or bad based on their ability to interpret and deliver the course material in a way that helped them memorize the content. Similar to the students in the medium level *RTOP* group, they did not feel confident in their ability to learn science, did not see science as being relevant unless it was interesting or applicable to their lives, and few felt able to apply their scientific knowledge to their future careers. The results indicate that the way science is communicated is important. Instructors that view teaching giving students scientific knowledge have students that view learning as memorization. Instructors that adapt teaching methodologies that give students the opportunity to build their own scientific understanding through hands-on experiences, problem solving, and collaborating with others have students who take a more in-depth approach to learning science. These results are similar to results found by Partin (2008) and Martin et al. (2000). The instructors in the medium *RTOP* level group used instructional methods advocated in the literature thought to promote student learning, but their students still viewed memorization as learning. This suggests that it is not enough for professional development programs to tell instructors about teaching methods; these programs must also help instructors understand the importance of including ideas on how students learn.

Quantitative analyses also revealed that students in courses with higher levels of instructional reform were more satisfied with their learning environments. The Communicative Interactions scale of the *RTOP* made a significant difference between the students pre- and post-tests rating on the Relevance, Uncertainty, and Student Negotiations scales. This indicates that the ways in which an instructor chooses to present science to the students impacts the way they viewed the relevancy of the science content, the nature of science, and the way they could communicate in the classroom and that the more they were able to do so, the more satisfied they were with the learning environment. In order for the students in this study to view the science content in their courses as being relevant, their instructors could not just give them a lecture and tell them why the content was relevant. Their instructors had to plan lessons that gave students experiences that allowed them to develop their understandings of why and how the course content was relevant. In order for students to develop an understanding of the nature of science, they could not be passive in their learning. Students who were given experience that allowed them to use their knowledge of science to collaborate with others and solve problems had a better understanding of the nature of science. Learning occurs when the students feel comfortable sharing their ideas and are encouraged to collaborate with others to build their understanding of the course content. The traditional lecture may be the fastest and easiest way to deliver content to students (ref). However, lecturing does not lead the majority of the students that experience them to learn science beyond memorization. In order for students to gain the ability to apply scientific knowledge, the students have to be given the opportunity to do so.

When students are given the opportunity to express their ideas in discussion or through hands-on activities, they express a higher satisfaction about their ability to learn the science content whether they defined learning as memorization or the ability to apply scientific knowledge. The more students were allowed to discuss science content in the classroom, the more relevant they felt the content was to their lives. The students who were allowed to share their ideas with others in the classroom and participate in hands-on activities that allowed them to solve problems felt that the content in their courses was relevant even if they did not like the course content. Students in courses with a low level of reform only felt the content was relevant to their lives if they were able to make the connections themselves. Their instructors may have given them examples of how the content was relevant, but the students did not make the connection. In light of these findings, professional development opportunities have to not only focus on instructional methods to help students learn. Simply replacing lecture with hands-on experience when the goal remains to disseminate knowledge is not enough to help students achieve the learning goals of science education reform at the university level. Instructors who wish to improve their teaching must learn to think about what the students should do in their classroom and not just what they should do (Biggs, 1999). Aspects of how students learn and support to help instructors feel comfortable not telling students the information need to be incorporated.

Implications

A college education is supposed to provide undergraduates with the knowledge and skills that they need to be prepared for entry level-jobs. The number of jobs requiring the ability to use science, math, and technology will only continue to increase in the future. In a study by

Casner-Lotto and Barrington (2006), employers felt that people with 2- and 4-year degrees were not prepared for entry level jobs. Employers expect that college graduates come to the job with the ability to use what they learned in college to think critically and creatively without constant input from their supervisors. The education that many undergraduates experience does not give them the opportunity to develop the types of skills that employers expect of a person with a college degree (Arum & Roksa, 2011). Science education reforms are intended to improve the experience that all undergraduate students have in their science courses in order to allow them to develop the ability to think critically and creatively (Seibert & McIntosh, 2001). The experiences that undergraduates have in the science classroom impacts their perception of the learning environment, and these perceptions of the learning environment affect the approach they take to learning science (Trigwell et al., 1999). Students begin to take a non-surface approach to learning when they are provided with experiences that extend beyond lecture and traditional labs (Trigwell et al., 1999). Students who perceive the learning environment as positive take a deeper approach to learning the course content. Pre-service teachers represent a special subset of undergraduates because of their future role and shaping the experiences that future students will have in science. Their experiences in their college science courses may determine their attitudes toward science and how they teach in the future.

This study examined the perception of the learning environments of university level science courses held by undergraduates and instructors. It examined the interactions of what the instructor believed about teaching and learning and how well students believed the learning environment was helpful in their learning the course content. The research from this study implies that the way science is communicated in the classroom impacts the way students perceive the learning environment and therefore their approach to learning the course content.

The research from this study implies the following actions as being research supported as ways to improve science education at the undergraduate level.

1. Science education reform in each course has to be carefully planned and implemented. Introducing a few educational reforms in the classroom has little impact on how students perceive the learning environment. In this study, a significant change away from teacher-centered instruction and toward student-centered instruction was needed before students perceived a more favorable learning environment. Instructors in this study had to implement a high level of instructional reform before students perceived their teaching methods as different. Qualitatively, the instructor has to set goals for the students in his or her class to develop critically thinking skills, the ability to apply scientific knowledge, or use the science content in their careers over solely focusing on content learning. When learning the content becomes the focus of the instructor's goals, the students do not perceive the classroom instruction to be different, and they do not think about science any differently than students enrolled in a traditional lecture course.

2. Undergraduate science instructors have to feel comfortable giving up control in the classroom. The instructors who implemented a moderate level of reform, one or two elements, provided students with the opportunity to do hands-on activity, but they still felt they had to tell the students what they needed to know. Consequently, the students in these courses held to their prior misconception that memorization was learning. Many of the students could not make connections between the lecture and the problem-solving activities in the classroom even though their instructors stated they explained what the students should learn. If the students did not feel the activity helped them memorize the content, the students did not view the activities as important in helping them learn.

3. Undergraduate science instructors need to be provided with opportunities to attend professional development workshops to help them improve their teaching. All of the participants in the study had similar goals for their students. They wanted their students to feel the course is relevant, to develop critical thinking skills, and to develop a better understanding of the course content. Not all of the instructors, however, had an understanding of how to reach those goals according to current effective theories of teaching and learning (National Research Council, 2005). Many believed that their students would learn the material if they had been told in a way that is clear, repeated many times, interesting, and/or fun.

4. Professional development workshops for improving teaching are needed to help undergraduate science instructors develop an understanding and find methods of using students' prior knowledge and misconceptions. Instructors must be aware that misconceptions and prior knowledge cannot be changed by telling students how they should understand the course content.

5. Undergraduate science instructors need to be encouraged to move away from teacher-centered instructional methods. The students in classes that were given a medium rating on the *RTOP* had the same conception of learning as students in courses that were given a low rating on the *RTOP*. Only in courses where the instructor indicated that their role was to act as a mediator for learning did the students begin to see learning was not memorization but the ability to use their critical thinking skills and their knowledge of science concepts to solve problems.

6. Undergraduate science instructors need to be more reflective about their teaching in the classroom. The instructors whose courses were given a high rating on the *RTOP* were very reflective about why, how, and what they were doing in the classroom. Professional development workshops should encourage instructors who teach science to take a scientific approach to their

teaching in that they should be aware of what their goals are, how they will reach their goals, and how they should evaluate their progress.

7. The instructional methods, represented in the teaching should reflect the goals of the course. If the goals of the course are to promote critical thinking skills, the ability to use knowledge to solve problems, and to view science as being relevant, the students must be given the opportunity in many class activities to participate in learning experiences that promote these goals. Simply replacing traditional teaching methods with an element or two of inquiry teaching may not be enough for students to gain scientific skills. If the focus of the course is the content and the instructor remains the one who is at the center of generating the knowledge, the students still focus on the content as a set facts and view the instructor as the one responsible for their learning.

Recommendations for Further Research

This research established a relationship between the way science is communicated in the classroom, students' perceptions of the learning environment, and the definition of learning. In undergraduate classrooms where the ideas of all participants were valued and the emphasis was moved from learning the content to learning to use science content, students were more satisfied with the learning environment and viewed learning as gaining the ability to solve problems. This relationship also established a relationship between what an instructor believes about teaching and learning and the learning environment of their courses. In order to continue developing and understanding of and improving science education at the undergraduate level, the following recommendations for future research have been made.

1. There is no instrument to measure the beliefs that instructors have about student teaching and learning. In order to improve science teaching at the undergraduate level, common beliefs held by college science instructors should be explored.

2. Professional development models aimed at improving teaching of undergraduate science instructors should be examined. There are professional development models available for instructors but little research on which models work and why they work.

3. Professional development models should not only include introducing faculty to teaching methods that work. The model must include methods for properly implementing the educational reforms in the learning environment. Also included in these models would be to provide faculty participants with lessons on how students learn. Research is needed on effective ways to help undergraduate instructors who rely on lecture to be made to feel comfortable that they can guide students to an understanding of science by allowing significant control of learning, as in the use of inquiry learning.

4. Professional development models need to address the problem of sustainability of science education reform. Support for faculty wishing to make changes in their teaching must be provided. Collaboration with others was seen as being important for instructors who received an *RTOP* score above 71.

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APPENDIX A

RTOP: REFORMED TEACHING OBSERVATION PROTOCOL

RTOP
Reformed Teaching Observation Protocol

I. BACKGROUND INFORMATION

Instructor/teacher Code # _____________ Announced Observation?__________________
(yes or no, or explain)

Location of class ____
(university, building, room/school district, school, room)

Lesson Observed __________ Year/Grade Level___________

Observer _____________________________Date of Observation _______

Start time ______________________End time _______________________

II. CONTEXTUAL BACKGROUND ACTIVITIES

In the space provided below please give a **brief description of the lesson observed**, the **classroom setting** (space, seating arrangements, etc), **and learning climate** in which the lesson took place (cooperative groups, teacher & student attitudes toward learning, classroom management strategies used etc), and **any relevant details about the students** (number, gender, ethnicity), **teacher, building climate, administrative constraints, and other factors not covered in** *RTOP* that you think are important for *RTOP* and other qualitative analysis that will lead to completion of the final report for the site visit. Use diagrams and more pages if they seem appropriate and are needed.

Record salient events observed here that you will use in completing ***RTOP*****.**

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred			Very Descriptive	
(1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
(2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
(3)	In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
(4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
(5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional Knowledge

(6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
(7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representation, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural Knowledge

		0	1	2	3	4
1(1)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
1(2)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
1(3)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
1(4)	Students were reflective about their learning.	0	1	2	3	4
1(5)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

V. CLASSROOM CULTURE

Communicative Interactions

		Never Occurre d			Very Descripti ve	
1(6)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
1(7)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students. students were not discussing there ideas, they were discussing the fact that they are confused	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	`There was a climate of respect for what others had to say	0	1	2	3	4

Student/Teacher Relationships

2(1)	Active participation of students was encouraged and valued.	0	1	2	3	4
2(2)	Students were encouraged to generate conjectures, alternative solutions strategies, and ways of interpreting evidence.	0	1	2	3	4
2(3)	In general the teacher was patient with students.	0	1	2	3	4
2(4)	The teacher acted as a resource person, working to support and enhance student negotiations.	0	1	2	3	4
2(5)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

*Adapted from Turley, J., Pilburn, M., & Sawada, D. (2001.

Additional comments you may wish to make about this lesson.

APPENDIX B

THE CONSTRUCTIVIST LEARNING INSTRUMENT (PREFERRED)

The Constructivist Learning Instrument (Preferred)

In this class I wish that the teacher would ask me questions.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I learned about the world outside of school.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that my new learning would start with the problems about the world outside of school.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could learn how science can be part of my out-of-school life.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I would get a better understanding of the world outside of school.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I learned interesting things about the world outside of school.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I learned how science has changed over time.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I learned how science is influenced by people's values and opinions.

Almost Never	Seldom	Sometimes	Often	Almost Always

I wish that I learned about the different sciences used by people in other cultures.

Almost Never	Seldom	Sometimes	Often	Almost Always

I wish that I learned that modern science is different from the science of long ago.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I learned that science involves inventing theories.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that it was OK for me to ask the teacher 'Why do I have to learn this?'

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that it was OK for me to question the way I'm being taught.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that it was OK for me to complain about anything that prevents me from learning.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that it was OK for me to express my opinion.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could help the teacher to plan what I'm going to learn.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could help the teacher to decide how well I am learning.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could help the teacher to decide which activities are best for me.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish I could help the teacher to decide how much time I spend on activities.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could help the teacher to decide which activities I do.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I got the chance to talk to other students.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could talk with other students about how to solve problems.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I had the idea to explain my ideas to other students.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that I could ask other students to explain their ideas.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish that other students could listen carefully to my ideas.

Almost Never	Seldom	Sometimes	Often	Almost Always

APPENDIX C

THE CONSTRUCTIVIST LEARNING INSTRUMENT (PERCEIVED)

The Constructivist Learning Instrument (Perceived)

In this class the teacher would ask me questions.

Almost Never Seldom Sometimes Often Almost Always

In this class I learned about the world outside of school.

Almost Never Seldom Sometimes Often Almost Always

In this class my new learning would start with the problems about the world outside of school.

Almost Never Seldom Sometimes Often Almost Always

In this class I could learn how science can be part of my out-of-school life.

Almost Never Seldom Sometimes Often Almost Always

In this class I would get a better understanding of the world outside of school.

Almost Never Seldom Sometimes Often Almost Always

In this class I learned interesting things about the world outside of school.

Almost Never Seldom Sometimes Often Almost Always

In this class I learned how science has changed over time.

Almost Never Seldom Sometimes Often Almost Always

In this class I learned how science is influenced by people's values and opinions.

Almost Never Seldom Sometimes Often Almost Always

I learned about the different sciences used by people in other cultures.

Almost Never	Seldom	Sometimes	Often	Almost Always

I learned that modern science is different from the science of long ago.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I learned that science involves inventing theories.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class it was OK for me to ask the teacher 'Why do I have to learn this?'

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class it was OK for me to question the way I'm being taught.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class it was OK for me to complain about anything that prevents me from learning.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class it was OK for me to express my opinion.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could help the teacher to plan what I'm going to learn.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could help the teacher to decide how well I am learning.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could help the teacher to decide which activities are best for me.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I wish I could help the teacher to decide how much time I spend on activities.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could help the teacher to decide which activities I do.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I got the chance to talk to other students.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could talk with other students about how to solve problems.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I had the idea to explain my ideas to other students.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class I could ask other students to explain their ideas.

Almost Never	Seldom	Sometimes	Often	Almost Always

In this class other students could listen carefully to my ideas.

Almost Never	Seldom	Sometimes	Often	Almost Always

APPENDIX D

FACULTY INTERVIEW QUESTIONS

National Study of
Education in Undergraduate Science

Faculty Interview Questions

Code Number:
Interview Site:
Interviewer:
Notetaker:
Date:

Background: (CoRe)

1) **How long have you been teaching science at the undergraduate level?**
2) **How long have you been teaching this "identified NOVA" or comparison course? What other courses do you teach over a normal one-year period of time?**
3) **Have you taught at any other levels such as high school, community college, or graduate school? If so, for how long?**
4) **Have you participated in any university professional development for improving teaching? Please describe the extent of this experience.**
   Have you taken university level education courses such as teaching methods? If so, please elaborate (certification, education degree, etc.).

Course:

5) **Describe your students' interest in this course and science in general..**
   What are the main goals that you wish your students to learn from this course?
6) **What should your students take away about science in general after taking this course?**
7) **What were the important knowledge and skills you needed to develop and teach this course?**
8) **Does the type of teaching (science instruction) relate to student interest and/or achievement in this course (e.g. lecture, hands-on, labs)? In what ways?**
9) **What were the significant barriers you overcame in planning and teaching this course? Compare this course to other courses you have taught at this academic level.**
10) **What advice would you give future faculty members when they start teaching about effective science instruction and/or strive to teach science effectively themselves?**

Class Session: (CoRe) (Note to the interviewer: These questions should be based on the lesson observed, but if the lesson has been observed prior to the interview, adjust the questions accordingly.)

11) **What will be the main ideas or concepts addressed during <u>this class session</u> or lesson?**

12) **Describe how you will teach these main ideas or concepts, and explain the rationale behind doing so.**
13) **How typical is this lesson for this class? If this is not typical, please describe a typical class session in this course.**
14) **Why is it important for students to know the aforementioned main ideas or concepts you taught during this class session?**
15) **What do you anticipate will be some difficulties and/or limitations connected with teaching these ideas or concepts?**
16) **What knowledge about students' thinking and/or learning influences your teaching of these ideas or concepts?**
17) **How will you assess students' understanding of, or confusion about, these ideas?**

APPENDIX E

UNDERGRADUATE STUDENT FOCUS GROUP INTERVIEW QUESTIONS

National Study of
Education in Undergraduate Science

Undergraduate Student Focus Group Interview Questions

Code Number:
Site Name: Interviewer:
Notetaker(s):
Date

Majors:
College Science Experiences

1) **Describe your interest in science.**
2) **What university level science courses have you taken?**
3) **How would you define science or the nature of science?**
4) **How has your definition of science changed due to the science courses you have taken in college? Which course(s) had the most influence? The least?**
5) **How has your attitude toward science changed as a result of the course(s) you have taken in college? Why did these course(s) change your view of science?**
6) **Describe how has your understanding of science content changed as a result of taking this course? (What have in general have you learned about science in this course?)**
7) **What specific activities or assignments enabled you to change your understanding of an issue in science or science content in this course? In other science courses?**
8) **Which instructional strategies and activities used in science courses so far did you feel were most beneficial for your learning?**.

Course Experience (Note to the interviewer: These questions should be based on the lesson observed, but if the lesson has been observed prior to the interview, adjust the following questions accordingly.)

9) **What is a typical lesson like for this course; i.e., what normally happens during your classes?**
10) **What were the main ideas or concepts for <u>this</u> class session? What science concepts did you learn?**
11) **Why is it important for you to understand these concepts?**
12) **What about these concepts did you find confusing before the lesson? What about these concepts do you, or do you not, find confusing after the lesson? *On the exam?***
13) **How did (will) the instructor assess student understanding of these concepts?**
14) **Did you feel that the teaching strategies used in today's lesson were effective for student understanding of the concepts covered in this lesson? Why or why not?**
15) **What would you have done to make the lesson more effective for your learning?**

Science Teaching (education majors or adjusted questions for groups that only have non-education majors)

16) Have your ideas of science teaching changed as a result of taking this class or others at the college level? (How do you think that science should be taught?)

17) Do you think that you can become an effective science teacher? (Do you think that you could be an effective science teacher? Why or why not?)

18) What do you feel is the best way to teach science in elementary schools? Why?

19) What science content or courses do you feel most prepared to teach? (What science content do you feel that you would be prepared to teach if the moment arose?)

Additional Comments:

APPENDIX F

CHARACTERISTICS OF REFORMED AND TRADITIONAL LEARNING ENVIRONMENTS

Inquiry is an instructional strategy that allows students to be engaged in science by doing science. Learners give priority to evidence which allows them to develop and evaluate explanations that address scientifically oriented questions. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understandings. Inquiry is a learning goal that includes developing students' understandings about how to begin to gather, evaluate, analyze, and synthesize data in order to solve a problem. Teaching science using inquiry allows students to develop a better understanding of the nature of science because science is not taught as a set of facts and the focus of the course is not on the past accomplishments of scientist. Instead students are allowed to see why science knowledge changes in response to new evidence, logical analysis, and modified explanations debated with a community of scientists by learning to use what they understand of the science content to solve problems (Hurd, 2000; Seibert & McIntosh, 2001; NRC, 2003). A reformed science course is a course that has been adapted to increase students' chances to practice using science inquiry in order to develop their ability to apply and use their scientific knowledge to solve real world problems (NRC, 2003).

The following Table describes the themes that will be used to determine differences in level of reform implemented in the classroom. In addition to the theme, the publications that describe the characteristic and the scale on the *RTOP*, *CLES*, or interview question that will be used is given.

Characteristics of Reformed Learning Environments					
Theme	Source	Publication	*RTOP* Scale	*CLES* Scale	Interview Question(s)
Integrated Lab and Lecture ***Knowledge is constructed by students*** Students are allowed to use scientific knowledge to solve real-world problems Students are allowed to make predictions and discover the answers to problems presented in the class Students are allowed to learn how scientist use research to investigate and solve problems Laboratory experiences are designed to allow students to develop their abilities to think critically and design experiments ***Just in Time Teaching*** Student activities and instruction are informed by students' prior knowledge and/or	Observations semi-structured interviews Student focus group interviews	Seibert and McIntosh, 2001 NRC, 2003 Novak, 1999 Luo, 2008 Garvin, 2006	Lesson Design and Implementation	Personal Relevance Uncertainty Shared Control Student Negotiation s	

performance or response to pre-instruction questions ***Interactive Lectures*** Students are actively engaged in lecture through demonstrations, questions, and interactions with peers. ***Traditional Labs*** Used to allow students to develop an understanding of concepts in the course so that students can apply the knowledge to novel situations in open ended labs ***Traditional Lecture*** Lecture is used to for clarification of student misconceptions Lecture is used to provide closure to a lesson					
Use of technology	Observation Semi-structured interviews	Seibert and McIntosh, 2001 Koehler and Mishra, 2009			
Student Discussion Student discussions are used to design lessons that are directed by ideas	Observations semi-structured interviews student focus group interviews	Seibert and McIntosh, 2001 NRC, 2003	Lesson Design and Implementation Communicative Interactions Student/Teacher Relationships	Personal Relevance Uncertainty Shared Control Student Negotiation	

coming from the students Student discussions are used for peer instruction Student discussions are used to allow instructor to access how well students are learning the content				s	
Open ended Labs Students are allowed to use scientific knowledge to solve real-world problems often in collaboration with others Students are allowed to make predictions and discover the answers to problems presented in the class Students are allowed to learn how scientist use research to investigate and solve problems Laboratory experiences are designed to allow students to develop their abilities to think critically and	Syllabus Observations semi-structured interviews student focus group interviews	Seibert and McIntosh, 2001	Lesson Design and Implementation Communicative Interactions	Personal Relevance Uncertainty Student Negotiation s	

design experiments					
Students are thinkers: students make and discuss predictions with others students ask questions Students make and discuss observations with others Students' prior knowledge is engaged and challenged Students use the knowledge gained in the course to solve problems	Observations Semi-structured interviews Student focus group interviews Syllabus	Seibert and McIntosh, 2001 Hurd, 2001	Communicative Interactions Student/Teacher Relationships	Personal Relevance Uncertainty Student Negotiations	
Teacher is a facilitator Acts as a guide Fosters cognitive growth through questioning Challenges students to clarify ideas	Observations Semi-structured interviews Student focus group interviews	Seibert and McIntosh, 2001	Communicative Interactions Student/Teacher Relationships	Shared Control	
Classroom Environment ***Collaboration*** High level of interaction between student and instructor Instructor and students work together to construct knowledge Students are given the chance to	Observations Semi-structured interviews Student focus group interviews	Seibert and McIntosh, 2001 NRC, 2003 Hurd, 2000	Lesson Design and Implementation Propositional Knowledge Communicative Interactions Student/Teacher Relationships	Personal Relevance Uncertainty Student Negotiations	

learn science by doing science Respect for others ideas and understanding ***Multidisciplinary*** Science is linked with other disciplines especially in the sciences and math ***Relevance*** the application of the scientific knowledge to modern society is apparent. The content focuses on more than the past achievements of scientist, but how scientist use and apply scientific knowledge.					
Characteristics of Traditional Classrooms					
Description	Source	Publication	*RTOP* Scale	*CLES* Scale	
Lecture ***Knowledge is transmitted (didactic)*** The instructor tells the students what they need to know The instructor presents science is a set of facts to memorized textbook is a source of knowledge The course content is the	Observations semi-structured interviews student focus group interviews	Seibert and McIntosh, 2001 Hurd, 2003 Martin, Prosser, Trigwell, Ramsden, & Benjamin, 2000 .	Lesson Design and Implementation Communicative Interactions Student/Teacher Relationships	Personal Relevance Uncertainty Shared Control Student Negotiations	

focus of the course students are passive in learning					
Traditional Lab ***Knowledge is transmitted*** The lab is designed to be a verification of facts The labs in the course are tightly directed labs meant to confirm a concept ***The instructor is the dispenser of knowledge*** Instructor is authority figure that clarifies procedures Tells students if they have the right answer	Observations semi-structured interviews student focus group interviews	Seibert and McIntosh, 2001	Lesson Design and Implementation Communicative Interactions Student/Teacher Relationships	Shared Control Student Negotiations	
Students are passive Students write down what the teacher says Students may ask and answer questions that repeat or confirm what the teacher stated in lecture Students repeat knowledge stated by teacher on test	Observations Semi-structured interviews Student focus group interviews	Seibert and McIntosh, 2001	Lesson Design and Implementation Communicative Interactions Student/Teacher Relationships	Uncertainty Shared Control Student Negotiations	

and quizzes					
The instructor is the dispenser of knowledge The instructor decides which topics are important and relevant for students to know The instructor tells students what they need to know The instructor focuses on pasts achievements of scientist		Seibert and McIntosh, 2001 Hurd, 2003	Communicative Interactions	Uncertainty Shared Control	
Classroom Environment ***Collaboration*** Students are passive Students do not interact with each other or the course content Teacher acts as the dispenser of knowledge ***Content Centered*** The focus of the course is the course content. The instructor does not make connections between the course content and other disciplines or (often) between	Observations	Seibert and McIntosh, 2001 Hurd, 2003 Martin, Prosser, Trigwell, Ramsden, & Benjamin, 2000	Lesson Design and Implementation Propositional Knowledge Communicative Interactions Student/Teacher Relationships	Personal Relevance Uncertainty Shared Control Student Negotiations	

concepts in the course ***Relevance*** The instructor does not attempt to make connections between the course content and modern society or current scientific practices					

APPENDIX G

RESULTS FROM FACULTY INTERVIEWS

Table 1 shows the common themes that were found analyzing the instructors' interviews about their beliefs on teaching and learning. Also included in Table 1 is the code number for each theme. Table 2 shows the statements given by the instructor and how they were coded. Some statements are not coded, but were necessary to provide context and meaning to the statement. For example, two instructors may have said they engaged the students in the lesson, but their use of the word engage may not have been equal. To some, providing an interesting lecture was engaging the student, and to others starting a discussion about pollution was used to begin getting the students to question the importance of knowing molecular structures.

Table 1: Themes dealing with beliefs about teaching and learning held by instructors

Student Learning	Lesson Design	Reflection on Teaching
Gain an appreciation/ A better understanding of science (SL1) Problem solving (SL2) Relevance (SL3) Concepts (SL4) Knowledge about Students and how people learn. (SL5) Think Like Scientist (SL6) Learn to Teach Science (SL7)	Engage Students in Learning/Content (LD1) Understand (LD2) Activities/Experiments/Hands-on/Inquiry (LD3) Explain/Lecture/Provide Examples (LD4) Depth vs. Breadth (LD5) Descriptions of how to teach concepts (LD6) Model/"Building" (LD7)	Reflections on Students (RT1) Reflections on Teaching Methods (RT2) Reflections on Teaching Ability (RT3)

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
BB: Paul	22	3	11	2	3	3	An understanding and appreciation (SL1) for the physical factors in our world. Also, want students to understand how to approach a problem and solve it. (SL2)	I try to engage(LD1) students as much as I can. I use Blackboard to post my notes so that they can spend class time concentrating on what I am saying rather than copying down information. I attempt to incorporate real world examples for the concepts that I teach(LD3) . I don't want students to memorize formulae or the periodic table. . Engage(LD1) your students, don't make	This (course) is much more challenging due to my background expertise (RT3)and the lack of interest of the students(RT1)	

Table 2: *RTOP* **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	*RTOP* Score	LD	PrCK	PrPK	CI	STR	Student Learning	Lesson Design	Reflections on Teaching	Other
								them memorize but understand(LD2) instead and provide real-world examples of the concepts that you are teaching. (LD3) *There is no comparison with what the faculty member said in his interview compared to what was observed in his class. The class was very traditional, with a vast speed of presentation of an enormously large number of concept being presented. He knows what needs to be done, but doesn't have the knowledge or skills to be an effective instructor.*		

Table 2: ***RTOP*** **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	*RTOP* Score	LD	PrCK	PrPK	CI	STR	Student Learning	Lesson Design	Reflections on Teaching	Other
AB: Rebecca	34	4.5	5	4.5	15	5	**Appreciation of world geopolitics of resources, Alabama economic implication, appreciate = value as good stewardship** (SL1)	**Experimentation, clickers, writing activitie**(LD4) **s, ask questions** **Need more hands-on , too large of a class, demo's ,** (LD4) **student presentations, clickers, not much depth**(LD5) **Expect students will not be able to grasp fact that rocks aren't always hard; use gum pull & break & stretch, can't show imagine conditions under surface of earth**(LD3) **, films show this –**		

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
								Hollywood		
DB: Peter	35	5	18	4	3	5	Be knowledge, try to remember to be student, make it interesting and enjoyable so they want to come to class (SL3) Overhead, use example, refer to Chernobyl, cause cancer and cure cancer (SL4) (awareness of nuclear power and safety)	*Explain to class situation* (LD1)/ (LD3) – *start slow*(LD1) *, get basics, and then accelerate getting more complex as students proceed.* (LD6)/ (LD7) Eclectic professor – little of everything. Demos(LD4)		

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							No - go through details, give enough (SL5) info to aware them and interest them. (SL1)	, lectures, f(LD3) ield trips, computer aided simulations… Student activities as HW but with in-class display. (LD4)		
FA: Robert	36.43	3.75	14.18	4	5.25	9.25	feel comfortable taking life sciences in their classroom. (SL7). Read a local newspaper, have the biological basis for being educated. (SL3) Self confidence and expertise. Student says you expect way too much from us (SL5), after all we are not	Give an introduction, (LD1) learn things not see in lecture. (LD3) Some labs are done lab first. (LD4) Molecules are hard for them, assign fewer pages in reading, (LD5) uses Campbell. Uses it because of the organization, can use it as a reference book.		

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							scholars. "we are only teachers" they struggle to have molecules in their head in a concrete way. (SL5) Talked about ATP in different context. (SL4) Build up, gets more accurate as they learn. (SL5) Learning is a building experiment. Doesn't worry about going interdisciplinary in terms of teaching picks up what we	Next weeks lab will be biochem and molecules. Organismal respiration at different temperatures (LD4) heartbeat of an arthropod at different temperatures. Prep things first and the lab follow. Labs set up for historical reasons.		

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							need when we need it and where they can (SL7) get it. Reorganize what they come in with. (SL5)			
EB: Connie	48	5	18	4	3	5	Basic skill development for future chemistry classes (SL4) I try to let them know that some things are abstract and have to be memorized. (SL5) As often as I can I show relevant examples. (SL3)		Needed to relearn chemistry Watched how other professors taught these concepts Picked up on ways to make the teaching of chemistry concepts more successful Eye contact and the pacing of the lessons	

Table 2: ***RTOP*** **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							Assume that they have different learning styles although I mainly lecture and they memorize (SL5) Lifelong skills for voting, etc. Enthusiasm for science Respect for science (SL1) diversity and difficulty Realize the relevancy of what they are learning (SL3)		Conceptual learning Educational courses helped(RT3)	

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							Chemistry is invisible – making is visible Tutoring and retaking the tests help Some concepts take more time to learn than others Chemistry concepts are hard for them to pay attention to during lecture and learn Difficult to teach chemistry in a linear manner for them			
GA: Tim	48	6	17	7	9	9	*prior background*	tomorrow's lesson	*helpful to have*	

Table 2: *RTOP* Scores and excerpts from interviews derived from semi-structured interviews with instructors.										
Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							is a consideration. *students own experience –* (SL5) *today, know some of the students pretty well. do check with those that have troubles with math. one of two was ok other needed to think about it for awhile.* *prior making the inferences is a real challenge. they don't know where to begin.* (SL5) *in most cases have to lead them through, give*	main activity will be phases of the moon – they've supposed to have taken observation. (LD5) give names to phases. model will helpfully allow them to arrive at the conculsion(LD2)/ (LD7) / that phases is caused by the sun earth moon angle. couple aspects that associate with eclipses. simplified model that would predict more eclipses than actually have. (LD6)/ (LD7) tell them about the (LD3) limitations of the model – leaves out the tilt of the moon's orbital plane.	*broad background in sciences.* (RT3)*some of the people who have taught the course have more specialized backgrounds and I tend to think of the course that is intended to provide some background across the physical sciences (chem, phys, earth)* *critical of myself at end of semester. what could have done.*	

Table 2: *RTOP* **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	*RTOP* Score	LD	PrCK	PrPK	CI	STR	Student Learning	Lesson Design	Reflections on Teaching	Other
							examples, and then they're able to pick up on it (SL3) *ask them to also make connection to the relation of science* (SL3) *activity oriented approach that covers variety of topics* (SL5). *On the activities have brief overview of national standards at least hinted at. make it seem that it is not just me deciding on the activities.* (SL5)	*long term observation of the moon – as individual or group of at most 4, asked to observe moon over period of time and then make 10 inferences or conclusions based on observations* relative time application sheet – try to impress upon the students. had them look at geology time scale (museum) – geologists have been able to make inferences about events before absolute dating methods had been developed. recognize as achievement of scientists – one country to next recognize sequence of	*time is a limiting factor. have to make a judgment about what to include.* (RT3)	

Table 2: *RTOP* **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							do want them to know more science. do want them to feel more positively about their ability to teach science both from additional background and also that they have better understanding how to conduct science in classroom (SL7)	events		
FA: George	62.49	11.42	15.09	10.90	11.92	13.16	Hope – more than anything, they gain an appreciation of science as way of knowing – approach for	Handout some questions (LD3) like draw their model of atomic structure at the beginning(LD6)/ (LD7)	I did have to expand my knowledge in other areas, astronomy especially. I need	

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							understanding the world that other (SL1) approaches don't provide. Given its limitations, they need to know about it and take seriously in teaching. That you can do science in lots of different ways. They don't see themselves as teaching science. (SL7)There are exceptions – typically older students – they have a much greater level of curiosity. (SL5)Think, on average, students	, he can predict, it is a pattern, use clickers and respond and talk about it, evaluation on the end and also HW, they get focus questions, questions they should get out of their reading, take couple of those for HWs *The whole course (both semesters) is an attempt to bring in key aspects of science, how it works and disciplines, application, science and society. Telling a story of how we get here* (LD7) *– big bang onward. This semester is biology – evolution of the earth. Right now, we're in the 3rd of 5 units. The 1st unit is evolution*	to know more than they know. Skills – been developing for 27 years through workshops including NASA-NOVA and conferences. (RT3) I knew of active learning, multiple learning styles, and constructivist approaches through a gradual development of skills. (RT1)NASA-NOVA allowed me to focus these skills on a population. *At beginning of*	

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							come away with a greater appreciation. (SL1) They won't admit it immediately, but later on. Major concepts – genes, stars (SL4) live and die, elements come from stars. Important to make decisions in the world – (SL1) climate change (SL4) – know what it means and what/how science is finding out. (SL6) Want them to not	*in general (Darwin). The 2nd unit is classical genetics (Mendeleev). 3rd unit is molecular genetics. Yesterday (Monday) was the first class of this unit. Today (Tuesday) is introduction to DNA, its structure and purposes. Wednesday – the lab is projects – engage* (LD1) *students in science, doing science.*	*some units, use 3 x5 cards to answer question* *Give them the* (RT2)*opportunity to talk about atomic models and details – because I've done it enough, I can predict the response.* *Use clickers in the lecture, respond, look at the results and then talk.* *Quiz and take-home exam at end of each unit* *Focus questions for all the*	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							be afraid of teaching science. Get students engaged in inquiry. Projects (SL7) – get them to have comfort with the process of science and then take it to their own classroom. (SL7)Look at project based work in the classroom as a method of assessment for the program – more is more successful. (SL5)Get them to see science is a process that anyone can do. (SL6)		*reading – pick a couple for the homework.* Paying attention what studies have been done, in any instruction, the obvious thing are not obvious, pay attention to students misconceptions, different kinds of (RT1)approaches. You can't be expert in all areas, you should pass that if you can't answer you are doing job, be co-learner. (RT3) Pass that lecture	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							A lot of specific prior knowledge and misconceptions, (SL5) dominant alleles, are related if they (SL4) appear, Students attitudes and motivation curiosity, (SL5)		is the way instead to know that science is the process we need to learn to learn and it is continuous process don't get discouraged if students don't(RT1) get . I continually revise – look for new ways, new approaches. (RT2) Challenge – some of the material is abstract. Feel students should understand the subatomic level	

Table 2: ***RTOP*** **Scores and excerpts from interviews derived from semi-structured interviews with instructors.**

Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
									to the biggest level (fate of the universe). To deny insight because it is abstract is a disservice to them. (RT1) Don't expect teaching Heisenberg Uncertainty Principle. Every student who takes science needs exposed. Not willing to accommodate this population – they need not only to think about their classroom but also need to	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
									expose them to the big, abstract ideas. *She didn't have the motivation to engage in the planning process. Who's going to teach the course?* (RT3)*I was familiar with the students – elementary education majors don't have great attitudes, motivation, or natural motivation in the topic. I knew what I was getting into and*	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
									took it on anyway. Some students will not engage no matter what. Strong sense that most courses taken by education (RT1)*majors are easy – not challenging as work or intellectually. This course is the hardest they have.*	
AA: Carl	64.29	12	11.64	11	13.65	13	Dispel fear of math and science. (SL5)Relationship between math & physics. Science is convenient(?) to study	I use hands-on experimental approach. Use analogies to simpler systems. (LD4) Somewhat influences other courses. Key ideas of the course content…(LD5)establish		

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
								relationship between math and physics.		
GB: Sheila	70	13	13	12	15	17	I try to incorporate different learning styles (audio, visual, tactile) because not all students learn the same way. (SL5) I try to be responsive to the students. I will switch the way I'm teaching something depending of the questions that the students have. (SL5) If a student asks a question that indicates they don't	Since the students are coming in without much background on the subject, I'll start out with an introduction to give them some background(LD1) . Normally I use the Internet and Powerpoint for that in the discussion section of the course, but since lab is not in a "smart" classroom, I'll use overheads to give (LD3) them the visuals. The students will write down the answers to the questions from their lab manuals and their data in their own lab		▪ Enthu ▪ Know the su ▪ Orgar ▪ Comp your Try t to the perso ▪ To us and h comp even You c stand ▪ To try appro stude many levels of dif teach techn

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Instructor	***RTOP*** **Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							understand the concept, I know I need to present the -Interactions between students (SL5) - Class discussions: Ask them what they think because everyone brings something to the table. (SL5) - Show them how it relates to their everyday lives. (SL1) Everyone wants something that relates to them personally. - I do a lot of	notebooks. I think it's great to have them keep up the (LD2) notebook because it helps them to learn linear thought. Having to write down things is very good for this class. They seem to be proud of their work.		

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Instructor	*RTOP* Score	LD	PrCK	PrPK	CI	STR	Student Learning	Lesson Design	Reflections on Teaching	Other
							activities, even in the "discussion" (SL5)section of the class. • I try to make students comfortable so they'll share and ask questions. information in a different way. (SL5)			
FB: Tina	73.75	15.50	16.25	13.50	13.25	15.25	learn something about bio and specifically for gen bio (SL4) course, had to know something about molecular bio, (SL4) trad. genetics and evolution. and a bit	*how does dna replicate – more bit memorizing, bit learning about stuff*(LD3) *. look at structure of dna. watson and crick's paper. try to relate structure they have to know to the paper they have. difficult for students to read – vocab , method of presentation, try to link up*	*hardest piece – get students engaged. always looking for ways to keep attention. use* (RT2)*animations. they like cartoons. why use clickers- -- they have to pay*	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							about how science works. inquiry. how do you write a hypothesis? test? build data based argument? history of bio (SL6) – wouldn't have to know to teach but makes more interesting for students. use to help students recognize that scientists change opinions (SL6) and that that isn't easy – use conceptual change in a scientist as a model for their lives (SL5)	*first slide of* (LD3) *lecture with last sentence of paper. build off of that. animation didn't get to try to tie to cell cycle, mitosis is just part of life of cell and replication part of the life of cell*	*attention enough to read question and think about answer* *like to think so yes otherwise wouldn't be doing it – over years try lot of different things. find that getting students engaged is a good thing. case studies.* (RT2) *vary it. clicker thing – keeps students engaged – new gadget but find useful. improves attendance. credit based on*	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							only way to get handle – talk to person and listen to what they have to say. not option for large classes. (SL5) *clearly use m.c. tests, short answer problems on tests.* *don't have answer. very difficult* *think can't have terminal – look at along way. interact with students in class. talk to me as I talk to them. find*		*clickers was for answers but not correct answers* *they have to think about learner and not about the delivery. have to understand what students bring to class, what ideas they have about the* (RT1) *subject – ways to get them to think abou their own thinking. can't just be expecting that you're going to deliver the message and they're going to pick it up.*	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							out info when they answer incorrectly or no answer. (SL5) hope they take away the process – (SL6) the process is quite useful. for buying an auto (SL1) or transcription of dna to proteins. laying out question, conducting test, and making conclusions based on it. Construction of a data based		*learning is hard work. real sense in college profs that* (RT2)_______*; package so that they can*_____*; different people learn differently. have to approach* (RT1)*instruction. offer smorgasboard so their are choices but in end they all get nutrition.* *always changing – connect with place where students are, can't assume that all students have*	

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							argurment and how to get the data to build the argument (SL6)		*the same background – need to change when you aim wrong with examples (Lorax, Star Wars)*	
BA: Sandra	80	12	16	17	17	18	Most kids right now the only science they are getting is to read in the textbook and answer the questions at the end. And that's not what science is. It's very hands-on, you do experiments; you do	I'm trying to do more hands-on(LD4) because especially for this course, which is targeting elementary majors. A lot of them do not have the best attitude toward science. It's not their favorite subject. They're afraid of it. They don't enjoy it. I'm trying to get them interested and	This one works so well, that I am trying to change my other classes to not lecture so much because they get the totally (RT2)glazed over look. They don't seem interested at all. And this class	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							demonstrations. (SL5)You're doing all kinds of things. In this county we need people doing that. We're getting farther and farther behind. And I think young kids really like science. We beat it out of them. They are so curious and it's perfect for them. But we make them read and that just kills it. (SL5) To me testing doesn't work. I mean they memorize it for the	engaged(LD1) . Using hands-on seems to be able to help a lot with that(LD4) . They're also a little more relaxed and so they tend to interact more with me. They tend to answer more questions and they won't in other classes. If it's just a lecture class. To get in my class, they already had to have taken general biology and physical science. When I ask them questions about what I know they have had in those classes, they rarely remember anything they have had in those classes. So, interest, whether they are engaging	is completely different. You are taking people who have no interest in it at all in the first place and at the end of each unit I actually ask them to write a little reflection. And often they will say I've never liked science before in my whole life. This is class is so fun that I'm changing my attitude. This helps me assess what I'm doing to. If I know something is not working by	

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							test and it's done. They're not going to remember it. It was in and then it was out. So, rather than focusing on tests, honestly I really just focus on the hands-on activities and try to get them involved. And hope that something in there is clicking. (SL5) Nothing formal and maybe the results of their scientific experiment.	with me or not. How well they are doing in the activities, how much they are participating. (LD1)	reading these, I can change what I'm doing. The hardest part was to make the transition from lecturing to not lecturing. One you're used to it and that's what you do. (RT3)Another component was is the time it takes to set this class up. It takes a lot of time to gather the supplies. Once you get it done the first time, it's much easier after that.	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
									You have the supplies. (RT3) That initial get it all together.	
CA: Nancy	83	15	17	15	17	19	Most of them are very interested (SL5) as seen by their being on task and learning things that they can take to their own classroom (SL7). Some still don't realize that they will need to know these science concepts. (SL5)	I use guided inquiry. Students develop(LD4) their own questions. I don't like seeing students bored, and it doesn't make sense that I should be the only one thinking. (LD1) I don't like the scripted lesson	My experiences in the Peace Corps in West Africa made me realize that I had to provide examples that are relevant (RT1)to the students. It's all right to question what you are teaching. If you are not comfortable with the curriculum then change it.	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							Students should be confident that they can create different circuits. (SL2)/ Also, they should be able to explain why they are seeing what they are seeing at structural and molecular/chemical levels (SL5)	plans developed for teachers. This course is a lot more hands-on with a(LD4) blurring of the division between lab and lecture. (LD3) There are no real barriers. The courses were developed around 12 years ago. They were still mainly quantitative courses (physics especially). There is not a methods course specific for teaching science, so I try to model good science teaching and give students ideas as to how they can adapt activities to their future classrooms. (LD7)	(RT1) I learn a lot from talking with colleagues and attending meetings that discuss science education I gained a lot from the National Research Council book *How Students Learn*. I understand the importance of relevancy, connectedness and prior knowledge. (RT1)	

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DA: George	84	14	18	17	18	17	Unfamiliarity of students with this type of course – they don't know the expectations, how to prep for exams or how to take notes. (SL5) In general, afraid of science. Finds elementary ed majors more afraid than others. Wouldn't take if it weren't required. (SL5) Elementary ed majors have low	5E model developed 2004 material OPPS Lousiana State (materials for in-service teachers) adopting the material for pre-service teachers (LD7)	1st time teaching by inquiry – needed to learn methods and knowledge. (RT1) Gain ability to ask students to figure out the answer and tell him Develop ability to pull out questions and ideas. Ordering of materials and modules. Now is his	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							confidence (SL5)– show them science is nothing other than refined common sense. Wants to show them that pre-knowledge is not necessary. They don't need to know more than others living in this (SL5)world. They can teach fine with very basic knowledge. (SL7) Asking what will happen opens the door to inquiry teaching. (SL2)		favorite course. Research shows students learn better through inquiry. Teachers will teach that way if taught that way.	
EA: Mike	89	16	17	19	19	18	I also want them to leave with some	In developing the course, we brought together former	I had to learn new ways to	I would like that students

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							basic understanding of science. (SL1) We teach everything from what is an atom to what is DNA in ten weeks (SL4) . Students who take the class say that after taking this class they now finally understand these basic concepts, even though they've had them in earlier classes. It relates to their lives (pollutants, chemicals, their (SL1) own bodies) and it will lead into	students, mentor teachers, and faculty from different areas to give input on a chemistry content course for teachers. They all said we should take the students out to schools. Even though this is a content class and not a methods course , I still have them go into the schools for some of their lab periods and teach lessons on topics we're covering. The main point is that I know the goal at the end of the class. I need them to be able to draw 2,3,dimethyl-pentane, and they need to be able to name it. If that happens, then I'm happy(LD2)	teach. (RT3) I thought I was a good lecturer, but I never did group work because I always hated working in groups when I was in college. I had to learn about groups and about teaching and learning. I still try to learn about that, which is why I go to workshops, conferences, and faculty development. I also know a lot of teachers (RT2) (RT2) (my parents and	course and lo forward to be Coming into I know that r students are apprehensive taking scienc Sometimes h class is made who have av science as lo could. I expe job is to turn around. Like when I student, whe "e" to a certa my brain wo and I would the whole thi I thought it w beyond my

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							functional groups and amino acids. It's important for them to understand what life is based on. I try to teach in the spirit of "less is more," focusing on giving students a motivation to learn. (SL5) If students want to go out and read more about (SL1) something, learn it when they need it(SL2), I want this class to give them the background to be	. It relates to their lives (pollutants, chemicals, (LD1) their own bodies) and it will lead into functional groups and amino acids. It's important for them to understand what life is based on. The important part is not that they know how to draw isomers or how to name compounds, but that they can get comfortable with what carbon can do and that it can do some pretty sophisticated things. My assessment is embedded in the teaching . I gauge how well they're getting it along	friends), and I asked them for advice when planning to teach the elementary methods course . I apply this information to the methods class and to this class. I want these students to learn to teach by example (RT2). Always question why you teach (RT3)what you teach and how you teach it. Teaching is about facilitating learning. I'm not tied to any one plan.	comprehensi then once so me that it wa another num sudden every OK.

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							able to do that. Good teaching is situationally specific. Learning is personal and you need to teach to your audience. Know your students. (SL5)Know who they are and what they want. Think about if your course is the only science your students may ever take in college and what is most important for them to know. If students are comfortable (SL5) seeing chemical	the way. In the end, I'll draw a structure on the board and see if they can name the compound	(RT1)Luckily I've taught this course long enough that I can be spontaneous and flexible (RT2)depending on their reaction.	

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							structures, for example, they won't (SL4) completely ignore them or turn off when they see them later. I try to give my students the basics – it's not just a bunch of lines, it's a chemical structure. I try to find their own barriers to learning and help them to overcome them. (SL5) This hooks them in because they want			

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							to be good teachers. That's their motivation. They relate to the science because they relate to teaching. My first priority is not teaching them chemistry, but making them good teachers of science and of chemistry in particular. (SL7)			
GA: Lauren	90	18	216	18	18	20	Liberal Studies students don't like science and don't want to teach it. (SL5) I don't put pressure on them to learn	The students should learn (LD2) about convection currents, movement of plates, history of plate tectonics, subduction, and acretion. I give them pre- and post-	I give them surveys throughout the course and find (RT1)that they feel more comfortable and confident to teach science.	Since I lack a degree, I don lot of respect tenured facul how to teach course.

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Instructor	***RTOP* Score**	**LD**	**PrCK**	**PrPK**	**CI**	**STR**	**Student Learning**	**Lesson Design**	**Reflections on Teaching**	**Other**
							the science, but give them a lot of opportunities to learn more science. I give them websites to use to add to their knowledge of science concepts (SL5)	tests. I also give them various items (piece of paper, lightbulb, battery and wire) (LD7) to test their conceptual knowledge. I role model a lot of the strategies that they will need to teach science (LD7)		
CB: Angie	93	17	19	19	18	20	They should have a fundamental understanding of what science is and what it means to think (SL6)	Designed course around teamwork- assign teams to be as diverse as possible (majors/genders/backgrounds) • Aware that the student population is very diverse.	When first started teaching the class about 10 years ago, focused mainly on content. (RT3)Had to realize that	

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Instructor	*RTOP* Score	LD	PrCK	PrPK	CI	STR	Student Learning	Lesson Design	Reflections on Teaching	Other
							scientifically They should be able to read artiCLES in (SL1) Newsweek or Time and understand and analyze them or critically think about the article I want them to understand the difference between primary and popular literature Less is more. (SL5) College is not about filling students' heads with facts. It's about helping them gain tools. Students	• The course is a required course for all students so students are from many different majors. Everyone who graduates from the college with a bachelors or associates degree needs to take this class i. short lecture(LD1)/(LD6) ii. presented with a problem to work on(LD3) iii. students work together to solve problems and share solutions. (LD4)	learning science is not about learning facts. It's more meaningful to students if they don't memorize. (RT1) Participating in workshops helped to see how people learn beyond memorizing facts. You can look up facts – it's what scientists do. You don't need to memorize everything. (RT1)	

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							need to learn how to learn. (SL5) Problem solving is a skill that they(SL2) (SL5) can use and apply to their everyday lives. (SL1) People trained in science think this way all the time. Scientists sometimes don't realize that we don't all think this way. Helping the students to think like scientists (SL6)	Do a group inventory of solutions Try to integrate lots of experiences into the class where they aren't just reading about how science works, or(LD1) participating in it, but they get to see how science works. Also uses films to use as model to show how science works(LD6) and discuss (watched film recently about the particle effects causing dimming of the sun and decreasing global warming) Focus of class is on understanding how science works, so everything based on		

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							Everyone has their own means for learning Tries to make the material available in a lot of different ways (questions, pictures, etc) (SL5)	that. Don't negate that people can have other belief systems, but this is how science works. Integrate a lot of different types of activities like debate. (They come up with (LD4) debate ideas and vote on them) Regardless of skill set, there's always a way for each student to shine Uses website from University of Buffalo for case studies		