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THE FLORIDA STATE UNIVERSITY
COLLEGE OF EDUCATION

THE TEACHER'S ROLE IN COLLEGE LEVEL CLASSES FOR NON-SCIENCE MAJORS: A CONSTRUCTIVIST APPROACH FOR TEACHING PROSPECTIVE SCIENCE TEACHERS

By

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A Dissertation submitted to the Department of Curriculum and Instruction in partial fulfillment of the requirements for the degree of Doctor in Philosophy

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TO EACH ONE IN MY FAMILY WHO PATIENTLY WAITED FOR ME TO FINISH THIS WORK AND RETURN. YOU WERE ALWAYS WITH ME DURING THIS JOURNEY IN MY HEART OFFERING ME ENCOURAGEMENT AND SUPPORT.
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ABSTRACT

This interpretive research set out to investigate the characteristics of an exemplary college science instructor who endeavors to improve teaching and learning in a physical science course for prospective teachers. The course was innovative in the sense that it was designed to meet the specific needs of prospective elementary teachers who needed to have models of how to teach science in a way that employed materials and small group activities. The central purpose for this study is to understand the metaphors that Mark (a pseudonym), the chemistry instructor in the course, used as referents to conceptualize his roles and frame actions and interactions in the classroom.

Within the theoretical frame of constructivism, human cognitive interests, and co-participation theories, an ethnographic research design, described by Erickson (1986), Guba and Lincoln (1989), and Gallagher (1991), was employed in the study. The main sources of data for this study were field notes, transcript analysis of interviews with the instructor and students, and analyses of videotaped excerpts. Additional data sources, such as student journals and the results of students' responses to the University/Community College Student Questionnaire which was developed by a group science education researchers at Florida State University, were employed to maximize that the assertions I constructed were consistent with the variety of data.

Data analyses and interpretation in the study focused on identifying the aspects which the instructor and the researcher might find useful in reflecting to understand what was happening and why that was happening in the classroom. The analysis reveals how the instructor used constructivism as a referent for his teaching and the learning of
his students. To be consistent with his beliefs and goals that prospective teachers should enjoy their journey of learning chemistry, Mark, the driver in the journey, used the roles of controller, facilitator, learner, and entertainer as referents for actions to create conducive learning environments. He was able to switch his actions based on which of the constituent metaphors he used as a referent to frame his actions and interactions, and thereby, to create an exciting environment for learning.
CHAPTER 1
INTRODUCTION

Background

In recent years, scientists and science educators have collaborated in an effort to find a clear path toward better science education. Science for all Americans, a project sponsored by the American Association for the Advancement of Science (1993), Scope, sequence, and coordination, sponsored by the National Science Teachers Associations (1992), and Science teacher preparation in an era of standards-based reform (Committee on Undergraduate Science Education, 1997) are examples of such efforts in the United States. These projects suggest major changes in what, when, and how science is taught. They strongly recommend that a more constructivist approach be employed in science teaching and learning instead of an objectivist approach.

In the objectivist approach, which is a traditional theory, knowledge is seen as a set of truths that exist "out there" (Johnson, 1987), that learners need to look for in the texts, or in the minds of their teachers. From a constructivist perspective, which is an alternative theory of knowledge, knowledge is "our own construction" (Bettencourt, 1993, p. 39). It refers to the "conceptual structures that epistemic agents [knowers], given the range of present experience within their tradition of thought and language, consider viable" (Glaserfeld, 1989, p. 124). Viability means
the acceptance of knowledge by the scientific community as "viable because of its coherence with other understandings and its fit with experience" (Tobin & Tippins, 1993, p. 4).

To be consistent with objectivist semantics (Johnson, 1987), the science teacher tends to view science as a body of knowledge that can be separated from knowers. Accordingly, s/he conceptualizes her or his role as a transmitter of information or knowledge while the learner acquires such information as 'absolute truths' by a process of absorption (Tobin, 1990a). The term 'teacher's role' refers to how a teacher considers his or her position when he or she is teaching in a particular class. A teacher may consider his or her role as a giver of knowledge, for example, in a teacher-centered class while another teacher may see his or her role as a facilitator in a learner-centered class.

From a constructivist perspective, knowledge is experiential and constructed within the minds of learners (Glasersfeld, 1989). Learners actively involved in the learning process use prior experience and knowledge to construct meanings in new situations. The phrase 'prior knowledge and experience' refers to the learners' ideas, conceptions, and views that are gathered in the course of their lives (Bettencourt, 1993, p. 47). The construction of knowledge is performed, as clarified by Glasersfeld (1989), who discussed it in terms of scheme theory, in three steps. First, recognition of a certain situation, such as water could be liquid, vapor, or solid. Second, association of a specific activity with that kind of item, such as water boiling and freezing. Third, expectation of a certain result, such as liquid water becomes ice with lowering temperature and becomes vapor with increasing temperature.

The role of the science teacher is to provide an environment where students can
actively learn and construct their knowledge. Accordingly, learning, which means "the growth of knowledge" (Bettencourt, 1993, p. 39), is a social process of making sense of experience in terms of what is already known (Tobin & Tippins, 1993). Teaching is required to facilitate students' learning and to monitor their understandings through appropriate ways such as clarifications (Tobin, 1990a). Within this approach, students learn science through "active engagement in activities in which [they] discuss ideas and problems with their peers, manipulate equipment, work independently, listen to the teacher in whole-class settings and respond to teacher questions" (Tobin, 1990a, p. 34).

Although science learning becomes student-centered in the constructivist approach, science teachers play an important role in students' learning. In science classes for prospective teachers, the instructor has a vital role to enhance science teaching and learning. Prospective teachers learn science in college classes in which instructors mainly use traditional styles of teaching. According to the expression "as I learned science, I teach it," the science teaching of prospective elementary teachers is influenced by the way they have learned science in college. When prospective teachers have an opportunity to learn and understand science differently, they teach science differently in their own classrooms (Gilmer, Barrow & Tobin, 1993).

In college-level science classes for prospective teachers, the actions of science instructors influence the style of science learning and how to teach science in their own classes. The term 'actions' refers to the intentional acts that are conducted by the instructor in the classroom such as lecturing, experimenting, arguing, and asking and answering questions. A teacher's actions in the classroom are a product of interactions among four elements: the goals of the teacher, the context in which actions occur, beliefs
that are a referent for a given set of behaviors, and the behaviors that occur (McRobbie & Tobin, 1995). Accordingly, such actions are associated with given teaching roles in specific contexts.

A teacher's role can be conceptualized in terms of metaphors and is defined by beliefs which influence what the teacher endeavors to do during classroom actions (Tobin, Kahle, & Fraser, 1990). A belief, as noted by Tobin and LaMaster (1995), is "knowledge that is viable in that it enables an individual to meet [his or] her goals in specific circumstances" (p. 226). Although beliefs are not always goals directed, they are "tied to the situations in which actions are contemplated" (Tobin & LaMaster, 1995). The term 'metaphor' refers to the way that science teachers use to think about their roles when they re-present their knowledge in science classes (Tobin, 1990b). A science teacher can use metaphors as referents to constrain teacher's and students' roles, and students can construct metaphors for their roles as learners to constrain their actions and to mediate those of the teacher (Tobin & Tippins, 1996).

In this study, I focus on the teacher's actions in a college science class and the instructional strategies used. The term instructional strategy, as it is expressed by Hofstein and Walberg (1995), is the way in which a science teacher uses materials, media, setting, and behaviors to create a learning environment that fosters a desirable outcome. The teacher's roles are associated with the various instructional strategies he or she uses. The more an instructional strategy becomes learning focused, the more the teacher's roles move toward guiding, facilitating and helping students to learn actively through the use of prior experience and knowledge to construct meanings in new situations.
The Problem

At the college level, prospective elementary and early childhood teachers (hereafter referred to as elementary prospective teachers) must enroll in science courses in the College of Arts and Sciences in order to fulfill requirements for the university and the College of Education. These courses are mostly traditional science lecture courses. Teachers in these courses typically maintain total control of the content, the pace of delivery, and the method of evaluation (Gilmer, Barrow & Tobin, 1993). The majority of them are concerned more with the quantity of information they teach and pay less attention to the extent to which students understand what they are to learn.

The majority of students in college level science classes engage in essentially rote learning most of the time (Edmondson & Novak, 1993). Rote learning refers to new knowledge may be acquired simply by memorization, but incorporated into a learner’s knowledge structure without interacting with what is already there (Tobin & Tippins, 1993). I had been involved in several undergraduate science courses during the first two years of my program at Florida State University. The classes were dominated by an objectivist approach of teaching and learning. The principal role of my teachers seemed to be to deliver knowledge and the main role of students was to take notes and memorize in order to pass examinations of the course. Tobin (1990a) has reported similar findings related to the teaching of college level science for prospective elementary teachers.

Although there is not much published research on college science teaching, the studies that have been published are consistent with a prevalent use of objectivism
(Johnson, 1987) to support traditional content coverage by teachers and memorization by students (e.g., Barrow, 1993; Bowen, 1993; Brush, 1993; Haidar, 1997; Lorsbach, 1991; Roth & Tobin, 1996). Most science teachers, whose pedagogic practices are influenced by objectivist beliefs about how to know science, emphasize learning of basic facts and definitions in science topics from science textbooks and lectures. Less attention is paid to understand science and know how to use it in their daily lives. Relatively little emphasis is placed on achieving the main goal of science courses that students understand science knowledge and know how to use it in daily life. The traditional role of the teacher is to adapt materials from textbooks for specific classes of students. In most instances this role involves partitioning the content and activities into manageable 'chunks' (Tobin, 1990) so that students can cover all or most of the work in the time available.

The problem in traditional science classes for prospective teachers is, as suggested by Tobin and Roth (1995), that instructors and students belong to different discursive communities with a wide gap between them. The language used by the instructor creates a barrier that prevents members of the student's community from crossing the border into the instructor's world of science (Griffiths, 1996). In the classes in which science teachers do not care whether meaningful learning occurs, most students tend to learn science probably without understanding, through memorizing facts, equations, definitions, and so on.

Meaningful learning occurs when learners must choose to relate new knowledge to relevant concepts and propositions they already know (Tobin, 1993 b). Tobin and Roth (1995) emphasized that in order to bridge this gap and facilitate the students' learning of science "it is necessary for the teachers to employ a form of discourse that
allows students to use their discursive resources in the process of building of understandings of physics." However, the point is that the methods used in college science classes are learned by the students. Therefore, in these classes, students do not only learn science, but also how to teach science in their own classrooms (Edmondson & Novak, 1993).

Every one, whether a student or a teacher, perceives the problem of using a traditional style of science teaching and learning, but they feel that this style is culturally supported. Using alternative approaches of teaching and learning in science classes may face some cultural constraints. Most of these constraints are considered as cultural myths which are suggested by Britzman (1991) to “offer a set of ideal images, definitions, and justifications that are taken up as measures for thought, effect and practice” (p. 6). Teachers who live in a given context with a specific cultural milieu need to adapt their actions to the cultural myths that constrain what happens (Tobin & McRobbie, 1996).

Most science teachers make sense of their teaching roles in terms of cultural myths such as translation of knowledge and preparing students to succeed in examinations (Tobin & McRobbie, 1996), or imagining the curriculum as a container whose contents need to be delivered (Taylor & Campbell-Williams, 1993). They serve to maintain traditional patterns of science teaching and learning practices in college level classes (Taylor, 1995). Myths can be found within any discourse community. Tobin (1995b) commented that “myths are socially constructed and within a community of practice are accepted as referents for action. They define what is normal practice and might be used to justify customs.”
Using a traditional way to teach science for prospective teachers in colleges is not a problem of just one particular place. It is a problem that transcends national and international boundaries. Science instructors often have a cultural transmission view of teaching (Tobin, 1990a) in which the instructor works hard in the classroom to transmit scientific information, rules, and values to the learners. The learner should acquire such information as 'truths' by “a process of iterative accumulation or absorption” (Tobin, 1990a).

In my home country, Yemen, for example, the style of teaching and learning is still dominated by an objectivist approach. When I began teaching in elementary school, my style of teaching was influenced by my science teacher in high school. He stood in front of the class explaining a science topic he had prepared, using the black board for drawing and writing his main ideas. So, I wanted my students to learn in a similar setting. I considered myself as the main source of information and I expected them to receive passively what I transmitted to them.

Most Yemeni prospective teachers depend “on mere memorization of the concepts without meaningful understanding” (Haidar, 1997, p. 181). Furthermore, they learn in college classes how to deliver science information to students in a controlled environment in their own classrooms. Accordingly, science educators and scientists in Yemen are looking for an effective approach to enhance science teaching and learning in schools of education and community colleges. They feel that it is important to focus on how to create an active style of teaching and learning in science classes (e. g., Haidar,
In the United States, as well as most college-level science classes in other parts of the world, prospective teachers learn science courses which are taught by science faculty in order to fulfill university requirements. Mostly, these courses are traditional science lecture courses. The science instructors mainly focus on the content, and may or may not include demonstrations or activities in the classroom (Gilmer, Barrow & Tobin, 1993). Their roles as teachers who know science are to structure experiences for students, most of whom had little or no formal experience with science, so that they can learn science (Tobin & Roth, 1995).

The interdisciplinary science courses, physical science, earth science, and biological science, as reported by Duffy (1993), Gilmer, Barrow and Tobin (1993), and Tobin & Roth (1995), were developed for prospective elementary teachers at Florida State University with funding from the National Science Foundation. These courses, each of which earns four semester hours of credit, are offered through the College of Arts and Sciences in conjunction with science educators from the College of Education. There is no distinction between laboratory work and lecture because they are integrated and taught by the same instructor(s) (Gilmer, Barrow, & Tobin, 1993).

The major purpose of this project was to plan, implement, and revise courses taught in science and science education for prospective elementary teachers (Duffy, 1993). An expected outcome of these courses is that the prospective teachers will conceive of science not as a list of definitions nor a series of facts, but as a process and a way of understanding the world (Gilmer, Barrow, & Tobin, 1993). Students would know science in a meaningful way and possess the subject matter knowledge and confidence to teach science when they become teachers in the elementary school (Tobin & Roth, 1997).
The study continues a series of longitudinal studies that have explored the extent to which the re-developed courses have addressed the needs for prospective elementary teachers. The study focuses on science teaching and learning in the Physical Science for Elementary Teachers course.

**Focus of the Study**

Data framing for this study was in the classes of the Physical Science for Elementary Teachers course. This course has been designed for prospective (and enrolled) elementary and childhood education majors, and it was developed in three steps (Duffy, 1993). First, the physics course was planned and implemented in the spring of 1992. Second, the chemistry course was planned during the spring of 1992 and implemented during the summer of the same year. Third, during the spring 1993 semester, the chemistry and physics courses were combined to create a single physical science course. The course met for a two hour block three days per week during the spring semester. The classroom science material and the laboratory were integrated by the same instructors. Since that time the course has been taught by the same professors each spring.

The physical science course has two sections, physics and chemistry. During the years 1993-1994 the course was taught by two physics professors and a chemistry professor. However, since the year 1995, the course has been taught by a physics professor, Adam (a pseudonym), and a chemistry professor, Mark (a pseudonym). I use pseudonyms throughout the study to protect the anonymity of the participants. In this study, greater attention was paid to the chemistry section of the course and the actions of
its instructor.

Mark was selected to be the focus of this study because of his reputation as an exemplary teacher, his enthusiasm for chemistry teaching and his willingness to share teaching experience. I am interested in studying Mark because, I had undertaken supervised research classes for a period of two semesters in 1995 which I observed Mark teach and analyzed data from videotapes of classes he taught in previous years. His teaching provided a context from which I believe I could learn a great deal from endeavors to make sense of his actions in the classroom and the roles he conceptualizes for himself as a college chemistry teacher. One focus for my research was on Mark's actions and the metaphors he uses to conceptualize his roles to modify conducive environments for learning in the classroom.

As a participant in the study, Mark is a scientist with almost 12 years of experience in teaching college-level courses to science majors from Florida State University. Mark has been a participant in other studies of his teaching (Brush, 1993; Duffy, 1993). He was a member of the planning and implementation group for the physical science course for prospective elementary teachers in the Spring of 1992; and he began teaching this course in Summer of 1992 (Duffy, 1993). Brush (1993) concluded in her study that Mark is enthusiastic in teaching science for prospective elementary teachers and is one whom students find very approachable.

Although science classes taught in the College of Arts and Sciences are dominated by a lecture-style of teaching, Mark's classes seem to be rich in interactions. It seems that Mark works hard in his classes to move from teacher-centered to learner-centered approaches in which alternative ways of science teaching and learning can be utilized. Whenever possible, Mark tries to make connections between chemistry and the students'
experience (Duffy, 1993). He always tries to mediate the students' learning, and to channel their thinking by asking them questions and stimulating interactions among students and between the teacher and students. Mark also used questions to monitor the students' understanding of chemistry (Brush, 1993).

Brush (1993) reported that constructivism was used as a referent for science teaching and learning in Mark's classes. Students are encouraged and stimulated to engage in class discussion in a variety of ways, such as asking questions, and to interact with Mark in their journals. They are encouraged, as stated by Duffy (1993), to answer questions and to express their opinions and beliefs to the instructor. Brush (1993) noticed that even when students gave the wrong answers, Mark continued prodding and giving hints so that the students would not feel frustrated, and give up on their thinking. Mark's approach to teaching is dynamic. He endeavors to maximize the participation for his students and he always is on the lookout for ways to stimulate active and varied ways of participation for his students who are non-science majors and frequently have negative feelings about science (Brush, 1993). Since it is the first or the second time for most of these students to attend college science classes, Mark's approach encourages them to engage actively in discussions and other activities intended to promote interest and learning (Brush, 1993).

Brush (1993) reported that Mark is not only effective and active when teaching chemistry, but also when he assumes the role of learner in the physics component of the course. As a learner, he asks questions during the class, and endeavors to stimulate discussion to promote students' thinking. Whether or not he is the instructor, Mark tries to show his students that he does not have the answers all of the time, and that he too is a learner in the class.
The Purpose of the Study

There is a need for a study of the teacher's roles in science teaching and learning in college level classes. Furthermore, there is a priority for studies of teachers who are regarded by their students and colleagues as exemplary. This study focuses on the teacher's roles and the instructional strategies employed by an exemplary instructor of chemistry. The instructor of a college physical science course, which was designed especially for elementary and childhood education majors at Florida State University, uses certain instructional strategies to enhance science learning with understanding.

The central purpose of this study is to understand the instructor's actions in the classroom to create the atmosphere for active science learning. The study analyzes the teaching and learning processes in the chemistry section of the physical science course with a focus on how the teacher and learners interact to produce learning environments, co-participation, and the emergence of new forms of discourse.

The teacher's role in a learner-centered college science classroom is to mediate the learning of students. Pedagogical knowledge plays an essential role in how to use instructional strategies in the classroom. It is presumed that teachers with pedagogical knowledge conceptualize roles in terms of more than one metaphor and associated sets of beliefs (Tobin, Kahle, & Fraser, 1990). As a consequence, these teachers are able to change their teaching strategies as the context of learning changes. This change of teachers' roles in classrooms was predicted by Glasersfeld (1988) when he noted that the teacher's role will no longer be to dispense 'truth' but rather to help and guide the student in the conceptual organization of certain areas of experience.
Although different questions may be constructed as a result of the research process, this study attempts to answer questions related to science teaching and learning in a college-level class. Major questions addressed in the study are:

- How is a teacher's role in the classroom related to his beliefs and goals?
- How are the teacher's actions and his instructional strategies related to his roles in the classroom?
- How is the construction of a teacher's role in the classroom related to the context within which science learning and teaching are performed?
- How do the metaphors that a science teacher uses in science teaching relate to his roles in the classroom?
- How is the creation of an effective learning environment in the classroom related to the teacher's roles?

**Significance of the Study**

Why is there a need for research to understand a teacher's role in science teaching and learning in college level classes? Generally, the approach of teaching science in college level classes encourages students to learn science by rote memorization. Most science teachers view science learning as knowing basic facts, concepts, and definitions from science textbooks and lectures. Relatively little emphasis is placed on understanding knowledge and how to use it in a learner's daily life.

Reports such as *Science for all Americans* and *Scope, sequence, and coordination* stated that the achievement of students is below expectations. More than 400 national reports (Hurd, 1994) have demanded reform. Classes for prospective teachers
dominated by the traditional style of science teaching and learning are inconsistent with the visions described in these reports. Therefore, pedagogical reform is one of the significant concerns of the study.

The findings of this study relate to what happens in college science classrooms and how teachers and students conceptualize their own roles and those of others in the class. The study also describes how a teacher's role can mediate the construction and maintenance of an environment that encourages and stimulates students to learn science actively through student-teacher, student-student, and student-task interactions. The implications of the study can provide bases for the future reform of college science teaching and learning for prospective teachers in this country and elsewhere.

Rationale for the Study

This study has academic, pragmatic, and personal interests. It provides some insights about how a science teacher in college-level classes conceptualizes his roles in the classroom and enacts the curriculum. It also provides valuable information on how scientists and science educators cooperate and work together. Reflections of both the researcher as a science educator and Mark as a scientist in the study may facilitate implementation of collaborative projects in my home country to improve college science teaching and learning for prospective teachers.

Since I have experience in teaching science and science education classes for several years in public schools and in college, this study is of great interest to me. My beliefs about science teaching and learning have changed dramatically during the past years in Florida State University. Also, studying videotapes about the chemistry section
and the instructor's actions in the Physical Science course for two semesters encouraged me to be involved in the physical science course and focus on the chemistry section and its instructor. However, I feel that a new theoretical approach has been constructed in my mind, helping me to construct a new view of the world and to understand actions and interactions of the teacher and students in the natural location or the classroom.

**Structure of the Dissertation**

The dissertation is designed to investigate and understand “what is going on?” and “why is that going on?” in college level classes for non-science majors. It aims to understand how a teacher’s role enhances science teaching and learning in classes for prospective elementary teachers. The study focuses on analyzing the teaching and learning processes and the strategies used by Mark, the chemistry instructor of a college physical science course, to create an atmosphere for active science learning. I endeavor to understand his actions and the metaphors he uses to conceptualize his roles in the classroom. Accordingly, this study has been structured in seven chapters that examine answers for the addressed and emergent questions of the study.

The second chapter of the dissertation is an overview of related research in science teaching and learning in pre-college and college level classes. I briefly review the studies that were conducted in the past few years about college science teaching and learning for prospective elementary teachers in Yemen and Florida State University. Further, I review some related studies that were conducted in middle and high schools about science teaching and learning.

The third chapter describes the methodology that I used to conduct the study. In
the first section of the chapter, I discuss the interpretive research design that I employ to investigate the problem of the study. The next section is about the participants in the study. Since I am one of the participants in the study I discuss the theoretical framework that I use during the process of conducting this research. The data sources for the study are described with more focus on data analysis, interpretation, and archiving. The last section is a description of the steps that I take to ensure that my study was rigorous.

In the fourth chapter, I endeavor to understand the culture of college science teaching for prospective teachers. The first section of the chapter focuses on the traditional style that dominates science teaching and learning in college classes. The focus is on how a traditional science teacher conceptualize roles for him/herself and for students in the classroom. Then I endeavor to learn about the nature and scope of the cultural restraints or myths that serve to maintain traditional patterns of science teaching and learning practices (Taylor, 1995). The second section describes the context of Mark’s actions in teaching science for prospective elementary teachers. The instructional strategies that were used in Mark’s classes to enhance science learning have been analyzed in this section. The focus is on the efforts that he exerts through his actions to move beyond the objectivist approach to science teaching and learning, and to create active environments for learning in the classroom. Then I discuss the constructivist approach that Mark endeavors to apply in teaching science for prospective teacher. The focus is on Mark’s beliefs and goals that influence his actions and metaphors he uses to think about teaching, learning, and classroom practices. This chapter generates a more insightful understanding of the objectivist paradigm that dominates the context that Mark works within to conceptualize his roles in teaching science in college level classes.
In the fifth chapter, I discuss the metaphors and teaching roles in science classes. I endeavor to understand the metaphors that Mark uses to conceptualize his roles in teaching science for prospective elementary teachers. The focus is on the roles that Mark uses to create a learner-centered rather than teacher-centered learning environment in the classroom. Accordingly, students feel that they have the power to talk, ask and answer questions, and express their ideas.

The sixth chapter is a description of the learning environment in Mark's classes. It explores the importance of a teacher's role in creating a particular learning environment. The focus is on analyzing the roles that Mark used to create an exciting environment for science learning in the classroom. Further, I endeavor to understand how such roles encourage students to learn science with understanding, and stimulate interactions and discourse in the class.

The last chapter addresses the conclusions of the research project. It discusses the research questions and the findings in the study. The implications of the study are considered at the end of this chapter.
CHAPTER 2
OVERVIEW OF RELATED RESEARCH

Introduction

Although there are not many published studies on college science teaching, the studies that have been published in the past few years about college science teaching and learning for prospective elementary teachers in Yemen and at Florida State University (FSU) are reviewed in this chapter. Most of the FSU's studies focused on teaching and learning in the physical science course and the other courses in the project funded by the national Science Foundation and the Dwight D. Eisenhower program for the improvement of science and mathematics education. In addition, I review some related studies that were conducted in middle and high schools about science teaching and learning. Most published studies are consistent with a prevalent use of objectivism as a referent for science teaching and learning in pre-college and college classes. Reviewing such studies helped me to construct a context for the terms I use in my study.

Several studies (e.g. Barrow, 1993; Bowen, 1993; Brush, 1993; Moscovici, 1994) about teaching and learning in science courses for elementary prospective teachers were conducted as doctoral dissertations in the last four years. Two other dissertations (Mattson, in progress; Hendren, in progress) are still in progress. Two Master's theses (Duffy, 1993; Sullivan, 1994) were also conducted in the physical
science classes and laboratories. In addition, many papers (e.g. Haidar, 1997; Moscovici & Gilmer, 1996; Roth & Tobin, 1996; Tobin & Roth, 1995; Tobin, Roth, & Brush, 1995; Roth, Tobin, & Shaw, in press) have been written on college science teaching and learning. Reviewing these studies and other related studies (e.g. McRobbie & Tobin, 1995; Ritchie, Tobin & Hook, 1997; Tobin & McRobbie, 1996; Tobin, LaMaster, 1995; Tobin, Tippins & Hook, 1994) conducted in middle and high schools provide a context in which my study is embedded. In the following sections I briefly review some studies that have been conducted about science teaching and learning in college classes and in school classes.

Science Teaching in College

Barrow (1993) was involved in the planning and implementing the physics course in 1992. His study's purpose was to determine the roles that the physics instructor played in the process of developing the curriculum of the course by analyzing the instructor's actions in the planning, translating and implementing of the new physics curriculum. He also focused on the students' perceptions of the classroom learning environment created by the new physics course and the extent of the fit between the experienced and preferred environment of students. One of the interesting recommendations was that the instructor should ensure that students become involved in the mediation of the curriculum at all levels of the course development. Barrow argued that when students feel ownership of a science course, learning with understanding, instead of grades, becomes their primary focus.

Bowen (1993) focused on students taking a chemistry course for non-science
majors (which included some prospective elementary teachers). The purpose of his study was to illuminate some of the frames that students used to make sense of their science class and how they interpreted their classroom life. He found that students assessed teaching effectiveness in the class in different ways. In addition, they conceptualized knowledge, teaching and learning in different ways. There was a preference for a more emancipatory learning environment as experienced by the students in the classroom. Some students preferred a learning environment where they were encouraged and empowered to learn and take charge of their own learning.

Brush (1993) intended in her study to analyze the teaching and learning process in the physical science course with more focus on the learning of chemistry. She focused on learners' perceptions of the components of the course, such as science, physics, chemistry, and the learning environment, and the instructors' views about teaching, learning and assessment. She found that the fit between the preferred and the experienced learning environment in the course was quite good for students' involvement and autonomy. The class preferred more relevance than was experienced, and the students felt that they should be more committed than they were in the course. She suggested that if students are accustomed to a very traditional approach of learning, it is very necessary that the new approaches be presented in a very supportive atmosphere.

Moscovici (1994) focused on the learners in the biology course for prospective elementary teachers. The purpose of the study was to understand if there is a difference between the perceived and preferred learning environments. She also attempted to understand what influenced students' goals and expectations for the course and how these goals and expectations influenced their perceptions of the class and their learning. Students in the course wanted more opportunities to get involved, more relevant subject
matter, more autonomy to decide the depth and duration of subject matter, and more commitment to learn. She found that there was still a high degree of discontent with students' experienced learning environments. She recommended that the environment should be improved in a direction to nurture rather than to control students' learning.

Another study in the biology course for prospective elementary teachers is conducted by Mattson (in progress). Her involvement in the development and implementation of the biology course encouraged her to focus on some issues and perspectives related to the course such as content, pedagogy, and assessment. Mattson, in her study, attempts to understand the perspectives characterizing the development of the course and the beliefs underlying the different perspectives. Building an understanding of how these beliefs shape course development is also one of her goals. In addition, she focuses on the educational reform goals and the strategies that could be used to encourage continued progress toward reform.

Hendren (in progress) endeavors to understand how students in the Earth Science course designed for prospective elementary teachers were enculturated into scientific discourse. He focuses on the classroom as a communicative environment where discussions between students and teachers occur. He presents a series of case studies involving students' and teachers' discussions to understand the nature of instructional conversations in the classroom. Also he is concerned about other issues related to the course such as what was being taught and learned, and how it was being taught and learned.

The development of the chemistry course for prospective elementary teachers was described by Duffy (1993). He described the enacted curriculum using a simple model based on the concept of an activity and how it evolved to a more dynamic,
integrated model. He focused more on the use of journals to facilitate a dialogue and interaction between the instructor and students. Also, the classroom learning environment as viewed by the students was analyzed in the study. One of his interesting findings was that there was a relatively small difference between students' experienced and preferred classroom environments. He attributed this finding to the high degree of approachability demonstrated by the instructor.

Sullivan (1993) focused more on studying the learning environments that were present in a laboratory course in chemistry for non-chemistry majors. She suggested that laboratory activities help non-major science students feel that the science they learn does have real world applications. She found that the environment the students preferred and the one they experienced in the laboratory were very close, except for the integration of theory and practice and suitability of the materials available to support learning. Although students did not like open-ended experiments, the laboratory environments helped them to have high cohesiveness, rule clarity, integration, and personalization.

In a series of studies on teaching and learning in science courses for prospective elementary teachers, six studies have been published about teaching and learning in the physical science course and the biology course. The first study was conducted by Roth and Tobin (1996) to understand physics lectures during the physical science course for prospective elementary teachers. The focus was on the function of demonstrations, discourse, and inscriptions in mechanics classes to understand the rhetorical aspects of the lectures. They concluded that the form of instructional delivery used in lectures about motion does not help students to become proficient in physical discourse. They called for an alternative style of physics instruction to facilitate students'
constructions, and to allow them to enter and participate in an emerging discourse community.

In another study, Tobin and Roth (1995) examined the teaching and learning of college level physics in terms of the teacher and students belonging to different discourse communities. Its focus was on the lack of co-participation between the instructor and the students in the mechanics classes. The researchers intended to understand how the gap between students' extant knowledge about the concept of motion and what they were required to learn contributed to the failure of students to learn physics. They concluded that within this environment, students could not access the language of the instructor nor make sense of physical concepts they were required to learn.

The third study performed by Tobin, Roth, and Brush (1995) investigated the beliefs of the instructor and the students about physics teaching and learning in the physical science classes for prospective elementary teachers. The researchers found that the instructor of the physics section had no prior experience in teaching prospective teachers, and many of his experiences as a college teacher were based on his teaching of physics to science majors. As a previous basketball coach, he conceptualized this role in science teaching and learning in the class as a coach. Also as an expert in physics, he constructed his role in terms of delivering significant scientific truths to students. The students had difficulties to learn physics and to communicate with the instructor. The researchers suggested that the beliefs of the instructor constrained the enacted curriculum to an extent that gaps between the needs of students and the enacted curriculum were wider at the end of the course than they were at the beginning.

A fourth study was reported by Roth, Tobin, and Shaw (in press) to understand why physics lectures, in the physical science course for prospective elementary
teachers, frequently were so difficult for students. Although the instructor was genuinely concerned in facilitating students' learning and understanding, students had many difficulties in understanding the concepts addressed in the lectures. The study's findings suggested that the lectures required students to follow different types of transformations through which the mathematical nature of the phenomenon of motion was constituted. Accordingly, the study concluded that the difficulty in the lecture arose from the large number of transformations required between the original phenomenon observed and the abstract inscriptions used to re-present it.

Moscovici and Gilmer (1996) conducted a study to address different alternative assessment strategies used by the instructors of the biology course. They discussed these alternatives (journals, portfolios, hands-on activities, in-class presentation, etc.), that had been introduced mainly by the science education group to the biology faculty during the developmental process of the course. The focus was to investigate the difficulties that led to discomfort, and poor fit between students' expectations and their actual experience in class. An important result in the study was that the multiple use of alternative assessment strategies in the course was not fulfilled in terms of grade representation for students' learning. The researchers attributed this finding to the instructors' unfamiliarity with theoretical aspects of these strategies, and their need to transform "subjective" entries like students' participation or portfolio assessment into "objective", quantifiable entries. They recommend that science instructors need to become familiar with alternative modes of assessment and the educational principles of such alternatives in which recognition of individual diversity replaces the instructor's subjectivity.

A sixth study, conducted by Griffiths (1996), was another effort to examine the
discourse in the biology course for prospective elementary teachers. The purpose of the study was to look at what communities existed in the class, and how the social interaction between these communities influenced learning. The researcher’s focus was on the patterns of language and science terminology used by the instructor. She endeavored to develop an understanding of the dynamics of the classroom communities as they relate to science language and terminology. She found that the students were having trouble understanding because they had limited access to the science language used in the class. So she concluded that the technical language used by the instructor created a barrier that prevented members of the student's community from crossing the border into the instructor's world of science.

Taylor (1995) conducted a study about the culture of community college teaching and learning. He visited seven of 28 community colleges around the state of Florida in the fall 1995. The focus of the study was to determine the practices of college teachers of science and mathematics in their classrooms. He found that the conventional style of teaching dominates science and mathematics teaching in college classes. This style is occurring right now in community colleges around Florida and, most likely, around the world. The explicit purpose of this style is to deliver information or to present the material that students asked to deal with in order to learn and to be ready for tests.

Haidar (1997) conducted a study in Yemen to investigate the quality and extent of understanding of certain chemical concepts which prospective teachers in Yemen possess. The results showed that the prospective teachers’ understandings of most of the concepts ranged from a partial understanding with specific misconceptions to no understanding. Most of them depended on mere memorization of the concepts without meaningful understanding. In addition, their knowledge about the concepts was
fragmented and not correlated. The study attributed the prospective teachers' misconceptions to defective instruction.

**Science Teaching in Schools**

Tobin (1990) conducted a study to figure out the relationship between the classroom environment and the metaphors used by a teacher in a high school to conceptualize his roles as a science teacher. He noticed dramatic switches in the environment of teaching and learning when the teacher changed his role from being a performer to being captain of the ship. When the teacher conceptualized his role as a performer, he was friendly and interacted with students in a way that encouraged them to be less formal in the class. When the teacher would switch to being captain of the ship, his own actions changed and so did students' actions. The interactions were more formal and the teacher was more in control of the class.

The study conducted by Tobin and LaMaster (1995) examined the relationships between metaphors, beliefs, and actions of a science teacher of middle and high school. This teacher conceptualized many of her teaching roles in the classroom, such as her role as assessor or as a controller, in terms of metaphors she used, such as the teacher as a fair judge or as a manager. The teacher had a problem in managing the class. She tried to improve her teaching to be consistent with her beliefs about constructivism through construction of a new metaphor for management, the social director, for her role as manager. The researchers noticed some improvement in the learning environment when the teacher managed her students in accordance with the social director metaphor. More improvements were noticed when the teacher used a new way of
assessment that was consistent with the metaphor that she was looking through a window into a student's mind instead of being a fair judge.

McRobbie and Tobin (1995) studied interrelations between teacher and student actions in a context of chemistry teaching and learning in a high school class. The purposes of the study were to understand the manner in which teachers and students make sense of teaching and learning, how they construct roles for one another, and how those role constructions constrain the actions of all participants in the classroom. The teacher and students used language to describe their practices, and construct mental models that fit with such practices and beliefs about learning. It was found that the teacher's constructions of the context for teaching chemistry were strongly influenced by a set of restraints associated with the culture of teaching.

The culture of teaching was examined in another study by Tobin and McRobbie (1996). The purpose of their study was to explore frameworks employed by a high school teacher and his students in a chemistry class as referents underpinning their actions. They found that the teacher made sense of his teaching roles in terms of four cultural myths related to transmission of knowledge, being efficient, maintaining the rigor of the curriculum, and preparing students to be successful on examinations. Such myths support the status quo and constitute a conservative force to many of the recommended changes.

A longitudinal study was conducted by Tobin, Tippins, and Hook (1994) to investigate the relationship between using constructivism as a referent for action and the change in the practice of science teaching and learning in the classroom. The focus of the study was on the way in which a middle school science teacher was able to change his personal epistemology from objectivism to constructivism over a period of time. Also
the researchers examined how constructivism was used as a referent for the science curriculum, and the relationships among constructivism, teacher actions, and the referents associated with the science curriculum. The researchers provide an example of classroom practices and associated narratives being used by a middle school science teacher as generative tools for building a metaphor. An analysis of the metaphor as a gardener, that the teacher built for himself, suggested that the main referent for the teacher’s role was control. The epistemology embedded within the metaphor varied from objectivism to constructivism. They suggested that in many instances the epistemology of action, in which routine practices were embedded, was more consistent with objectivism than constructivism.

Conclusion

Looking through the studies conducted about science teaching and learning indicates that college science classes as well as pre-college classes are still dominated by a traditional style of teaching. The epistemology underlying most traditional practices in science classrooms is objectivism, which differs from constructivism in its basic postulates (Roth, 1993). In an objectivist science classroom, teaching is consistent with a transmission metaphor for disseminating knowledge to students who were regarded as receivers of the knowledge (Tobin & Tippins, 1996). Conventional science teachers like to use this widespread accepted metaphor to conceptualize their roles in the classrooms.

The problem becomes more complicated with the continued use of traditional ways of science teaching and learning for prospective teachers in college classes.
Prospective teachers, who learn science within such a system, tend to use a metaphor in their own classrooms to promote knowledge transmission from the teacher and the text to the students. They conceptualize themselves as sources for knowledge while the learners are regarded as receivers for this knowledge. Therefore, more teachers with similar beliefs are expected to join schools each year.

Accordingly, before thinking how to reform science teaching and learning in public schools, it is very important to begin our efforts of reform in college science classes for prospective teachers. However, many questions are raised as a result of the continued use of the traditional way of teaching in college classes, such as: Why do science teachers retain these traditional ways of conceptualizing their roles in their classes? Why do they continue to use objectivism as an epistemology and referent for most practices in their classrooms? What are the social constraints that restrain the use of alternative ways of thinking and acting when teaching science? Why do teachers not use the epistemology of constructivism as a referent to construct their metaphors and to conceptualize their roles when teaching science? One of this study's purposes is to construct answers for these questions.
Addressing the Problem

In this study, I use the interpretive paradigm, which proceeds from the basic beliefs of constructivism (Guba & Lincoln, 1989) and calls for a methodology different from what I have had in my traditional thoughts about research. This study is not designed to obtain abstract results or to generalize its findings, but to interpret actions in their original un-stripped context (Guba & Lincoln, 1989). In interpretive research, the researcher is an essential instrument of the study. He or she needs to be able to determine the most salient or representative events to be studied and focus on the events for the most significant interpretations.

In the Spring 1996, I worked with the instructors of the course, Physical Science for Elementary Teachers. I videotaped all classes, lectures, demonstrations and class activities. I also wrote field notes and memos about what was happening in classes. Also, I interviewed the two instructors of the course and selected students. However, my focus was on the instructor of the chemistry section of the course and his actions in the classroom. I endeavor to understand actions and interactions in which he was involved in the classroom, and how the metaphors and roles he used as referents for actions in the classroom related to his beliefs about teaching and learning.

An interpretive research design, described by Erickson (1986), Guba and
Lincoln (1989), and Gallagher (1991), is employed in the study to construct answers for subjective questions that emerged in a particular context during the research process. Interpretive research was defined by Erickson (1986) as a function of “the immediate and local meanings of actions, as defined from the [participants'] points of view” (p. 119). The basic assumption of this type of research is that the researcher, and his subjective experience, provides the lens through which the research develops (Brush, 1993). Using a constructivist approach to study teaching and learning, as suggested by Guba and Lincoln (1989), requires that the study takes place in the natural location or place, such as a classroom or a laboratory, where we can construct interpretations about the “facts” that we want.

A qualitative design which follows a hermeneutic cycle (Guba & Lincoln, 1989) is used in the study. Hermeneutic cycle is described by McRobbie and Tobin (1995) as “what was learned was informed by what was already known; reading of the literature; experience in the field; and continuous data framing, analyses, and interpretation” (p. 375). Data selected for construction of this interpretive study provide evidence of the assertions that were formulated and that emerged from observations and questioning in this particular context.

**Participants in the Study**

The field site consists of a physical science classroom containing twenty one elementary prospective teachers and their instructors. Permission to conduct the study was secured from the instructors, students, and the University Human Subjects Committee. The Human Subjects committee grants permission for this study to take place
in the physical science classroom for elementary prospective teachers. The Committee
approval letter is found in Appendix E. The Consent Form for participants who were
involved in this study is located in Appendix F.

In addition to the target students and the researcher as participants, the
chemistry instructor, Mark, is the leading character in the study. He is the instructor of
the chemistry section in the physical science course. Although I videotaped both the
physical and the chemical sections of the course, my concern was more on science
teaching and learning of the chemistry classes. The study focuses on actions and
interactions in Mark's classes to identify the strategies he uses in teaching science to
prospective elementary teachers, and the roles he conceptualizes in the class to create
learning environments that enhance students' learning with understanding.

Written transcripts that highlight special issues from the videotaping and audio-
taping and copies of field notes were presented to Mark by the researcher to request his
critique or to suggest changes. Use of this procedure provided an opportunity for him to
reflect on his actions in the classroom and analyze and make critiques of them. For
example, a copy of the vignette that I wrote about the dry ice, liquid nitrogen, and
balloons activity (Chapter 6), was presented to Mark to look at and provide feedback.
Mark read the vignette and agreed that these accurately represented what happened in
that class. The videotape of that class was also submitted to him to watch, so he could
reflect more on his actions. By providing Mark with videotapes about his classes to view,
he had opportunities to reflect on the coherence of his actions, his beliefs, and his roles
in the classroom.

The participating students were selected from four separate working groups in
the course. There were twenty one females in the class, including two African Americans.
The students had arranged themselves in five separate groups at the beginning of the semester for collaborative projects and activities. Although I planned to select one individual from each group to interview, I was only able to speak with four students, for the fifth student was very busy with her job and classes. In addition to selecting one from each group, I used midterm grades, major, level, and the participation in class discussion as criteria for selecting students.

The class primarily consisted of freshmen who were not majoring in science, who most likely had negative attitudes about science (Brush, 1993), and were attending their first or second college science courses. The majority of the class consisted of prospective elementary teachers who were planning to major in early childhood and elementary education. They cannot actually major in it until their junior year.

I selected the participating students after the midterm test. Huda, an Afro-American student, was a freshman planning to major in early childhood education, and obtained a moderate grade on the midterm test. She was selected from the project activity group with which Mark worked during the student projects. Muna, a sophomore Caucasian student planning to major in elementary education, obtained the best results on the exam. Fatima, a freshman white student planning to major in elementary education, obtained a low grade. She was selected from the group that I worked with during the student projects. Nora, a white student planning to major in early childhood education, received a moderate grade on the test. She was part of one of the most active groups in the class. These four students were interviewed during the last quarter of the semester. Transcriptions of the interviews were submitted to them at the end of the semester in order for them to provide feedback to the researcher. More students participated in the study through the use of their journals and responses to the
University/Community College Student Questionnaire (Appendix B) as additional sources for data in the study. At the end of Mark's classes, students were requested to respond to the University/Community College Student Questionnaire (Appendix B). This survey was developed by Florida State University (FSU). It was intended to provide evidence as to what is occurring in science and mathematics classrooms in Florida's Community Colleges and Universities. The purpose of this survey was to obtain data that would establish a baseline of quantitative information regarding the needs, concerns, opinions, attitudes, and beliefs of students in science and mathematics classes. My purpose from using this survey was to obtain some insights about students' views of learning environments in Mark's classes. More details about using the questionnaire and its results will be provided in Chapter 6.

As a researcher in this study, I am also a science teacher with several years of experience of teaching in public schools and college level classes. I believe that a researcher is one of the participants in the research study. My personal feelings, theories, and cultural background are always part of what is being studied, and I can never be completely separated from the interpretive process. Bogdan and Biklen (1992) emphasized that the researcher's feelings and frame of mind are important vehicles for establishing rapport and for discovering participants' perspectives and are not something to be repressed. The interpretation of events in the study is influenced by my own cultural background and feelings about science teaching and learning. However, if the researcher's feelings and background are considered during analyses and interpretations, they can be a source of research hunches (Bogdan & Biklen, 1992).

As a science teacher having grown up in a different culture and experienced the world in a different society, I needed to be aware of two diverse perspectives that
influenced my role as a researcher over the course of this study. On one hand, my role was “etic” (an outsider’s view) by virtue of my different culture and language. On the other hand, my role was “emic” (an insider’s view) because I am also a science teacher, like the chemistry instructor who was studied. As a science educator, my insider view about science teaching and learning has changed radically through my involvement in courses, especially on qualitative research, and the influence of intellectual and cultural pressure during the last two years in Florida State University.

The differences that I have noticed due to culture and language are less significant now than they were when I arrived in the United States as a graduate student two and a half years ago. The cultural gap has diminished as a result of my living in this country during my doctoral studies, functioning within its cultural boundaries, and becoming acculturated. In addition, I was involved in the Earth Science course during the Fall semester 1995, videotaping the classes and interviewing the instructors and some selected students. Such work helped me become familiar with the environment of science courses for prospective elementary teachers. Furthermore, I endeavored to use some of the strategies developed by Moallem (1992) to overcome the problem of being an outsider.

One of these strategies, for example, was practicing high tolerance for ambiguity and uncertainty to develop personal knowledge about the rules of the participants and perceive the same meanings in actions and interactions as they did. Another strategy that helped in interviewing the selected students was to ask one my American colleagues, such as a graduate student in the science education program, to attend each interview. Since my colleague has the same culture and language of the students, her participation in interviewing the students helped to decrease the effect of the cultural and lingual
differences. These strategies, in addition to my previous experience, made it easier for me to bring into my consciousness the cultural differences that I carry with me into the classroom. I feel that my theoretical framework used in the study, in addition to my previous experience and knowledge, helped me to find more contextual meanings for the actions of the instructor and students in a definite place and time.

**Theoretical Framework**

The theoretical framework used in the study is drawn from and supports my belief that the teacher in the classroom acts as an expert learner. His or her role is to help students learn actively through the use of their prior experience and knowledge to construct meanings in new situations. In other words, the teacher's role is to mediate the learning of students (Tobin & Tippins, 1993). To engage in active learning, students are provided with opportunities for quality learning experiences that provide a solid basis for learning with understanding (Tobin & Tippins, 1993).

I believe that my personal theories and assumptions influence all aspects of the research process. My role as a researcher is to use these theories and assumptions to understand meanings of actions from the participants' points of view (Erickson, 1986). The theoretical framework in this study is derived from constructivism, the theory of human interests, and the co-participation theory. These theories have some common aspects related to teaching and learning in the classroom.

**Constructivism**

The main approach adopted for the implementation of this study emphasizes meaningful learning based on constructivism (Glasersfeld, 1989, 1993).
Constructivism as a theoretical framework is an epistemology addressing how we come to know (Glasersfeld, 1989). The basic tenet in this epistemology is that knowledge is personally constructed but socially meditated (Tobin & Tippins, 1993). It asserts that knowledge is not a commodity that can be given or taken, but must be constructed by cognizing beings (Glasersfeld, 1989). Learning is a social process of making sense of experience in terms of extant knowledge (Tobin, Tippins & Hook, 1994). In addition to extant knowledge, as it is noted by Lorsbach (1991), senses are the only tools that the individual uses to receive messages from the environment. With these messages, the individual builds a picture of the world. Therefore, knowledge is always the result of constructive activity by an individual while he or she exists in a socio-cultural sense.

In contrast to objectivism, which recognizes truth or science as a body of knowledge separated from knowers (Johnson, 1987), truth is replaced by viability (Glasersfeld, 1993) in the constructivist approach. Knowledge is viable so long as it coheres with our understandings and stands up to the constraints of our experiences (Ritchie, Tobin & Hook, 1997). This approach enables us to make sense of how students learn and how the teacher’s role in the classroom can facilitate their learning.

Within a constructivist framework, participants are empowered and given opportunities to act and reflect on their actions. Through interaction with others they can negotiate meanings of actions to arrive at a consensus on what has been learned. When such a consensus is faulting, additional inquiry with more interaction can be carried out by participants to determine the different points of view. As a referent for teaching, constructivism redefines the teacher’s role in the classroom. He or she, as stated by Tobin and Tippins (1993), “takes account of what the students know, maximizes social interactions between learners such that they can negotiate meaning,
and provide a variety of sensory experiences from which learning is built” (p. 10).

**Human Interests Theory**

Habermas's (1972) theory of interests, which affects human actions, presents an interpretation of how actions in the classroom are associated with human interests, or goals. The enacted curriculum in the classroom, and hence the learning environment it creates, is driven by fundamental human interests. This theory categorizes human interests as technical, practical, and emancipatory.

According to Grundy (1987), technical interests are grounded in the human need to control and manipulate environments. Actions of the majority of science teachers in classrooms can be explained in terms of technical interests. Practical interests are grounded in the need to live in the environment as a constitutive part rather than in competition with and/or seeking to control it. Emancipatory interests reflect individuals' needs for autonomy and independence from all that is outside of them. A teacher with an emancipatory interest creates an atmosphere of emancipation and empowerment in which learners “engage in autonomous actions arising out of authentic, critical insights into the social construction of human society” (Grundy, 1987, p. 19).

The teacher's interests have a powerful effect toward determining actions in a particular context. Although Habermas (1972) argues that human interests can be represented as goals, it is clear that each of these interests reflect different goals. The goal of a teacher with technical interests, for example, is to control, while the goal of a teacher with a practical interest is to understand. Accordingly, the essential goals for the majority of the traditional science teachers with technical interests are to cover the science content in the texts and the course plan in a limited time, to be in control of students, to prepare students for the tests, and to help students to succeed in the course.
by passing examinations (Tobin & McRobbie, 1995). To achieve these goals, the beliefs and associated actions of both the teacher and students are associated with an objectivist or transmission model of teaching and learning.

Technical interests seem to be more related to an objectivist approach to teaching and learning, while the constructivist approach seems to be more aligned with practical and emancipatory interests of teachers and learners. A teacher's role is determined by his or her actions in the classroom. These actions develop as a result of integrating different factors. Some of these factors are the teacher's beliefs, goals and interests that are related to the teacher and students. The science teacher's actions acquire their expressions in the specific context of the classroom.

Actions may not exist independently of the context in which they are generated, and acquire their authentic significance only within that context. In such a place and in an appropriate moment, a teacher's beliefs, goals, and interests interact with his or her value system to activate or inhibit expression of the specific action (McRobbie & Tobin, 1995). While the teacher's behavior is an explicit action, his or her beliefs, goals, and values interact to present an action that may not be explicit, but rather implicit (Tobin, 1995a).

Co-Participation Theory

When science is viewed as a form of discourse, learning science in the classroom "can be considered as learning a new way to make sense of experience" (Tobin, in press-1). Discourse refers to a "social activity of making meanings with language and other symbolic systems in some particular kind of situation or setting" (Lemke, 1995, p. 8), such as a science classroom. When students learn science as a form of discourse, it is important that they are able to adapt their language resources as they practice science
in the classroom. The instructor(s) who know science assist them to learn by engaging activities in which co-participation occurs (Roth, 1995).

Co-participation implies, as stated by Tobin (in press-1), "the presence of a shared language that can be accessed by all participants to communicate with one another such that meaningful learning occurs." Accordingly, active science learning occurs in situations in which co-participation occurs. In such situations, students are empowered to engage actively in the process of knowledge construction, and have the autonomy to ask questions when they have problems (Tobin, in press-1). When students feel that they have the power to talk and express their ideas in the class, they can argue or ask for help when they do not understand (Tobin, in press-1). In a setting where co-participation is occurring, "the focus is always on what students know and how they can re-present what they know" (Tobin, in press-1).

The intent of science learning and teaching would be to help students to "develop discursive competence for talking about empirical phenomena" (Roth & Tobin, 1996, p. 149). It is the responsibility of science teachers in college level classes to create a high quality environment for non-science majors to understand science concepts. In such an environment, the instructor needs to employ a form of discourse that allows students to use their discursive resources in the process of learning. Accordingly, they can access the language of the instructor and make sense of science concepts they are required to learn (Tobin & Roth, 1995). Science instructors need to provide students with opportunities to interact through asking questions, discussing, explaining, clarifying, elaborating, arguing, evaluating, reconstructing, collaborating, and attempting to reach consensus on what was learned in the classroom.
Data Framing for the Study

Data for this study are gathered in a science class where the instructor endeavors to use a constructivist approach as a referent for science teaching and learning. The data sources for this study are the actions, interactions, and reflections of the chemistry instructor and students in the classroom. As pertinent to the study, data framing makes use of videotapes of classes of the physical science course, field notes, artifacts, and interviews with the instructor and the target students. The data sources consist of narratives from field notes and memos, audio/video transcripts, written documents used for learning and assessment, and reflections of the participants on data and interpretations. In this study, data are derived using the procedures described in the subsections that follow.

The Videotapes of the Classes

Using videotapes or audiotapes is considered by Erickson (1986) as a main source of data framing in interpretive research. The classes of the chemistry section of the physical science course were videotaped three times per week for two hours each session. Transcripts of the videos were made and were analyzed for Mark’s and students’ actions and interactions in the classroom.

Videotaping the classes provides an advantage in that the researcher has the opportunity to replay each videotape at his/her convenience for more analysis. Through replaying a videotape, the researcher can analyze not only the actions that occur more frequently, but can also re-observe and re-analyze actions to avoid the establishment of immature judgements (Erickson, 1986). Such tapes are available to review as many times as necessary without losing discourses and actions that occurred in the classroom.
Audiotapes of Interviews

An interview is, as it was defined by Bogdan and Biklen (1992), "a purposeful conversation, usually between two people ... That is directed by one to get information from the other" (p. 96). The interviewer's role is "to communicate genuine curiosity, respect, and acceptance" (Ellis, 1994, p. 370). Reproducing the thoughts of the interviewee in a more complete way without having to make pauses to write notes on what the speaker comments is one of the advantages of using this technique in interpretive research. Another advantage is that the audiotapes are available for more review when it is necessary to enrich the analysis and description.

In this study, interviews of Mark, the instructor, as well as of the target students in the class were conducted and taped by the researcher. Two interviews have been conducted with Mark during the semester. Four students were interviewed in the last quarter of the semester. The main purpose of the interviews was to find more meaning to the words and actions of Mark and students in the class. During the interviews, Mark was asked to answer questions about his goals to participate in teaching this course, his beliefs about teaching and learning, the students and their learning, the role of science teacher in the classroom, and so on. The participating students were asked to answer questions about their beliefs about the course, the teacher, science learning and teaching, teachers' roles, and students' roles in the classroom.

Field Notes and Analytic Memoranda

Taking field notes is a very important source for the study. It is important to frame the data and to provide additional information that help in the analysis and writing process. According to Bogdan and Biklen (1992), the field notes should have two parts:
First, the description of the setting, the people, and the actions. Second, the reflective part that captures the feelings, the concern; this second part which is called 'memoranda' or 'memos' relates to the lives of the participants from the observer's points of view (p. 108).

Glaser and Strauss (1967) use the term memos to refer to the reflections when the researcher writes notes that are not directly related to the observed actions. Such memos can contain analytic reflections, patterns that emerge from the data, reflections on methods, ethical dilemmas, what influences the thoughts of the researcher, and the points that need to be clarified. Miles and Huberman (1994, p. 72) describe memos as primarily conceptual in intent. They do not just report data; they tie together different pieces of data into a recognizable clusters, often to show that those data are instances of a general concept.

The researcher was involved in the classes of the physical science course during the spring semester, 1996 for observing and writing field notes. Observations in this study focused on the instructor actions and interactions, instructional strategies he used and the interactions in the classroom. Making decisions on what to notice and what to ignore, what notes to write and what not to write were the responsibility of the researcher. As soon as the researcher completes writing his observations in each class, it is important to write interpretive memoranda that provide details of what happened and perhaps spell out some of the more salient stories that occurred in the observed class. Appendix A shows a narrative as an example of my field notes and reflections from the class in which Mark taught about chromatography.

Artifacts

Artifacts are the documents or written materials that are used in the class such
as textbook and laboratory manual or are brought to the class by the instructor such as handouts and test papers. Students' journals or portfolios and test questions and answers are also important resources for data about science teaching and learning.

In this study, some artifacts and documents were used by the researcher, such as student journals, test questions and answers, and the University/Community College Student Questionnaire (Appendix B), as additional data sources. More details about using this survey and its results will be provided in Chapter 6. These resources offered the possibility to present direct evidence about assertions that were built in the process of searching for meaning.

Data Sources Archiving

The data sources and interpretations were organized into an archival system. The NUD•IST (Non-numerical Unstructured Data Indexing Searching and Theorizing) software was employed to help establish a data archive. The use of NUD•IST helps storing and categorizing new ideas and establishing logical relationships between them. Transcripts of videotapes and audiotapes were archived and organized in special files and soft-disks. Such an archival system allows the committee to check that the study was being conducted in a manner that assured a viable outcome. Also, other researchers are able to audit the quality of the research and undertake secondary analyses.

Data Interpretation

Data interpretation in the study was an ongoing interactive process. Assertions
were developed after each class observation, videotaping, and interview. That means the study followed a hermeneutic/dialectic cycle (Guba & Lincoln, 1989) in which the assertions develop in a continuous cycle of data gathering, analysis, and interpretation. Each stage was informed by what has already been known from previous studies, the literature, interviews, and field notes (McRobbie & Tobin, 1995). Divergent constructed assertions were represented to participants in an interactive process to achieve a higher-level synthesis of them all (Guba & Lincoln, 1989).

When more interpretations from data are constructed, the number of evidences increase which allows for the acceptance or rejection of the previous assertion. The aim of the hermeneutic/dialectic process, as stated by Guba and Lincoln (1989), is:

to reach a consensus when that is possible; when it is not possible, the process at the very least exposes and clarifies the several different views and allows the building of an agenda for negotiation ... All (participants) are thus simultaneously educated, because they achieve new levels of information and sophistication, and are empowered because their initial constructions are given full consideration and because each individual has an opportunity to provide a critique, to correct, to amend, or to extend all the other (participants') constructions (p. 149).

As the study progressed, patterns were developed by the researcher according to questions that emerged in the research process. In order to accomplish this purpose, interpretation of data was carried out in three steps (Brush, 1993). First, the data, especially audio/video tapes, was reviewed as many times as necessary to determine the overall orientation of the research. Such a review was expected to help the researcher focus more on the participants' actions and their beliefs about the teacher's and students' roles in the classroom.

Second, there was a more intensive review of data, using the research questions
to guide the interpretation of data as the needed sections were transcribed and coded while data interpretation continued. Third, assertions that were generated were further developed through the use of numerous data sources, as well as through the detection of inconsistencies that provide contrasting evidence.

Many computer programs are available to help in the analysis of texts found in data sources of qualitative studies. I used the NUD•IST program in the process of data analysis. This program is designed for handling of unstructured texts found in the data such as audio/video transcripts, conversations, and field notes. It is used to analyze qualitative documents to help in the handling, exploration, and description of complex documents. This advantage allowed me to organize new ideas and theories embedded in the data without losing their context and complexity.

A data tree was designed (Appendix D) to codify and manage categories of concepts to several levels of complexity and to show relationships between categories. Nodes were created to process the text of data into the NUD•IST. The node is situated in the index tree integrating all nodes connected in an hierarchial pattern where a higher level node subsumes all of the nodes directly beneath it.

An example of this use of NUD•IST, is found in following quote from an interview transcript with Mark:

My role is to facilitate that [the learning process]. I have to find some reason that a student finds this material interesting or relevant. I can't transfer my interest or my sense of relevance to other students. They have to construct that for themselves.

This text unit is containing a theme which can be situated into one or more nodes in the tree. It is situated into two separate nodes in the NUD•IST tree index. The first node is labeled "Mark" which is dealing with Mark's beliefs about science teaching and
learning. This node is situated in the following hierarchical outline:

- Culture
  - Context
    - Beliefs
      - Mark

The second node is labeled “Tour Guide” which is dealing with Mark’s role as a guide tour or a facilitator in the classroom. This node is situated in the following hierarchical outline:

- Roles and Metaphors
  - Roles
    - Tour Guide

**Criteria to Judge the Quality of the Study**

The standards of quality for judging the viability of this study have been a real and constant concern of the researcher. Since this study was conducted in a constructivist paradigm, its findings were “the literal creation of the hermeneutic process of dialectic negotiation” (Schaller & Tobin, in press). Trustworthiness, authenticity, and hermeneutic process were three main criteria suggested by Guba and Lincoln (1989) to be used to judge the quality of interpretive research. These criteria were used in an integrated way during the study process to maximize its trustworthiness. The criteria and an explanation of how I used them in my study are described in the following section:
Trustworthiness Criteria

Credibility, confirmability, and transferability are the criteria that I used to judge the quality of my study and effect necessary modifications and reinterpretations. These criteria are parallel to the "rigorous" criteria used in quantitative research (Guba & Lincoln, 1989). For example, internal validity in quantitative research parallels to credibility in interpretive research; external validity or generalizability is parallel to transferability; reliability is parallel to dependability; and objectivity is parallel to confirmability. The use of the trustworthiness criteria was integrated with the criteria of authenticity and hermeneutic/dialectic process, each of which are described later.

Credibility: The condition of credibility of the data in the study was obtained by adapting the procedures of member check with the participants, peer debriefing, prolonged engagement with the participants, persistent classroom observation over a lengthy period of time, negative case analysis, and progressive subjectivity. Presenting transcripts of the interviews to Mark and the students enabled them to provide feedback to the researcher, frequently suggesting changes to improve credibility of the data. Using member checks helped each participant to understand and appreciate new issues and constructions of other participants.

Peer debriefing ensures that the researcher relates his findings to both the data of the study and the research of others (McRobbie & Tobin, 1995). I endeavored to justify the assertions of the study to my "disinterested" peers, such as scientists, faculty members and graduate students from science and science education program at Florida State University. I also presented some findings of the study in science education annual meetings. I presented, for example, in the Southeastern Association for the
Education of Teachers in Science (SAETS) annual meeting in Atlanta, November, 1996 and in 8th National Conference on College Teaching & Learning in Jacksonville. For instance, the title of the SAETS's paper was "Roles used by a chemistry instructor in a class for prospective teachers." It focused on how Mark used metaphors and roles in science classes to create a learner-centered rather than teacher-centered learning environments.

The disinterested peer in the meetings poses, as it is stated by Guba and Lincoln (1989, p. 237), searching questions in order to help the researcher understand his own posture and values and their role in the inquiry. Peer debriefing may help to reduce the psychological stress of the researcher and to provide an opportunity to search out and try next methodological steps in an emergent design. It also facilitates the inclusion of "multiple voices" in the study. When data and interpretations are shared with the participants "they could check intentionality and errors that may have been made by either the participants or the researcher, elaborations, summary statements, and opportunities to agree or disagree with the assertions of the research (McRobbie & Tobin, 1995, p. 376)."

Prolonged engagement with the participants was achieved through my being involved in the class throughout the spring semester, 1996. Substantial involvement at the site of the study is an essential process in interpretive research. My engagement in the class for the whole semester reduced the appearance of uncommon action by the instructor and students as a result of my presence in the class. The process of prolonged engagement with the participant is important, as it emphasized by Guba and Lincoln (1989), to "overcome the effects of misinformation, distortion, or presented fronts, to establish the rapport and build the trust necessary to uncover constructions, and to
facilitate immersing oneself and understanding the context culture" (p. 237).

Persistent classroom observation over a lengthy period of time was achieved through my engagement with the participants during the whole semester. Performing sufficient observations in the class during the semester enabled me to identify characteristics and elements in the situation that are most relevant to the problem being pursued. I could focus on each action and interaction in detail. For example, I could focus on the strategies that Mark used to stimulate students to talk with him and with each other in the classroom. With persistent observation of Mark's actions, I could understand if he acted to stimulate students' participation in each class meeting, and if he focused on some target students or the whole class.

Negative case analysis was exerted by the researcher to look for evidence to refute as much as to support all assertions in the study. It is the process of thoroughly examining all discrepant data that do not fit the emergent assertions of the study and making sure they can be explained (Schaller & Tobin, in press). For example, I looked for all evidence that support as much as refute the assertion that the students learn science with interest in Mark's classes. Using this process confirms that "the assertions from [the] study need to be viable in the sense that for each assertion there is ample evidence to support it, that efforts have been made to refute all assertions" (Schaller & Tobin, in press). Negative case analysis also enabled me to retain the diversity among data. As well as describing central tendencies I also will be able to show a rich diversity in the data.

Progressive subjectivity is the process of analyzing the researcher's own developing constructions. It is like the criterion of ontological authenticity, which I discuss later. I endeavored to learn how my own prior constructions evolved throughout
the study. One of my prior constructions about science teaching and learning, for example, is that the quiet environment in the class enhances students' learning. Now I believe that students learn science with interest and understanding when they are encouraged to act and interact actively in the class through talking, asking and answering questions, arguing with the others, and working in activities individually or in groups. Progressive subjectivity is a crucial process to "ascertain whether the subjective constructions of the researcher change as a result of the study and to ensure that the researcher does not see only what he wants to see" (Schaller & Tobin, in press).

**Confirmability:** Using numerous data sources ensured that the study has what Guba and Lincoln (1989) referred to as confirmability. Use of a wide variety of data assures the confirmability that the assertions and the interpretations are directly from the classroom, and they are thoroughly represented in such a context. Using numerous data sources was an important procedure in this study to maximize the probability that the emergent assertions were consistent with a variety of data.

**Transferability:** Transferability refers to the usefulness of the findings of the study in the mind of the reader. Implications of the study transferred to the readers who can interpret them for themselves in their context. It occurs to the degree to which the text in the study is considered useful by the readers in the context of their own relationships with the participants.

The concept of generalizability in interpretive research is argued by McRobbie and Tobin (1995) that it "is viewed as an interaction of a reader with a text, and the extent to which the interaction holds relevance to the problems the reader frames from personal experience" (p. 377). However, there are some ways to make the study more likely to be transferable, such as thick description during analysis and interpretation.
Authenticity Criteria

In order to maximize the authenticity of the study, five criteria were considered overall in the process of data gathering. These criteria relate to fairness and negotiation with the participants, ontological authenticity, educative authenticity, catalytic authenticity, and tactical authenticity (Guba & Lincoln, 1989).

Fairness addresses the degree to which the participants have been involved in the negotiation process. Fairness, as defined by Guba and Lincoln (1989), “refers to the extent to which different constructions and their underlying value structures are solicited and honored within the evaluation process” (pp. 245-246). Participants were invited to comment, negotiate on the meaning of their experience, set up rules for negotiation during the interview sessions, and review the field notes and audio/video transcripts.

Ethics were considered throughout the study to the extent which the researcher exhibits practical wisdom in terms of the balance between being fair, caring, courageous and honest (Sockett, 1993). Practical wisdom is an important criterion in a complex process such as research. More concern in the study was given to honesty, since the researcher dealt with knowledge, and to courage because “both learning and teaching involve facing difficulty and taking intellectual and psychological risks” (Sockett, 1993, p. 62). As a teaching assistant in the class, the researcher was responsible to be fair in a one-to-one relationships and to exercise infinite care for all participants in the study.

Ontological authenticity maximizes evolution, improvement, maturity, elaboration of the information, and the use of new knowledge by the participants (Guba & Lincoln, 1989). Employing the process of hermeneutic circles in the study helped
participants to understand a broad range of issues that they previously failed to understand. For example, providing Mark with some students' constructions about teaching and learning in the class might help him to learn how students thought about his style of teaching. For me as a participant in the study, I learned that, in contrast to a controlled environment of learning, students learn science with understanding in the atmosphere in which they feel have the power to engage actively in the process of teaching and learning. Understanding such issues by participants is an indication of the ontological authenticity of the study.

Educative authenticity represents the extent to which the participants understand and appreciate the constructions of others outside their group (Guba & Lincoln, 1989). Through the negotiation process in the study, and with integration with member check and hermeneutic cycle, participants were informed and understand some constructions of others different from themselves. Some of Mark's constructions were learned by students, and some students' constructions were learned by Mark.

Catalytic authenticity is defined as the extent to which action is stimulated and facilitated by the research process (Guba & Lincoln, 1989). With the integration of other criteria, such as prolonged engagement with the participants, fairness, and member checks in hermeneutic cycle, I endeavored to stimulate and facilitate actions throughout the process of data framing, such as interviews. For example, providing Mark with the vignette that I wrote about his class (Chapter 6) and the videotape to watch himself might stimulate his actions in the class, or promote him to express new ideas in the next interview.

Tactical authenticity refers to the degree to which participants are empowered to act during the process of data framing (Guba & Lincoln, 1989). Mark and other
participants were involved in empowering forms of actions and discussions that provide them with opportunities to contribute inputs to the study and have a hand in shaping its focus and strategies.

Hermeneutic/Dialectic Criteria

The hermeneutic/dialectic process was employed throughout the research process to maximize quality control of the study (Guba & Lincoln, 1989). Assertions of the study were based on analyses of transcribed audiotapes and videotapes and other data sources. Hermeneutic criteria were achieved through feeding back these assertions to the participants for their comments, elaborations, corrections, revisions, or expansions. The assertions developed in a continuous cycle of data gathering, analysis, and interpretation. Each stage was informed by what has already been known from previous studies, the literature, interviews, and field notes (McRobbie & Tobin, 1995). Divergent constructed assertions were represented to participants in a cyclic process to achieve a higher-level synthesis of them all (Guba & Lincoln, 1989).

The three main criteria (trustworthiness, authenticity, and hermeneutic process) of the study worked in an integrated way throughout the study process in order to authenticate the findings. Prolonged engagement with persistent observations in the classroom enabled the researcher to frame data and feed it back in hermeneutic/dialectic process to participants for comments, elaboration, correction, revision, or expansion. The justification of the study’s assertions and findings to the researcher’s peers facilitated the inclusion of “multiple voices” in the study. This diversity in voices helped me to clarify some aspects related to the study process that I misunderstood, or did not understand. Discussing these aspects with colleagues or in professional meetings clarified important aspects in the design, research methods, data framing, and data
analysis to construct the study’s assertions. Analyzing data provided evidence to support or to refute assertions which help to improve the researcher’s own constructions. The sharing of data transcription or interpretation with participants for whom they have relevance provided them opportunities, not only to authenticate such data but also to be reflective on their content.

Feeding back the study’s assertions and constructions to the participants helped them to understand and appreciate new constructions that belong to other participants. Using the hermeneutic/dialectic cycle to share texts with the participants allowed them to be simultaneously educated, because they achieved new levels of information and sophistication, and are empowered because their initial constructions were given full consideration. The review of texts, as stated by Schaller and Tobin (in press), allows participants to see their actions through the eyes of someone else and as such can serve as catalytic, tactical, and educative catalysts for learning and change.
CHAPTER 4

THE CULTURE OF SCIENCE TEACHING AND LEARNING IN A CLASS FOR PROSPECTIVE TEACHERS

Introduction

Background

It is productive to make sense of science teaching and learning in college-level classes by regarding the classroom as a culture (Tobin, 1995a), with the main participants being students and their instructor(s). Nixon (1994) referred to the culture of teaching and learning as the invisible and apparently shared meanings that teachers and their students bring to science classrooms and that govern their interactions in it. Culture, within the context of this chapter, refers to the shared knowledge, beliefs, goals, values, and rules about behavior that exist in science classrooms to be used as a referent for its participants' actions.

Teaching science in college-level classes has traditionally been based on the instructor's view of the subject and his or her perceptions of the students (McDermott, 1993). The main goal, as many instructors construct, is to transmit science knowledge to students— an idea connected with a view of students as "absorbent sponges of universal truths and of teachers as dispensers of privileged knowledge" (Taylor, 1995, p. 2).

Approaches to teaching and learning science in traditional college classes are
The text is as follows:

culturally supported to provide certain actions of instructors and students with the right feel. Lectures are still the most frequently used teaching technique in college level classes. According to Roth and Tobin (1996), there is a belief among college instructors in general, and science instructors in particular, that lectures are an effective way of transmitting knowledge. This belief is supported by policy makers in colleges, such as provosts, deans, and heads of departments, who see economic advantages of lectures to large sections of students (Roth & Tobin, 1996).

In this chapter I endeavor to describe and understand the culture of science teaching and learning within college-level classes taken by prospective teachers. Analyzing of such a culture will provide insights into the context of actions in Mark's classes for prospective elementary and early childhood teachers. My focus, in the first portion of the chapter, will be on the traditional styles that dominate science teaching and learning in college classes. I endeavor to learn about the nature of the social forces or the cultural myths that serve to maintain traditional patterns of science teaching and learning practices in colleges. Accordingly, I will discuss how other research has described traditional science teachers' conceptualization of their roles and those of their students.

The second part of the chapter will focus on specific actions in Mark's classes. My concern will be to understand his efforts to shift from a traditional approach of teaching and learning to an approach intended to create active environments for science learning in his classroom. In addition, the instructional strategies Mark utilized to enhance science learning will be analyzed. This chapter generates a more insightful understanding of the culture that dominates the large context of science teaching and learning characterizing the university in which Mark enacts a chemistry curriculum.
for prospective elementary teachers.

**Teaching Science in Colleges**

In a traditional science classroom, lessons are run in a completely teacher directed manner. These teacher-centered, as distinct from student-centered, approaches are also often utilized for science teaching and learning for prospective elementary teachers. The instructor stands in front of his or her students during class time to present the topic he or she has prepared, and uses the blackboard or the overhead projector for drawing or writing the main ideas, facts, or concepts. In such a course, the instructor spends class time speaking, writing on the board, and answering questions posed by a few of the more outgoing students. His or her focus is to cover the information prepared for the class time allowed. The students’ role is to listen and copy the notes presented by the instructor. Good students are those who can record most of what is said or written by the instructor. The main goal of students is to read these notes carefully, and consequently, be ready to reproduce science information when the instructor demands them to do so, and pass a test or obtain good grades. When it is required to take laboratory hour(s) for a science course, a distinction is often made between laboratory work and lectures. Moreover, the instructor has total control of content, pace of delivery, and the method of evaluation.

Although certain components of instructors' beliefs and practices in these classes, as noticed by Cronin-Jones (1991), allow for success in the curriculum’s implementation, most of the beliefs were incongruent with the philosophy of the curriculum and, thus, impede the success of its implementation. Furthermore, in many of these classes, less concern is paid to facilitating meaningful learning as contrasted to rote memorization, which is practiced by many students and encouraged by instructional
and evaluation practices (Edmondson & Novak, 1993).

Taylor (1995) emphasizes that 'conventional' science teaching and learning is currently occurring in colleges around Florida and, most likely, around the world. In addition, he expresses concern regarding the impact of such 'conventional' practices on science learning on prospective teachers. College science instructors are experts and knowledgeable in their subjects; however, their actions in the classrooms are governed by their traditional views of teaching and learning. Moreover, although most of them have in depth understandings of the content knowledge of their subject, they may not possess as good grasp of what some educators (e.g., Shulman, 1987; Taylor, 1995; Tobin, 1990a) call pedagogical content knowledge.

Knowing how far to develop science concepts to be learned actively in a class for prospective teachers is an example of pedagogical content knowledge. Developing such concepts requires an understanding of how students learn as well as a deep understanding of the content to be learned (Herron, 1996). According to Shulman (1987), all instructors need to understand pedagogical content knowledge or the general principles of teaching and learning, in addition to the scientific subject matter they are teaching.

Taylor (1995, p. 2) noted that "the limited number of real world learning experiences provided to them [college science instructors] by college degree programs, experiences legitimated by the daily didactic practices of college teachers" make them wedded to a traditional view of teaching and learning. Tobin (1990a) emphasizes that the manner in which the science teacher structures the learning environments is directly influenced by four cognitive factors. These factors are "the beliefs of teachers, metaphors used to conceptualize teaching roles, knowledge of science content to be taught, and knowledge of how to teach specific science content" (p. 34).
Understanding the culture of science teaching and learning in college classes needs to be considered from actor-oriented and structure-oriented perspectives (Galtung, 1980). The actor-oriented perspective views actions from the frame of the individual actor while the structure-oriented view regards actions as a function of the position of individuals in social settings in which professional practice occurs (Reyes-Herrera, 1996). In analyzing why instructors do what they do in teaching science, it is necessary to consider these two dimensions in dialectic relationship to one another. Traditional practices in science classes for prospective teachers can be described in terms of these interactive dimensions.

**Action in Science Classes**

In classes for prospective teachers, the actions of the instructor influence the methods students use to learn science. While the teacher's behavior is a non-purposeful conduct, such a behavior interacts with the teacher's beliefs, goals, and context to present an action (McRobbie & Tobin, 1995). ‘Actions’ refers to the intentional acts conducted by the instructor and students in the classroom, such as lecturing, experimenting, arguing, asking and answering questions, and so on. According to McRobbie and Tobin (1995), an action is:

> a holistic concept that can be thought of as a set of dialectic interactions involving an individual's goals, the belief that a set of behaviors is viable in a given context, the individual's construction of the context in which the action is embedded, and the behavior of the individual. (p. 381)

According to this definition, a teacher’s actions in a science classroom are a product of
interactions between four elements: the goals of the teacher and students, the context in which an action occurs, beliefs that are referents for a given set of behaviors, and the behaviors that occur (Tobin, 1995c). Such elements form a coherence between them to accomplish a given set of actions.

When knowledge becomes viable in that it enables an individual to meet his or her goals in specific circumstances, it becomes a belief for that individual (Tobin & LaMaster, 1995). In a dialectical interaction between beliefs, goals, behavior, and context to produce an action, beliefs serve as a referent for a set of behavior in a specific context, which in turn depends on the goals of the teacher (Tobin, 1995c). Many teachers, for example, believe that students learn by repeating and practicing (Cronin-Jones, 1991) or teachers should have control over students (McRobbie & Tobin, 1995). Such beliefs direct actions in classrooms in order to be consistent with the goal of transmitting knowledge to students. Although beliefs are not always goals-directed, they are "tied to the situations in which actions are contemplated" (Tobin & LaMaster, 1995).

The teacher's goals have a powerful effect toward determining actions in a particular context. For instance, the learning environment may alter dramatically if the instructor in the classroom changes his or her goals (Tobin & Tippins, 1993). The essential goals for many science teachers include covering the science content in the texts and the course syllabus in a limited time and preparing students to succeed within the course or passing examinations (Tobin & McRobbie, 1996). To achieve these goals, the beliefs and associated actions of both the teacher and students are associated with the transmission model of teaching and learning.

Actions may not exist independently of the context in which they are generated,
and acquire their authentic significance only within that context (Tobin & Tippins, 1993). In such a place and in an appropriate moment, a teacher's beliefs and goals interact with their value system to activate or inhibit expression of the specific action (Tobin, 1995a). According to McRobbie and Tobin (1997), context is constructed by individuals within the social milieu of schooling in which personal factors, such as commitment to learn, interact with social factors, such as the will to succeed in science courses. Such a context supports the goal of the teacher and students to be successful in the course.

While the actor-oriented view (Galtung, 1980) focuses on actions in terms of actor's beliefs, goals, behaviors, and constructions of context, the structure-oriented perspective (Galtung, 1980) examines social systems that affect teachers' actions in the classroom. What happens in a classroom acquires greater meaning when it is associated with the social system at large (Reyes-Herrera, 1996). Teachers and students know how to act in given situations because they have lived in a cultural milieu and have adapted their practices to the socio-cultural forces embedded in the culture (Tobin & McRobbie, 1996). The next section focuses on some of these socio-cultural forces or cultural myths (Britzman, 1991) that enforce actions and interactions in many science classes for prospective teachers.

**Cultural Myths**

Many reports (e.g., Milne & Taylor, 1996; Tobin, 1995a; Tobin & McRobbie, 1996) reveal the need to understand not only teachers' actions, but also the myths embedded in the culture about teaching and learning. Cultural myths (Britzman, 1991)
are the hidden forces that support the status quo and constitute a conservative force to many of the recommended changes. In addition, these forces resist changes to the traditional ways of science teaching and learning because they act as powerful constraints for action, either by strengthening possibilities of actions, or by inhibiting their expression (Reyes-Herrera, 1996).

Cultural myths serve to maintain traditional patterns of science teaching and learning practices in college level classes (Taylor, 1995). They “take the form of restraints that are conceptualized as beliefs that given behaviors are appropriate to enable specific goals to be attained in the contexts that apply to action” (Tobin & McRobbie, 1996, p. 226). However, the meaning given to myth, as emphasized by Tobin and McRobbie (1996), “is not an idea that is wrong, but a belief that is a referent for intuitive action in given social settings” (p. 225).

Milne and Taylor (1995; 1996) discussed the powerful cultural myths rooted in the history of science, and the extent to which these myths had colonized school science. Milne and Taylor (1995) noted that “myths emerge in science as a cultural force to propagate universal ideas about the practice of science and the legitimation of scientific knowledge.” These myths debilitate the innovative decision in science classes and provide frameworks of reference which favor the development of traditional practices in the classroom (McRobbie & Tobin, 1995).

A careful review of literature concerning college science teaching and learning (e.g. Barrow, 1993; Bowen, 1993; Moscovici, 1994; Moscovici & Gilmer, 1996; Roth & Tobin, 1996; Taylor, 1995; Tobin & Roth, 1995; Tobin, Roth, & Brush, 1995; Roth, Tobin, & Shaw, in press) indicates that actions in science classes are mostly interpreted in terms of the myths of transmission, efficiency, and preparing students to obtain high
grades (Tobin & McRobbie, 1996). In addition to their close relation to one another, these myths are "built on a foundation of beliefs that knowledge exists separately as a discipline that is separate from knowers and that the teacher should have control over the enacted curriculum" (Tobin & McRobbie, 1996, p. 237). These myths are used by parents, administrators, college instructors, and their students to evaluate science teaching and learning.

The Transmission Myth

Many science instructors in traditional classes believe the utilization of a transmission model of teaching can guarantee a greater percentage of students with the desired quantity of knowledge at the end of the course (McRobbie & Tobin, 1995). Moreover, they view themselves as transmitters of truths and their students as empty vessels or receptacles for knowledge (Tobin, 1995a).

Acceptance of the transmission-receiver model of teaching and learning is widespread and usually supported by teachers, students, and parents. The myth of transmission is supported by three dimensions, an objective view of knowledge, a mental model for teaching, and a belief that the teacher should have power over students in most classroom situations (Tobin & McRobbie, 1996).

Objectivism: Objectivism (Johnson, 1987), the prevailing myth underlying educational thoughts and practice for more than three centuries, is an important myth that has characterized science teaching and learning (Tobin, 1993a). Many science teachers use objectivism as a referent for making sense of actions and interactions in their classrooms. To be consistent with objectivist semantics, the science teacher tends to view science as a body of knowledge 'out there' in the world that can be separated from knowers. According to this philosophy, objectivity enables observations to be matched
with an external and accessible reality (Guba & Lincoln, 1989).

From an objectivist perspective, knowledge is viewed as "sets of truths and procedures or unquestionable truths. Knowledge is regarded as a commodity, a means to an end" (Grundy, 1987, p. 24). Moreover, knowledge has only to be accessed by the senses to be transferred to the learner. The most accepted model for instruction is based on the hidden assumption that knowledge can be transferred from the mind of the instructor to the minds of students.

Teaching strategies used in many traditional science courses appear to "have developed from objectivist assumptions about knowledge and incorporate a conduit metaphor whereby knowledge is piped from a [teacher] to a learner" (Tobin, 1993 a, p. 244). Therefore, science teachers often appear to conceptualize their roles as transmitters of information or knowledge while learners acquire such information as 'absolute truths' by a process of absorption (Tobin, 1990a).

Mental model of memorization: The myth of transmission is supported by a mental model for teaching and learning that is characterized by memorization (Pitts, 1994). A mental model is "an individual's conceptualization of a domain or system" (Rieber, 1993, p. 202). According to Pitts (1994), the term 'mental model' refers to "cognitive constructions that are a network or web of related understandings" (p. 23). Many science instructors and students appear to develop and use a mental model for science teaching and learning that is characterized by memorization. Within this model, instructors teach students how to memorize definitions, facts, and approaches to solving particular types of problems.

The significant role of memory is one of the central components to science instructors' mental model in colleges (Tobin & McRobbie, 1996). These instructors
structure most of their students' learning experiences around a belief that they need to know certain key facts in order to make sense of science as well as answer questions likely to be tested. Consequently, instructional and evaluation practices in science classes facilitate rote memorization instead of meaningful learning. For instance, the way instructors ask questions in the classroom or write test items, such as multiple-choice test questions, focus on recalling facts and fragmented information. This supports the mental model that highlights the role of memorization in teaching and learning. In addition, such actions appear to tell students what is considered important, and thus, what they should remember (Herron, 1996). For this reason, students may be observed trying hard to memorize the points that they believe are important before taking a test.

Some science instructors possess the view that learning with understanding will occur at some distant time when enough facts have been memorized and students have sufficient time to think about issues (Tobin & McRobbie, 1996; Tobin & Roth, 1995). Students within traditional science classes are encouraged to focus on learning specific information emphasized by the instructor, and ignore other important points that should be learned (Herron, 1996). They are encouraged to commit more facts to memory and learn algorithms to find solutions to problems (Tobin & McRobbie, 1996).

Furthermore, the instructor in a such classroom might conceptualize her or his role as a creator of memory joggers to assist students in remembering facts.

Power in the classroom: Deeply rooted in the history of teaching and learning is the belief that an instructor should have power over students in most classroom situations. Students, parents, administrators, and other groups in the community expect instructors to possess most power in the classroom. In addition, students consider their instructor as the main source of knowledge, and therefore, the individual who should
have considerable power in the classroom.

With respect to most aspects of teaching and learning, students regard themselves as having relatively little power to determine their own learning objectives, in relation to the power of their instructors (Tobin & McRobbie, 1996). Moreover, students in the classroom act within the assumption that "if the teacher has the knowledge that [they] need to learn, then it makes sense for the teacher to have the power to set up situations in which [they] can discover what they need to know or receive from the teacher" (Tobin, 1995a).

The Myth of Efficiency

From an efficiency perspective, science instructors in traditional classes believe that keeping students quiet enhances learning in science classes. In such classes, the instructor can transmit information to students, provide them with opportunities to practice, and then test what they have learned. The myth of efficiency in college science teaching can be considered in terms of three components; the instructor possessing control of students; time being a commodity in short supply; and content coverage being more important than meaningful learning (Tobin & McRobbie, 1996).

Control: Cultural myths make sense to science instructors and their students in traditional classes because they are related closely to one another. Such myths are built on "a foundation of beliefs that knowledge exists separately as a discipline that is separate from knowers and that the teacher should have a control over the enacted curriculum" (Tobin & McRobbie, 1996, p. 237). Accordingly, science instructors in traditional classes believe that being a good instructor involves gaining control over students in the classroom.

Instructors feel that by maintaining control, students will make progress
through the work program and learn more efficiently (McRobbie & Tobin, 1995). Activities in the class can only occur under the instructor's direction. Therefore, the major goal of a teacher is to make sure that there are enough tasks to occupy students for the entire lesson. Keeping students busy and task completion are regarded as desirable and often rewarded (Tobin, 1993 b).

The traditional science classroom seems to be conceptualized in terms of the school as work place (Marshall, 1990a) and the instructor as controller of student views and practice. In this culture, the instructors' main goal is to maintain control of student thinking and behavior. In addition, classrooms are commonly conceptualized as work settings where workers (students) are supervised or controlled by the manager or the instructor (Marshall, 1990a). In other words, just as control is emphasized in the sense that employers and shop stewards control employees, instructors control students in traditional classrooms.

The majority of science instructors' classroom actions can be explained in terms of technical interests (Habermas, 1972). Therefore, technical interests are grounded in the human need to control and manipulate environments (Grundy, 1987). Instructors who are guided by technical interests often have a basic orientation toward controlling and managing learning environments in the classroom.

According to Grundy (1987) a technically informed curriculum is designed to be implemented in learning environments in which students' behavior and learning are strongly instructor-controlled. The instructor controls what is to be learned or performed in the classroom, and he or she decides at what pace students will cover content. Moreover, assessment tasks generally emphasize engagement in and completion of tasks rather than involvement in meaningful learning in which learners can relate
new knowledge to relevant concepts and propositions they already have (Tobin, 1993 b).

**Content coverage:** In a traditional science class, the instructor has the responsibility to ensure students' coverage of all course content material within allotted time frame. In order to accomplish this, it is very important to control actions in the class. Following a study of an experienced mathematics teacher, Taylor (1994) concluded that "the objectivist myth readily extends reification to the curriculum which becomes imbued with a mythical image of the curriculum as a container whose contents need to be delivered or the curriculum as a map whose terrain needs to be covered" (p. 5).

The course syllabus in science college classes may be viewed as a contract between the instructor and his or her students (McRobbie & Tobin, 1995). Therefore, instructors feel professionally obligated to cover all of the content indicated in the syllabus within the course time. Covering the course content in total is vital in preparing students for tests as well as in meeting the course objectives described in the college's bulletin. Operating within this assumption, less attention is paid to meaningful learning in the classroom.

**Limited time:** Many instructors feel constrained by pressing time lines and therefore, believe active learning in science courses to be unattainable. Consequently, when forced to make judgments about how to spend their limited time in teaching science and covering the content of the course, instructors feel that the traditional style of teaching and learning is an efficient method to meet time lines. Some instructors, for example, believe that when students work in groups they are not moving at a fast enough pace for the instructor who is restricted by the syllabus of the course (McRobbie & Tobin, 1995).
In order to complete the required content in the time available, instructors feel they must set the pace of science teaching and learning (Tobin & McRobbie, 1996). Thus, regardless of understanding, students have to move from one topic to the next to remain on schedule. If students do not understand, they should memorize the important information and understanding is expected to occur later in its own good time (McRobbie & Tobin, 1995; Tobin & Roth, 1995).

The Myth of High Grades

The belief that instructors should prepare students to succeed on tests or to obtain high grades represents a major concern for instructors and their students. During the first classes, each instructor endeavors to ensure that students know the course requirements and what is expected for high grades. Brickhouse and Bodner (1992) found that the primary issue motivating students to learn in science classes is grades. The first comment following the announcement of an assignment is commonly directed toward how such an assignment would affect student grades. Accordingly, a college science instructor views his or her role in terms of assisting students to do well on tests and hence obtain high grades.

Directing more attention to obtaining high grades than learning with understanding is consistent with current schools’ and departments’ requirements for acceptance into a specific program. Elementary prospective teachers at Florida State University, for example, need to obtain high grades in science courses in order to be accepted in the elementary education program. In addition, high grades often provide students better opportunities for good jobs following graduation.

Many science instructors accept these cultural myths and find them compelling referents for sustaining traditional practices in classrooms (Tobin & McRobbie, 1996).
Furthermore, many students are well served by such practices since their goals are to pass exams or to obtain high grades. However, traditional practices in classes designed for prospective teachers are inconsistent with the widespread calls for reform in science education. Such calls advocate changes to the traditional roles of teachers and students in science classes, and recognize that students should build understandings about what they are endeavoring to learn.

The Need for Reform

The need for the reform of college science teaching is increasingly apparent during the past two decades. Since the publication of *A Nation at risk: The imperative for educational reform* (National Commission on Excellence in Education, 1983), reforms have been demanded by more than 400 national reports (Hurd, 1994). These reports, such as *Science for all Americans* (Rutherford & Ahlgren, 1990), *The liberal art of science: Agenda for action* (American Association for the Advancement of Science, 1990), *The national science education standards* (National Research Council, 1996), and *Science teacher preparation in an era of standards-based reform* (Committee on Undergraduate Science Education, 1997) called for major reforms in science teaching and learning, specifically in classes for prospective teachers.

The pressing need for major changes in how science is taught and learned is expressed in *Science for all Americans* (Rutherford & Ahlgren, 1990):

In learning science, students need time for exploring, for making observations, for taking wrong turns, for testing ideas, for doing things over again; time for building things, calibrating instruments, collecting things, constructing physical
and mathematical models for testing ideas; time for learning whatever mathematics, technology, and science they may need to deal with the questions at hand; time for asking around, reading, and arguing; time for wrestling with unfamiliar and counter-intuitive ideas and for coming to see the advantage in thinking in a different way. Moreover, any topic in science, mathematics or technology that is taught only in a single lesson or unit is unlikely to leave a trace by the end of schooling. To take hold and mature, concepts must not just be presented to students from time to time but must be offered to them physically in different contexts and at increasing levels of sophistication. (p. 193)

Meaningful learning occurs when learners are provided with enough time and power to engage in activities that have potential relevance to their lives and will be perceived by them as important (Tobin & McRobbie, 1996).

Students need to learn science with understanding to be able to live in a society in which science influences every aspect of life as well as to meet the challenge of the 21st century (American Association for the Advancement of Science, 1990). The following excerpt from The liberal art of science: Agenda for action (American Association for the Advancement of Science, 1990) demands that science should be taught as science is practiced at its best:

Education in science is more than the transmission of factual information: it must provide students with a knowledge base that enables them to educate themselves about the scientific and technological issues of their times; it must provide students with an understanding of the nature of science and its place in society; and it must provide them with an understanding of the methods and the processes of scientific inquiry. To achieve this goal, science should be taught as science is practiced at its best. (pp. xi-xii)

The need for students to engage actively in learning science is expressed in the following excerpt from the National science education standards (National Research Council, 1996):
Schools that implement the standards will have students learning science by actively engaging in inquiries that are interesting and important to them. Students thereby will establish a knowledge base for understanding science. In these schools, teachers will be empowered to make decisions about what students learn, how they learn it, and how resources are allocated. (p. 13)

Recently, a report of the Committee on Undergraduate Science Education (1997) recommends that science instructors can make a substantial contribution to reform science teaching and learning by improving their styles of teaching in classes for prospective teachers. This report emphasizes that

Because future teachers take many science course from faculty in science departments, these faculty members provide future science teachers with their most recent and prominent models of science teaching. Science faculty can be powerful influences on how future teachers understand and appreciate science by the ways in which they present their knowledge of science and the modes of investigation they employ to acquire new knowledge. (Committee on Undergraduate Science Education, 1997, p. 5)

To achieve the goal of reform for enacting curriculum in classes for prospective teachers, it is necessary for instructors to reshape their beliefs used as referents for actions in the classroom. A teacher's action often has associated with it a belief that circumstances support the appropriateness of a given behavior. Therefore, if he or she wants to change such actions, it is necessary that the associated beliefs also change. Since beliefs are constructions that are viable in allowing individuals to meet their goals (Tobin & LaMaster, 1995), there is an obvious difficulty in expecting individuals to change given beliefs unless they are persuaded of the increased viability of alternatives (Tobin, 1993 b).

Plans to enact reform begin with contemplating alternative approaches to replace the traditional style of teaching and learning in science classes. Although much attention
has been drawn to the need to involve all parts of the educational system in efforts to initiate and sustain reform (e.g., Anderson & Mitchener, 1994; Tobin & Tippins, 1996), the reform of teaching practices evolves as instructors use an alternative referent, such as constructivism, to make sense of their roles and those of their students (Tobin, 1993b). Mark, who is one of those instructors, used an alternative referent to construct new metaphors for actions and interactions and to conceptualize new roles for the instructor and students in the classroom.

Within this context, Mark worked hard in his classes for prospective teachers to improve teaching practices and to move from teacher-centered to learner-centered approaches. The next section focuses on actions and interactions in Mark’s classes in terms of his beliefs about teaching and learning, and strategies he used to achieve goals through constructing a context for learning within the social milieu of science teaching and learning.

**Context for Chemistry Teaching**

Analysis of data from field notes, interviews, artifacts, and videotapes of the physical science classes for the Spring semester of 1996, and videotaped data from the last few years indicated that Mark struggles to move beyond the traditional approach to science teaching. My role as a researcher was to observe his actions in the classroom and understand how such actions are related to his beliefs about science teaching and learning, while focusing on his role as a science instructor. However, it is very important to understand the classroom and institutional constraints that Mark works within as a college science instructor. Then I analyzed the instructional strategies that
he used to move beyond traditional practices and to create and maintain a high quality learning environment.

**Mark's Beliefs and Science Teaching**

Mark's approach to teaching science was dynamic. It was clear that he worked hard in chemistry classes to move from teacher-centered to learner-centered approaches of teaching and learning where he could utilize different alternative ways of science teaching and learning. Mark endeavored to maximize the participation of his students; and he was always looking for ways to stimulate active and varied ways of participation for his students. These findings are consistent with those of two studies conducted in the past few years (Brush, 1993; Duffy, 1993).

In most of Mark's classes students engaged actively in the process of chemistry teaching and learning. For example, students enjoyed the first chemistry class in which they actively participated to learn about temperature through an activity involving dry ice, liquid nitrogen, a balloon. A vignette on this activity was provided in Chapter 6.

Mark used to begin chemistry classes with a hands-on activity (Brush, 1993). He believed that it was a good idea to start the first class in each semester with a hands-on activity to make students familiar with the laboratory environment related to the course. Involvement of this type, he believed, also creates some excitement for the rest of the course. This action might be consistent with his beliefs about science teaching and learning. Mark emphasized his beliefs about the importance of active learning in the classes for prospective teachers as follows:

I understand the constructivist's view that we cannot transfer knowledge intact to our students, but initially I thought that I could transfer my enthusiasm about something intact to someone else. I know now that I cannot do that, or at least I can only do it for a little while. The students have to construct their own
enthusiasm. My role is to facilitate that process. I have to find some reason that a student finds this material interesting or relevant. I can't transfer my interest or my sense of relevance to other students. They have to construct that for themselves.

Underlying Mark's beliefs about learners who are actively involved in science learning is a set of beliefs about the nature of learning and knowledge, that he referred to as constructivism.

As a referent for teaching, constructivism can shape the direction of an instructor's actions and his role as a science instructor in the classroom. Based on this set of beliefs, the science instructor takes account of what the students know, and provides them with learning experiences to facilitate learning what society regards as having greater viability at that time (Ritchie, Tobin & Hook, 1997). In a learner-centered classroom, learners are no longer passive agents, but they engage in interactive discussions or in small group problem solving activities. Accordingly, the teacher's role changes from a giver of knowledge to a mediator of learning (Tobin & Tippins, 1993). As a constructivist instructor, Mark viewed his role as a facilitator of learning. His professional actions were directed toward facilitating student learning, not transferring his knowledge to "empty vessels." Therefore, his focus, through such actions, is to stimulate students to participate and interact actively in chemistry learning.

It seems that Mark's beliefs about science teaching and learning evolved during his work as a science researcher and a college science instructor involved in a cooperative work with science educators to plan and implement the physical science course for prospective elementary teachers during the last four years (Brush, 1993; Duffy, 1993). Mark commented on how his beliefs about science teaching and learning evolved during his work as a science researcher and a college science instructor in the
following way:

I was very intrigued by this notion of constructivism, because I had heard Ed. Mellon [a chemistry professor at FSU] talk about it from the point of view a science faculty member. I didn't understand constructivism very well at [that] time. To me it was simply something we all know, which is that you learn by doing.

Marks continues reflection on how his beliefs' evolution was related to his work as a science researcher and a science instructor for college science courses:

I had heard a great deal about constructivism before beginning these courses. I think we all know that you learn by doing. Show me something and I'll remember it for a minute; let me do it and I'll remember forever. So I thought constructivism was just another way of saying that the best way to learn something was to do it. That is why I wanted to get on board [in this project] because I knew that is true from my own experience with laboratory research. The best teaching we do, the best learning environment we create for students, is when we bring them into our laboratory and have them do science in a mentoring relationship. As I learned more about constructivism, I started to see that it is a little bit different, but it is still basically a notion I can buy into. ... Constructivism says that I can't take my understanding and give it to [someone else]. What that has in common with learning through research is that both processes recognize the importance of doing for yourself. A constructivist says the student should be doing things to construct their own understandings. Somebody who is a research mentor would say learn science by doing science. Just like you learn to work on cars by working on cars.

In an interview (Duffy, 1993), Mark talked about his beliefs when he began teaching science for prospective elementary teachers and how such beliefs related to what he knew about constructivism as follows:

...what I was hearing about constructivism sounded very similar to a belief I already had that you learn by doing. I understand now that constructivism is not same thing as learning by doing, but what they have in common is this emphasis on hands-on approach. I was also beginning to recognize that learning is not passive (p. 106).
Apparently, Mark relates the evolution of his beliefs about science teaching and learning to his primary work as a science researcher and being a member of a group of science faculty and science educators to plan and implement the physical science course.

It seems that Mark’s work and interactions with science educators, in addition to his evolving beliefs as a science researcher helped him reshape his beliefs and goals about teaching and learning, and thereby, improve his pedagogical knowledge. Relating such improvement to interactions with science educators was evident in interviews with Mark, such as the following statements:

*I think [being involved in this course] has been a really good experience for me and the other faculty involved. And I think I have learned a lot from doing it.*

*One of the things I have learned, from you guys [science educators], I ...*

*That is one of the things I mentioned that I learned from Craig Bowen [a science educator involved in the project].*

*My experience as the classroom instructor is that I always learn more than the students do. So getting involved and doing stuff with students is good.*

Accordingly, he believes that to have students learn science by doing means to create learning environments in which learners are no longer passive agents, but they engage in interactive discussions or in small group problem solving activities. Within this belief, an instructor’s role changes from a giver of knowledge to a mediator of learning (Tobin & Tippins, 1993).

As a constructivist instructor, Mark viewed his role as a facilitator of learning. His professional actions were moved from achieving the goal of transferring knowledge toward facilitating students’ learning. Accordingly, the focus of such actions is to
stimulate students to participate and interact actively in chemistry learning. Students in such an environment learn actively through doing science, so they can construct their own understanding of science concepts.

Despite Mark's beliefs about the importance of creating an atmosphere for active learning, some traditional practices of science teaching and learning, such as lecturing for a long time, were observed in his classes. It seems that Mark, who works within many classroom and institutional constraints, struggles to use his evolved beliefs, instead of old traditional views about teaching and learning, as a referent for actions in the classroom. In a similar study, Ritchie, Tobin and Hook (1997) observed some traditional practices in a classroom in which the science teacher used constructivism as a referent for practice. This teacher was reported to view learning in terms of knowledge construction at times, and at other times as knowledge transmission (Ritchie, Tobin & Hook, 1997).

Tobin, Tippins, and Gallard (1994) saw these paradoxes as further evidence of a dialectic struggle between old and new beliefs about teaching and learning. Throughout their study, Tobin, Tippins, and Gallard (1994) established a link between teaching referents and teacher action in a particular context, and concluded that "the referents given highest priority ... have greatest impact on how a teacher acts" (p. 246). To understand why some traditional practice was observed in Mark's classes from time to time, it is important to understand the context in which Mark and his students practice science teaching and learning.

Classroom and Institutional Constraints

Although teachers' and students' beliefs exerted a strong influence on practices within the classroom, as it was found by McRobbie and Tobin (1995), there was
nevertheless an infrastructure which depended on elements from the predominant culture. This means that context of science teaching and learning is not only constructed by the culture of the classroom, but also the culture out of the classroom. Infrastructure is the culture which molds actions of the teacher and determines what meaningful learning opportunities should be created in the classroom.

Context can be considered as the circumstances that surround and affect a particular event or situation such as science teaching and learning in the classroom (Grasser & Magliano, 1991). Actions in a science class are constrained by the instructor's hierarchy of beliefs and interactions with students, colleagues, and social organizations (Tobin & Tippins, 1993). A science instructor's constructions of the context for teaching science are strongly influenced by what is described as the culture of teaching (McRobbie & Tobin, 1995). There are two sets of factors related to the culture of science teaching: micro and macro-cultures.

According to McRobbie and Tobin (1995), the microculture of the classroom is characterized by the actions of the teacher and students in a class. The macroculture includes the actions of others out of the class, such as other instructors and administrators in the school and other related organizations and people out of the school. Macroculture interacts with the microculture of the classroom in the framing of goals and context. Actions that take place in the context of a classroom may be influenced by microculture or macro-culture or both. Accordingly, context is considered to be a product of the set of forces or constraints that belong to a specific culture. The traditional practices that were observed in some of Mark's classes can be attributed to classroom and institutional constraints (Brickhouse & Bodner, 1992), such as students' traditional views about teaching and learning in college level classes, which enforce
traditional practices of instruction and evaluation in science classes.

Lecturing was a traditional practice observed in some of Mark's classes. For example, in the chromatography class Mark talked for about 30 minutes while students were passively listening and taking notes. His role in that lecture can be characterized as informer; and there was a lack of co-participation among the students and the instructor. Giving students a help session class before the final examination to help them obtain good grades was an action enforced by the traditional practices of instruction and evaluation. Also, controlling what was to be learned in the classroom according to the syllabus of the course, or the pace students would cover content was another traditional practice in Mark's classes.

As an essential component of the microculture, students' actions in Mark's classes were considered as classroom constraints (Brickhouse & Bodner, 1992). The experienced context in a science class is mediated by the actions of students (McRobbie & Tobin, 1995). Interactions between students and instructors influence the development of the instructor's perspectives of how learning occurs in the classroom (Brickhouse & Bodner, 1992).

Practices of teaching and learning in the physical science course might be mediated by students who were mostly in their freshmen year of college. Most of them were straight out of high school and were not experienced as a student at a university. They were still trying to get used to the university scene and become more familiar with science learning and teaching in the physical science course and other science courses. Students in the physical science course are non-science majors and frequently have negative feelings about science (Brush, 1993).

When Mark first taught this course, during the summer semester of 1992, he
endeavored to empower students in shaping what and how to learn science in the classes (Duffy, 1993). This practice has not been observed anymore in his classes. Mark discussed why he did not encourage the students to have a role in shaping what and how they learn science, although he believed in the importance of it, in the following way:

In this course, I should share with the students the role of shaping the course. In the very early stages I did “The Big Experiment.” I empowered my students. I said “You are empowered” and assumed that we would get to the science. And that didn't work. Or at least it didn't work for me. I think when you empower the students without structure, they just drift because they don’t know what to do. You can’t suddenly take students who have been through 14 years of education and say “all right you’re in charge, this is your course, you tell us where you want to go.” They don’t want to go anywhere. They just want to sit there. But you don't go back to not giving the students any role in the classroom. So what I learned in my early versions in this course is that if you empower the students you’ve got to do it in a way that keeps the instructor in control and provides structure. ... You’ve got to provide a fair amount to structure. But then, within that, you give them a chance to shape the direction.

Since it is the first or the second time for most of these students to attend college science classes, they had negative attitudes toward science (Brush, 1993). Mark commented on students' negative feelings about science in the following way:

when you are a college student just out of high school just focusing on your major, you’re not into it [science]. You know, you’re just taking these courses because someone is making you.

Mark needed to work hard in order to have these students become familiar with academic work in college classes and learn science with interest. The teaching approach that Mark developed in classes for prospective teachers was to encourage them to engage actively in discussions and other activities intended to promote interest and learning (Brush,
Prospective elementary teachers came to science classes with traditional views about teaching and learning. They view lecturing as the main instructional style in college classes, and the instructor, who is the main source of knowledge, has the power to control instructional and evaluation practices. Also, they were involved in science courses with the purpose of obtaining high grades, so they can be accepted in the elementary teaching program. Muna, one of the target students in this study, expressed her view when she said in an interview:

Basically my ideal science teacher is the one who can give me things that I can perform myself.

Nora, another target student, viewed the ideal science teacher as follows:

I don’t know. I guess [s/he is] a person who would know how to balance out lecturing with asking questions with doing hands-on work.

The microculture of the classroom interacts with the macroculture that includes the actions of others in the university, in which Mark works, and the educational system at large. The educational system, in which students have been through 12 years of education before coming to college classes, supports the hidden aspects of this macroculture. Such an interaction forms the culture in which Mark frames his goals and contexts for teaching and learning. The hidden aspects in this culture may influence shaping practices of teaching and learning in Mark’s classes. Some of macrocultural aspects are: lecturing is the way of teaching in college level class, the instructor has the power to control the teaching and learning process, and the main goal of a student is to obtain high grades.
Despite the presence of some traditional practices in Mark's classes, most of his actions in the classroom were consistent with his stated beliefs about teaching and learning. It seemed that his main goal was to maximize the participation of his students. He always was on the lookout for ways to stimulate active and varied ways of participation for his students (Brush, 1993; Duffy, 1993). Mark's efforts to create productive learning environments are consistent with his beliefs to utilize different instructional strategies.

**Instructional Strategies**

It is clear that Mark stimulated and encouraged students to be strongly engaged in the process of learning; so they could learn chemical concepts with understanding. Several instructional strategies were implemented in Mark's classes to create active learning environments. Mark developed some strategies to encourage students' participation and interaction including demonstrations, problem-solving activities, and brief lectures.

**Demonstrations**

Enriching the class with demonstrations was an essential strategy developed by Mark to enhance chemistry teaching and learning. It was obvious that Mark's goal of using different demonstrations was to create a good quality environment for active learning, so students could engage in discussion to construct meaning of the concepts they learned. Using this strategy encouraged students to engage in meaningful learning through student-instructor and student-student interaction. Students were asked to participate in performing most of the demonstrations, whether inside the classroom or...
Data from the field notes and videotapes enabled me to intensively analyze some of the demonstrations conducted in Mark's classes. The demonstrations about the concepts of 'atom' and 'covalent bonding' were examples in which students participated to learn about these concepts. To clarify the concept of atom and its components, protons, neutrons, electrons, Mark asked all students, in addition to Adam (the physics instructor) and the teaching assistants, to go out of the class to demonstrate the structure of atoms, ions, and compounds.

At the beginning, Mark discussed atomic structure and the positions of electrons, protons, and neutrons. He then had students, the physics instructor, and the teaching assistant construct some neutral atoms, such as hydrogen (H), helium (He), and lithium (Li). They also asked to construct some ions, such as the hydrogen ion (H⁺). Finally, they constructed the compounds of lithium fluoride (LiF). Some of them constructed a nucleus by playing the role of protons with positive charge and neutrons without charge, and others to be electrons with negative charge in the valence and inner orbits of an atom.

Students learned that the protons and neutrons in a neutral atom, such as (Li), rotated in the center and electrons moved in their orbits around the nucleus. Normally, an atom has as many electrons as protons. All neutral atoms have a zero net charge because the number of the protons in the nucleus equals number of electrons whirling about the nucleus. This is electrically balanced. A charged atom, such as (H⁺), is called an ion. When an atom loses one or more electrons it has a net positive charge, and when it gains one or more electrons it has a net negative charge. Some chemical compounds, such as (LiF), are formed through the attraction between the ion of Li⁺ and the ion of F⁻.
A similar demonstration was performed in the class to clarify the concept of covalent bonding. Mark began to pose a question about what's the force that holds similar atoms together to form molecules, such as H₂, N₂, and O₂. Then he referred to this force as covalent bond which means a sharing of chemical combining power. When two hydrogen atoms share an electron with the other, they are both attracted to the electrons and are held together. Mark felt that students could not imagine how hydrogen atoms are held together by their mutual attraction for the two electrons that they shared. They needed help to understand this concept.

To help students understand the concept of covalent bond, Mark asked four students to move to front of the class and demonstrate how two hydrogen atoms are held together to form H₂. Two students were asked to be the hydrogen nuclei (protons) and the other two to be the electrons. He had the two nuclei stand apart from each other while each electron was moving in an orbit around the nucleus. Adam (the physics instructor) participated in the activity helping students to understand how electrons rotate in their orbits. Students learned that the electrons experienced identical nuclear charges from both sides of the nuclei, so they were attracted to both sides equally. The students represented their understanding to the concept by moving equally in the both sides of the nuclei.

Some demonstrations were performed to stimulate students' reactions and interaction in the class. Mark used such demonstrations to create an interesting environment for learning. Some of these demonstrations included activities involving dry ice, liquid nitrogen, and balloons, described in the vignette in Chapter 6; the chromatography demonstration (Appendix A) and demonstrations involving
neutralization of acids and bases, and gas-inflated balloons.

In the neutralization demonstration, Mark used electrical bulbs to demonstrate how strong acids and strong bases are completely ionized, and weak acids or bases are partly ionized. When a strong acid such as hydrochloric acid (HCl) or a strong base such as sodium hydroxide (NaOH) were used, all the bulbs lighted with strong and bright light. But some of the bulbs lighted with a weak light when a weak acid such as acetic acid ($\text{HC}_2\text{H}_3\text{O}_2$) or a weak base such as ammonia ($\text{NH}_3$) was used in the demonstration.

In the gas-inflated balloons activity, which was conducted to help students learn about energy and chemical reactions, different colored balloons were hung at the front of the class to be used in the demonstration. After a short discussion with students about types of energy such as mechanical, chemical, light, heat, and stored energy, Mark lit the end of a long pole and brought it close to the blue balloon which was filled with hydrogen. There was a loud explosion with a flame. The students reacted excitedly and started to talk with each other about what happened.

When Mark approached the yellow balloon, filled with oxygen, with the long pole that had been lit, students, especially in the front of the class, seemed afraid of the explosion. They got ready to cover their ears with their hands. Mark seemed happy to see the students’ reaction. Students were surprised because the explosion was less than the first one. When Mark discussed with them why it did not blow up, students answered that there was no fuel. Discussion between Mark and students about hydrogen, oxygen, burning, and energy continued after igniting the balloon that contained a mixture of oxygen and hydrogen and the another balloon that contained helium gas.
**Group problem-solving activities**

Students worked in groups and sometimes individually to conduct activities or to solve problems on work sheets related to chemical concepts they learned in class. Most of the problems were related to students' daily life experiences, such as the activity of producing soap to learn about organic chemistry, and about pure compounds or mixtures. Mark used group problem-solving work to stimulate students to participate actively in learning science with interest and understanding. He emphasized that students had to combine hands-on work with minds-on thinking to learn and understand what they were doing.

The chemistry quiz and the final test were problem-solving activities in which students could understand more about science concepts. Mark tried to improve his assessment strategies in his classes to fit into his constructivist approach of teaching and learning. The quiz and the final were open book and open note. Students could work together to solve the problems in the quiz, but Mark asked them to work individually to solve the problems in the final test.

The purpose of the problems in the quiz and the final test was to stimulate students' thinking and understanding. Their answers should reflect their own understanding. An example of the quiz problems was: *Which do you expect to have a higher boiling point: CH₄ or NH₃? Why?*

Also, the following was an example of one of the final problems:  
*CO₂ is non-polar, but SO₂ is polar. Explain why.* Students perceived that they had to learn science concepts with understanding, because they did not need to memorize science information to be ready for the quiz or the final test. Accordingly each students solved...
test problems according to her understanding of the concept in the problem.

Nora, for example, showed her understanding of the polar and non-polar problem in the final test in her answer as follows:

C only has 2 things around it, therefore canceling each other out making it nonpolar. S has three things around, two are bonds and one is alone pair of electrons, so one is negative and one is positive making it a polar molecule.

Another student, Lisa, expressed her understanding of this problem from another perspective. She wrote in her answer:

\[ \text{CO}_2 \] is nonpolar because the O's are pulling evenly. \[ \text{SO}_2 \] is polar because there is an even pull on the S. The e's don't have the same force as the O's.

Students' answers and grades in the final test indicated that they were concerned about learning with understanding more than the rote learning. About half of the students obtained A and A' and half of them obtained B in their final test.

Mostly, students worked in groups of 5, 4, 3, or 2 students. They arranged themselves in groups during the first weeks of the course. Mark provided them with guidelines to help them before or during activities. Students in each group were discussing observations, such as the kind of reactions they had, how to prove it, and how to record observations. While students were doing activities, Mark was moving around from group to group helping students whenever someone needed help. He served as a consultant for the students during their work. He was discussing with each group what they observed, giving hints about certain observations the students made, and explaining to them how to write chemical equations. Adam and the teaching assistants also helped students to work and learn from activities.

Most of the activities did not need much experience or much previous knowledge
to be conducted. The students might need only to use common products, such as chlorox, soap, or materials, as balloons, pennies, nails, and test tubes to conduct chemical activities. Probably Mark thought that such activities would help students to become familiar with the science laboratory and enjoy doing chemistry. It was clear that providing group activities modified learning environments in which students worked cooperatively to learn science with interest and understanding.

Students felt that they understood science more through hands-on activities and demonstrations. Nora expressed her feeling about hands-on work and demonstrations in the following way:

I learn better hands-on. Because if I am just, if somebody is lecturing to me, I'll write down the notes, and that is all good. But, if I am doing it, then ... I'll have to understand it. Because if I get to a point where I don't understand something, I'll have to, I'll have to ask the question and learn it. And then I can go on, so. If I am actually doing something like a work-sheet or demonstration of something, then I am making myself understand it. I'll have to, if I do it, right.

Huda felt that she learned chemistry concepts with understanding in Mark's classes because she had the opportunity to do many hands-on activities.

I learned better through the activities, because if I am doing an activity, I remember. I can say 'oh, I did' when I poured this in, 'this happened,' and it happened because of this. And I will remember that because I saw it physically, and I did it myself, versus having somebody tell what they did and what happened. I mean, I have the physical evidence for myself. Yes, this happened because I did it for myself.

Huda commented on the activity that she did with the other students in Mark's class as follows:
... And like that was interesting today when we did it in the class with [Mark]. It was like I remember these things because that teacher did hands-on. And because this teacher is doing hands-on I know I remember it, because when he was explaining it in the lecture, I am like 'oh, yeah, that is the ionic bond and that is the covalent bond.' I always remember it because I had something physically to see, and I did it hands-on versus someone who just lectures to me. I'll probably memorize the notes and everything and forget it later.

Students enjoyed working in the activity of iron nails to learn about reduction and oxidation. Every student put copper sulfate (CuSO₄) in a small glass bottle, then put a piece of paper over the CuSO₄. She added sodium chloride (NaCl) to the bottle and put another piece of paper over it. New iron nails were put over the paper then water was added carefully to the bottle. The bottles were left while students were observing what happened to the nails. After a while they began to observe change in the color of the nails. Their color began to change to brownish/red. In other words the new nails turned to rusted nails. Mark asked students to keep the bottles for the next class to observe what would form.

This activity and the discussion among students and their instructor helped them to understand that what happened to nails was oxidation and what happened to copper was reduction. Two electrons transferred from iron (lost 2e⁻) to copper (gained 2e⁻). Iron (Fe) was oxidized to Fe²⁺, and copper (Cu²⁺) was reduced to Cu as in the equation:

$$\text{Cu}^{2+} + \text{Fe} \rightarrow \text{Cu} + \text{Fe}^{2+}$$

Obviously, students did not only need to use their hands to conduct activities, but also their minds to think about what they observed and why such things had happened. They could understand science knowledge effectively through learning by doing, especially when they had the opportunity to work in groups to solve problems. They
could learn actively and construct knowledge through the combination of hands-on/minds-on activities.

Meaningful learning is possible in science classes, as long as students are provided with opportunities to use equipment and materials while working cooperatively with peers to solve problems which interest them (Tobin, 1990). Enriching science classes with group problem-solving activities is an effective strategy of science teaching and learning. If students don't have a chance to practice and perform science activities, they tend to memorize science facts and concepts regardless of whether they understand what they learned or not.

Short lectures

Lecturing becomes an effective strategy for teaching when it is used to facilitate meaningful learning instead of a way to deliver facts and canonical knowledge. Students are limited in their understandings of science, and thus, learning with understanding might be facilitated through the use of a short lecture before undertaking tasks “to review the extant knowledge of the students and tailoring of the tasks such that student could be successful in completing them” (Tobin, 1997). Mark used short lectures as an instructional strategy to facilitate learning. Before or after each demonstration or activity, Mark gave a short lecture about the concept that the class needed to learn. For example, before the covalent bond demonstration, he gave a short lecture about the difference between ionic and the covalent bonds. Most of the lecture time, Mark moved around in the class using his body language and moving his hands to argue with students, ask, and answer questions. Mark used the chalkboard to clarify conceptual relationships, chemical reactions, and equations.

The way that Mark used lectures as an instructional strategy in his classes was
consistent with his beliefs about the importance of creating an active learning environment to maximize students' participation. In the short lectures he used to pose questions and encourage students to ask him questions and argue with him. In long lectures he endeavored to interact with students during the presentation. Students were encouraged to talk loudly in the classroom when arguing, asking or answering questions. Mark encouraged interaction by reacting positively to their questions or comments, such as "you have asked a great question" or "this is a good point." His actions gave students the impression that he was not an expert, but a co-learner in the class.

To avoid providing students with ready answers for their questions, Mark sometimes asked students to think about their own questions, or tried to stimulate their thinking by asking another question such as "how do you know?" Clearly, Mark wanted students to try thinking about answers, since his role as a teacher was to stimulate thinking rather than to provide ready answers. Students had to know that they should not regard themselves as empty vessels in need of topping up with knowledge (Tobin, 1990a).

Conclusion

Science classes in colleges are dominated by traditional styles of teaching and learning. Cultural myths support the status quo and make it difficult to enact and sustain change to these styles. During the past decade, some educators have begun to think about alternative approaches to take the place of the traditional style of learning and teaching in science classes. A constructivist approach with the assumption that science learning is not a teacher-centered activity, but is learner-centered has received increased
consideration. Most students can learn new concepts with understanding if they are
connected to their existing understanding of the world (Glasersfeld, 1989). In contrast
to traditional instructional approaches, constructivism and conceptual change
approaches focus primarily on students’ pre-instructional understanding and attempt to
develop strategies to help students to new conceptions (Roth & Tobin, 1996).

In particular reference to Mark’s classes, students learned science concepts with
interest and enthusiasm through the use of different strategies for learning. They
perceived that it was not enough for them to learn passively by memorizing facts and
equations about science concepts. Their requirement to work in activities, solve
problems, and interact in the classroom enhanced their learning with understanding.
Each student tried to use her prior experience and knowledge to construct meanings in
new activities and situations. As the result of the strategies Mark utilized in the class, a
student learned how to interact with the instructor, with other students, and with the
task.

Data in this study indicated that active learning in the chemistry section of the
physical science classes stimulated students to become more involved in the learning
process. To create an environment for active learning, more than one learning and
teaching strategy should be used in a science class. Short lectures, demonstrations,
problem solving in groups or individually, and various class interactions are some of
these strategies which can be effectively used in producing active learning in the
classroom.

When students feel that they have the power to talk and express their ideas in the
class, they can argue or ask for help when they did not understand (Tobin, in press-1).
In a setting in which co-participation is occurring “the focus is always on what students
know and how they can re-present what they know" (Tobin, in press-2). Encouraging interactions is an important characteristic of a learner-centered class in which students can learn science actively.

It is the responsibility of science instructors in college level classes to create a high quality environment for prospective teachers to understand science concepts. Creating such an environment is influenced by the roles that the instructor uses for himself in the classroom. A teacher's role can be conceptualized in terms of metaphors that the instructor uses in science teaching and learning. In the next chapter, I will endeavor to understand the roles and metaphors which Mark used in his classes to create active learning environments.
CHAPTER 5
METAPHORS AND ROLES USED IN CHEMISTRY CLASSES

Introduction

Background

Research in science education (e.g., Roth & Tobin, 1996; Tobin & Roth 1995; Taylor, 1995) has shown that many instructors in college science classes use the transmission-absorption metaphor to make sense of their classrooms. They use this metaphor to assume science learning is teacher-centered, and they conceptualize their role as transmitters of knowledge. Students are viewed as empty vessels or receptacles for knowledge.

The constructivist view (Glasersfeld, 1989, 1993) is that science learning is learner-centered. Accordingly, instructors mediate the learning of learners. Students actively involved in the learning process use their prior experience and knowledge to construct meanings in new situations (Glasersfeld, 1989). In a learner-centered classroom, a science instructor uses constructivism as a referent to think about teaching and develops new metaphors for conceptualizing the roles he or she considers to have greatest salience for teaching (Tobin, Tippins, & Hook, 1994). In such a class, an instructor becomes more concerned about facilitating students learning rather than transmitting fragmented content of knowledge.

Metaphors can be used to conceptualize teaching roles and the instructor's actions
in science classes (Tobin, 1990a). Other factors, in addition to metaphors, are the instructor's beliefs, knowledge of science content to be taught, and knowledge of how to teach specific science content (Tobin, 1990a). In this chapter, I endeavor to learn about metaphors and how they relate to actions and interactions of science instructors and their students in classrooms.

The central purpose of this chapter is to understand the metaphors and images that structured the way that Mark perceived situations and events in his classes (Marshall, 1990b). My focus will be on the metaphor that Mark used to conceptualize his roles in teaching science concepts for prospective elementary teachers. To understand how actions were related to his beliefs about learning and teaching, Mark's reflections and actions to create a learner-centered rather than a teacher-centered environment for learning will be discussed.

Metaphors and Science Teaching

Metonymy (Lakoff, 1987) is an important aspect of language and knowing. It occurs when an individual uses part of a concept to give meaning to a whole, such as using computers to think about technology (Lorsbach, 1995) or using management to think of teaching. Another way to think about metonymy is to identify the central or peripheral concepts to give meaning to a concept, such as using teacher's roles in the classroom to define teaching (Tobin, 1993a). One way to understand the metonymic models individuals hold as having salience for teaching and learning is through metaphors that instructors use to conceptualize their roles (Lorsbach, 1995; Tobin, 1993b).

The term metaphor is regarded by Lakoff and Johnson (1980) as a mechanism that an individual uses to create new realities, especially social realities. They argue
that “the way we think, what we experience, and what we do every day is very much a matter of metaphor” (p. 3). Lakoff and Johnson (1980) emphasized that all language is metaphorical and that the words in a language represent how people conceptualize the world. The essence of metaphor is understanding and experiencing one kind of thing in terms of another (Lakoff & Johnson, 1980, p. 5). Lakoff and Johnson (1980) consider metaphors as central to the search for what unifies our own diverse experiences in order to give coherence to our lives. Just as we seek out metaphors to highlight and make coherent what we have in common with someone else, so we seek out personal metaphor to highlight and make coherent our own pasts, our present activities, and our dreams, hopes, and goals, as well. A large part of self-understanding is the search for appropriate personal metaphors that make sense of our lives. (pp. 232-233)

Metaphors in science classes refer to the way that instructors think about their roles when they represent their knowledge (Tobin & Tippins, 1996). Metaphors and images can be used to make sense of implicit belief systems associated with science teaching and learning (Marshall, 1990b). Collins and Green (1990) note that “each way of talking about [teaching and learning] is a language that brings with it a particular way of looking at the world (i.e., particular metaphors) and understanding what occurs” (p. 71). Carter (1990) adds that metaphor is chosen as the vehicle for modeling teachers’ comprehension of their work not only for its pervasiveness, but also for its plausibility for framing the meanings persons assign to events.

Science instructors can develop metaphors to be referents for constructing visions of what their classes could be like. They use these metaphors to conceptualize their roles and those roles of their students in classrooms. Exploring teaching metaphors is not only a means for assisting science teachers to think about who they are as
teachers, but also it enables explorations of coevolving conceptions of students (Bullough & Stokes, 1994). Perhaps the most powerful teacher role in traditional science classes is embedded in the metaphor that a teacher is 'one who knows' (Bullough & Stokes, 1994). Within this metaphor, instructors conceptualize teaching in terms of the roles of knowledge transmission and classroom management. Accordingly, a vision of many science classes could be either the instructor lecturing while students copy notes or the instructors keeping the students on task as they work on their assignments to get them done on time.

Beliefs and Metaphors

Metaphors unconsciously serve to guide actions in the classroom and organize sets of beliefs about teaching and learning (Tobin, 1993 a). Beliefs associated with a metaphor are consistent with each other in that they lead to thoughts and actions that make sense to the instructor in the contexts in which they are applied (Tobin, 1993 a). Marshall (1990b) emphasized that belief systems affect teachers’ thinking and actions, and consequently, the actions of students. According to Tobin (1993 b), "If beliefs are found to be viable, they are retained, and if not, they are modified or discarded so that the belief set enables the teacher to satisfactorily fulfill her [or his] role" (p. 218). Therefore, beliefs about how students learn science can have a direct influence on the roles utilized by science instructors (Tobin, 1990b).

If a science instructor, for example, has a belief that students mostly learn science by listening to lectures, then his/her actions in the classroom are often consistent with a transmission-absorption metaphor. In such circumstances an instructor tends to conceptualize his or her role as a disseminator of knowledge to students who are regarded as receivers of such knowledge. When an instructor perceives
the classroom as a workplace (Marshall, 1990a) or factory, he or she may focus attention on keeping students working. As a consequence, students may concentrate on completing their work and give little thought to learning (Marshall, 1990a).

Mark’s Metonymic Models

An assumption underlying this study was that many of Mark’s beliefs about teaching and learning are metaphorical. It is proposed that, as Mark reflected on his actions and considered the various roles that he might adapt, he made sense of his roles by the use of metaphors. Mark’s personal epistemology is considered relevant in deciding whether or not a particular role is appropriate for use for science teaching. Therefore, if the role is consistent with his beliefs, the decision might be to adapt the role, but if not, the role might be considered inappropriate (Tobin, 1990b).

Data from field notes and videotapes indicated that Mark’s approach to teaching science was dynamic. This approach was consistent with his goals to create learning-oriented environments (Marshall, 1990a) and to maximize the participation of his students. Using different strategies for teaching indicated that Mark was always on the lookout for ways to stimulate active and varied ways of participation for students. It was clear that he worked hard to move from teacher-centered to learner-centered approaches of teaching and learning in which alternative ways of science teaching and learning could be utilized.

If learning is considered from a social constructivist perspective, learners are no longer passive agents, but they engage in interactive discussions or in small group problem solving activities. Accordingly, the teacher’s role changes from a giver of
knowledge to a mediator of learning (Tobin & Tippins, 1993). As a referent for science teaching and learning, constructivism shapes the direction of Mark's actions and his role as a science instructor in the classroom. Mark believes that to have students learn science by doing means to create an environment in which alternative ways of teaching and learning can facilitate students' learning process. His classroom actions aimed to stimulate students to participate and learn actively through doing science in which they can construct their own understandings of science concepts.

Data in the study revealed that actions in Mark's classroom were metaphorical and consistent with his beliefs about teaching and learning. It was clear that such actions were embedded in the metaphor that 'learning is an exciting trip.' Mark used his beliefs, which are associated with constructivism, as a referent for actions in his classes and for the metaphors in which his actions were embedded. To be consistent with his beliefs that students should enjoy while learning science meaningfully, Mark used the 'trip' metaphor to construct a vision of what science classes for prospective teachers could be like. Such a metaphor was evident in interviews and in actions and interactions in Mark's classroom.

The 'Trip' Metaphor

According to Marshall (1990b), "One path toward highlighting teacher's awareness of their implicit belief systems involves focusing on the metaphors and images they use as they describe their teaching" (p. 128). The observations and interviews suggest that Mark developed a new metaphor that was consistent with his goals and beliefs about science teaching and learning in classes for prospective teachers. Mark described actions and interactions in his classroom in terms of a 'trip' metaphor in which his role was conceptualized as the trip driver and students's role as the
In an interview, Mark described the way in which he used the metaphor of a trip to justify his approach in teaching and learning as follows:

Learning is like a trip, and the instructor is the driver. [The driver points out to a building] “And this is the capitol and it was built in 1856. .... Let's go over here, I want to show you this, the legislative building, two bodies.” .... The students are in the back saying “What is that building?” You go, “That's a neat building, do you want to go see it?” Or “That building is not very interesting. Do you really want to go there? Maybe we can come back to it if we have time” This is quickly thrown together metaphor for what I think the instructor should be doing. The first time I taught the Chemistry course [an early version of the Physical Science course] I thought I should empower the student. I thought “It's their course ..... I'll let them drive. I'll let them decide where we go.” Sound great in theory, but it did not work very well. Students are not used to being empowered. They don't know where to go or how to get there.

Data in the study revealed that the trip metaphor influenced the way in which Mark perceived his role in the classroom and the way in which he taught. It was obvious that his teaching behavior was related to the metaphor he used to conceptualize his role and the role of students in the classroom. The use of different instructional strategies to maximize students' participation and interest in learning activities suggest that this metaphor was used as a referent for actions and interactions in Mark's classroom.

Since a referent is a “set of beliefs that acts as a guide to the actions of an individual” (Tobin & Tippins, 1996, p. 716), Mark described how he used this metaphor as a referent for actions in his classes:

... the instructor sets the tone in the class, the instructor is the one that says 'now we are going to do this, now we are going to do that, enough of this, let's start this.' The instructor is driving. The students may say 'let's go here, let's go there, now let's go here, let's spend an hour at Disney world, and then pop down to Tampa.' But it is the instructor that is driving, and if I make a bad turn, if I go too fast in the car or in the classroom, ... Then I feel bad about it until I have
the opportunity to make it right.

Underlying the trip metaphor was a more constructivist epistemology in which every person, including the driver, was involved actively in the trip and associated activities. Another important referent used by Mark was enjoyment. He believed that learning chemistry should be enjoyable. The driver endeavors to create a high quality atmosphere in which travelers enjoy learning about things and places along the way in their trip. This was consistent with Mark's actions in classes for prospective teachers during Spring, 1996 and the last few years (Duffy, 1993; Brush, 1993), to create exciting environments of learning through the use of different demonstrations and learning activities.

Teaching practices in Mark's classes for the last few years (Duffy, 1993; Brush, 1993) indicate that Mark, as a constructivist instructor, developed this metaphor to be a referent for his teaching practices. It was obvious that as soon as Mark used constructivism as a referent for his teaching he considered alternative metaphors in relation to the theory. Furthermore, being involved in teaching science for prospective teachers for several years, in which active engagement of students was encouraged, helped Mark to consider alternative metaphors. Over this period of time Mark developed the trip metaphor to improve his style of teaching.

Mark commented on how his style of teaching has been influenced by being involved in teaching science for prospective teachers for several years as follows:

It has been a really good experience for me and the other faculty involved. And I think I have learned a lot from doing it ... I thought originally the goals of this course were to develop different teaching methods that could be eventually taken into all of our teaching. And that may be a sub-goal now, but I think the main goal which probably everybody else thought all along was to develop a special
classroom environment for a special group of teachers, where we would teach science in a way that they would teach science.

In a similar study, Ritchie (1994) described how a teacher used a metaphor of teacher as travel agent to transform her teaching to better agree with constructivism. This teacher used the metaphor as a referent for actions in her classroom. After a period of time the teacher taught in a more routine manner and was less reliant on using the metaphor to guide her teaching practices. Using the trip metaphor allowed Mark to focus on facilitating student learning through the use of instructional strategies to maximize the participation of all students in learning activities.

The Trip of Learning

The trip driver enjoys the trip when he feels that other participants in the trip do so. Mark, too, taught science with interest when he felt that students in the classroom became excited and engaged actively in learning activities. It was obvious that Mark became very excited about what was going on in the classroom especially when students were fully involved in the events. This situation was observed in many classes during the semester, such as the class on temperature, on covalent bonding, and on reduction and oxidation. Mark described his feeling when instructional strategies work effectively to maximize students' interest and participation as:

I put a lot of time and energy into it [the physical science course], especially when I am teaching my part. I take it personally and I take it hard when things don't work, and I feel great when things do work.

The main goal for Mark as a trip driver was that all participants in the trip enjoy learning and knowing new and exciting places and things along the way of the trip.
Participants were encouraged to participate actively in the trip program using their prior knowledge and experience to construct new knowledge through watching, listening, asking questions, arguing with others, and reading carefully the brochures and posters about their journey. Each participant has his or her own prior knowledge and ideas about places and things on the trip. The driver can use his experience to help participants construct new knowledge about things and places on the trip.

Within this metaphor, students are active agents on the trip of learning to achieve the goal of learning with understanding about topics and concepts in the course. Students use their prior knowledge built by home, TV, high school, and other organizations in the community to construct new knowledge about science concepts. Learning by construction implies a change in prior knowledge, where change can mean replacement, addition, or modification of extant knowledge (Cobern, 1993). Mark commented on the importance of students to conduct a fruitful trip of learning as follows:

The instructor is in charge, the instructor sets the tone of the class ..., but at the same time, the students are very important. So the students can say 'let's go here, I want to see this' but the instructor drives them. They say 'all right, let's go here and spend an hour.' [The instructor may reply] 'that's good idea, or don't go there, or stay very long or no, we are not going over there, we just don't have time, we can't stop there.' That is the instructor's job, but the instructor does his or her job best if he or she does it with the input of the class.

Since the main goal of Mark as an instructor was to maximize the participation for his students, using the metaphor of a trip as a referent for actions encouraged the class community to develop interaction in the classroom. The trip community created a shared language that permitted all participants to engage.

Co-participation implies that each of the participants shares a language and can
understand what is happening to the extent that there is freedom to participate and learn with understanding (Schon, 1985). The language is negotiated and is constantly evolving as learning occurs. Co-participation among participants in Mark's classes was stimulated through the use of different instructional strategies. Mark always was on the lookout for ways to stimulate active and varied ways to attain co-participation. Students learned chemical concepts with understanding because they feel that they have the power to talk, ask and answer questions, and express their ideas. The importance of creating a discourse that is shared among participants in science classes is emphasized by Tobin and Tippins (1996):

In a community in which coparticipation is occurring there are interactions among participants in which negotiation and consensus building are apparent and learners are empowered to participate and learn because of their ability to use a shared language. (p. 715)

**Mark's Roles in Science Classes**

Through the use of the trip metaphor as a referent for actions in the classroom, Mark could constrain his roles and students' roles in science teaching and learning. In terms of the instructor's actions, students could also construct metaphors for their roles as learners to constrain their actions and to mediate those of their instructor (Tobin & Tippins, 1996). Mark emphasized his role in the classroom as a driver for a trip:

I think my role in the classroom is first of all [to be] the driver. I'm the expert; the person who says what we are going to do and when we are going to do it. The instructor is the person who makes decisions on the fly about how things are going in the classroom. So that is my role as instructor.
Within the metaphor of a trip and to be consistent with his beliefs about teaching and learning, Mark considered himself as a driver for the trip in which the participants wanted to enjoy and learn. Mark viewed himself as no more than one of the other participants in the trip, but with more experience about the route. Since he was always driving in this way, he was an expert traveller with more knowledge about exciting things and places along the way of the trip. In each trip, the driver learns more about activities that maximize participants’ enjoyment and involvement, and the activities that do not work.

In science teaching and learning, Mark felt that some activities and demonstrations, such as dry ice, liquid nitrogen, a balloon activity and the gas-inflated balloons demonstration, are effective to be used in each semester but other activities are not. He expressed his frustration about how the use of the fluorescent detergent demonstration did not work in stimulating students in the classroom as follows:

I think [the fluorescent detergent demonstration] is just really neat, and I talk about how and why these fluorescent dyes are added to detergent, and how it is like a bluing agent. The dyes absorb UV light and emit high energy visible light which masks the yellow color in white clothes. I think it is so cool. I've done it three times ... and it hasn't worked yet. I mean it is a cool little demonstration, but it just doesn't work. I've got it in my notes that this doesn't work, but each year I still try it because I think it is so cool. I think it is one of the neatest simple things you can do in the classroom, but it doesn't work for the students. They basically understand it, but it doesn't get them excited. It doesn't get them thinking.

When the goal of a trip driver is to create environments in which participants enjoy their trip, such a driver needs to use other roles to maximize travellers' interest.
Such a driver can change his role from a driver to a tour guide, for example, based on contexts and situations in the trip. It was observed that Mark was able to change his actions in the classroom as the context of learning changes. The metaphor of a travel agent (Ritchie, 1994) or a trip driver encompasses managerial roles as well as aspects of constructivist learning theory (Ritchie, 1994). Ritchie (1994) notes that the travel agent metaphor:

eliminates the need for several metaphors, from which to select or ‘switch’ to, depending on the role requirement. The travel agent [as well as the trip driver] instructor encourages students to explore new routes as well as visiting well known destinations by establishing a supportive environment based on mutual respect and trust. The link between the teacher as a travel agent and constructivism helps validate the use of the metaphor in this context. (p. 296)

Shifting from one role to another within the trip metaphor as a referent for actions was observed in Mark’s classes. In the trip of learning, Mark was able to switch his role from a driver to a tour guide or to an entertainer to create learning environments in which students learn science with interest. Change of instructor’s roles in the classroom was predicted by Glasersfeld (1988) when he noted that the teacher’s role “will no longer be to dispense ‘truth’ but rather to help and guide the student in the conceptual organization of certain areas of experience.” Mark’s actions shifted according to the role he used as a referent for a specific action in a particular situation to facilitate learning.

For instance, in the class to discuss a question in the last quiz about ‘why isopropyl alcohol is very soluble in water, but it is also an effective degreaser?’, Mark used several roles within the “trip” metaphor to help students learn science concepts with understanding. The following text of discussion in the class showed how Mark
shifted from one role to another to stimulate student-instructor and student-student
interactions to learn about dying and bleaching concepts:

Mark: One more time with the quiz, and let's go back to talk about
the electrolyte activity. The question about this molecule (Mark pointed to
the structure of isopropanol molecule on the board and continued
discussing the answer) ........ So isopropanol doesn't really act like a soap.
And you know that. When you use isopropanol, it doesn't suds up and it
doesn't make a foam. But it is a good greaser and people often use it as a,
as a, a ...

Student 1: A stringent.

Mark: A stringent. Thank you. Isopropanol is the cheapest stringent that you can
use. It's soluble in water because rubbing alcohol is a mixture of
isopropanol and water. ... (Mark continued using the chalkboard to draw a
structure clarifying the relationship between isopropanol, water, and
degreaser). There was an implication that the grease would go to the
carbon, and that's not really right, the grease goes to the non-polar part
of the molecule. It is this whole part right here that's non-polar. Does
that make sense? The combination and application of the ...

Student 2: What part is the non-polar part?

Mark: The part that is non-polar. The part that has carbon-hydrogen bonds. ...
(Mark went back to the board to clarify which part is polar and which one
is non-polar in the structure of the molecule).

Student 3: So doesn't a carbon have something in the middle. ... I mean, ... Because
there they're only ones that can ...

Mark: Maybe only one that, ... if the grease went into the water, it
moved here to break up the strong water-water interactions.
Therefore there's no grease because the interaction between
the hydrocarbon and the water is very weak, compared to the
interaction between the water and water. Imagine you had two
people that ever played red rover, red rover, please send someone over,
and you line up and hold hands. What's the rule to that game?

Students: You have to try to break the barriers.

Mark: If you break through you're free. If you don't break through,
you're captured. When you call someone over to play, do you pick the big kid or the small kid?

Student 4: The small kid.

Mark: You pick the small kid because the small kid doesn't have the energy to break that interaction. But water molecules have a very tight hold on each other. The only thing that's going to break it up is something which has a strong interaction with water like a polar molecule like this OH group, like an ion, that's something that's going to break up water. ...

Student 5: So if the outer edges were blocked because they were a larger molecule ... they have to bond with O and H?

Mark: Yah, that's right. This part is a hydrogen bond ...

Student 5: How do you know that grease is attracted to the hydrocarbon?

Mark: The question is how do you know that grease is attracted to this part of the molecule. I would think that it's common knowledge. Give me an example. I mean, can you think about something you do know that you've done that involves grease being attracted to molecules like that?

Student 6: The thing when we make soap?

Mark: Yah, the soap, you don't know which end is doing it. So let's pick something which is just a hydrocarbon

Student 7: Is it because they're both non-polar?

Mark: Okay, that why it happens, but it doesn't answer the question "how do I know that works?"

Student 1: How about water, I mean you put grease in water, you know like if your boiling, getting ready to do spaghetti noodles ...

Mark: The grease floats on the top. So you know the grease doesn't go underwater. That tells you it doesn't interact with water, grease interacts with hydrocarbon. Let's think about this example: You ever had grease on your hands working on a car or something like that and what do use to clean them off, ever used kerosene?

Student 8: My dad used to do it.

Mark: You're painting with an oil based paint. What do you clean the
Student 4: Mineral spirits.

Mark: Mineral spirits. Mineral spirits is hydrocarbon. It’s like gasoline. Let’s use the mascara example, when you are trying to take waterproof mascara off, which is greasy, that’s why it is not soluble in water, it’s a grease, water doesn’t do a very good job. Somebody mentioned vaseline, which is kind of hard to get out. When I was a kid, when I was like in high school, they had a 50’s party. Everybody used to slick their hair back, I didn’t have anything to do that. So I used vaseline. (Students were laughing). Do you know how long it takes to wash vaseline out of your hair? If you wash your hair three times a day, it takes exactly twenty days to get the vaseline out of your hair. (More laughing in the class). For a party in college, I wanted to go as a beach bum, so I dyed my hair blond or tried to. I bought the lightest and blond dye you could buy, put it in my hair. It didn’t lighten it at all, my whole thought was I had my hair for the party. So I rooted around the medicine cabinet and got hydrogen peroxide. I dipped my hair in it very carefully, didn’t touch it. (Students became excited). What I am going to do, I am a chemistry major in graduate school. I notice all these problems, I take the towel, I soak the towel in hydrogen peroxide wrap my hair with it and took a nap. Wake up two hours later, my hair turned orange. Flaming Richy Cunningham orange, (Students were so excited) which kept getting lighter and lighter over the next month because the reaction kept going on.

Student 6: Did you shave your head? (Students laugh)

Mark: What I did was, I went to this party, and heard from at least five different people “I had a cousin who did that once and all his hair fell out.” or “all her hair fell out.” That’s when I understood what it takes to make hydrogen peroxide a good oxidizing agent. Every bit of what we’re talking about now you’re going to understand in terms of the simple chemistry in this class, acid-base chemistry ... reaction. What I did was I ended up at the time being a red head for a couple of weeks. What I did was, I dyed my hair black because when I bought the blond dye, I bought the black dye also, I dye my hair blond going to the party, I dye my hair black on the way back from the party, so a couple of months later, when the dye started to wear off, I started having black roots with black and orange hair. That’s back before people did that on purpose, then I got a really short haircut. So these are the reasons why I am telling you the things I did, I am trying to think of things you might have done, use the makeup, clean the grease off your hands, because I think you can make sense of things you had experienced, ...
Student 9: Okay, let's say I wanted to dye my hair blond, and I applied everything, and I came out with green hair, "what went wrong?"

Student 10: My friend did it, she had blond hair, and she wanted to dye her hair black and it turned green.

Student 9: Your supposed to do it strand by strand

Mark: Let me tell you what I learned about this ....

Student 3: What if you sprayed lemon juice in your hair, what color would it turn? (Students were giving their answers all at once)

Mark: Every point I'm trying to get across, every bit of this, you can understand in terms of chemistry, that we're talking about.

Student 10: Why if you have blonde hair and a light color hair, and you swim like in the summer and you have chlorine, why does your hair turn green?

Mark: This is so cool. Let's talk about this. You'll get a short answer and then with a promise we'll come back to this. When a person dyes their hair blond, what do we call that process? What do they do to their hair?

Students: Bleaching.

Mark: Bleaching. Dying is something different from bleaching. When you dye something you put a different color over it. When you bleach something you take the color out. When you want to bleach your clothing to take out stains, to take out color, or when you accidentally, or in my case when you are washing the colored clothes and you forget, then you don't put the chlorox in those. (Students laugh) What are you doing to them? You're also bleaching, right? What do you add to clothes to bleach?

Students: Bleach

Mark: You add bleach, you add chlorox. What do you add to a pool to kill the microbes?

Students: Chlorine

Mark: Chlorine. Same thing, the chlorine that you add to the pool is chemically the same thing as the chlorox that you add to your clothes. They are both oxidizing agents, oxidizing agents are molecules that rip electrons out of things. ... When you
combine an oxidizing agent with an acid it becomes a better oxidizing agent and you bleach your hair better.

Student 5: My mom used to tell me when I was little, I had a lot longer hair, she used to say that if you wet your hair down with a hose before you put something ...

Student 9: I think if you cut it up into ...

Mark: I think you're making up this green stuff. (Students argue that it is possible that your hair can turn green). Who here would be willing to do that? I would like to see this.

Student 10: I have pictures of when I was little, I can bring to you, with green hair.

Mark: And you didn’t dye it green because of a party.

Student 11: If you swim everyday and you don’t rinse your hair, you don’t rinse the chlorine out of your hair (students give their explanation all at the same time)

Student 9: It's not green like her jacket (pointing to a student's jacket)

Student 12: It's like a green tint.

Student 13: My sister was platinum blonde and she was a swimmer, she swims every single day of the week, her hair turned green.

Student 3: I used to be a lifeguard, and little kids use to come to the pool and their hair used to be that color, I mean their hair was green.

Mark: I could deal with it, I will find out why hair turns green, chemically, not just not because of this stuff, I will find out chemically why hair turns green if you guys work as hard as you can to apply the level of enthusiasm and interest that you applied to this conversation (students are laughing) then on Monday we'll do makeovers (students still laughing). Aren't you impressed with what I know about makeovers, there's a term I don't get to use in my speech everyday, let's take advantage of the 20 minutes we have left, ...

This excerpt revealed that Mark used several roles in teaching about dying and bleaching. Mark was a guide or a facilitator when he helped students to understand the
difference between the concepts of dying and bleaching. For example, Mark used the ‘red rover, red rover, please send someone over’ game to help students understand the difference between water-water and water-grease interactions. It was clear that students were guided in this discourse to relate what they learned to their previous knowledge and to their daily experiences with chemicals, such as soap, vaseline, and waterproof mascara. To facilitate the learning of science it is essential that the instructor “infuses scientific discourse activities and provides a scaffold into the languages of the child and of science” (Tobin, in press-1).

Mark was as an entertainer when he told students about what happened to his hair as a result of dying and bleaching when he was a high school and a college student. Mark as a learner was clear when he told them “I will find out why hair turns green, chemically.” In addition, he paid attention to students’ ideas and used simple language to share discussion in the class. Furthermore, he was a controller when he initiated the discussion by saying “one more time with the quiz, and we’ll go back to talk about electrolyte activity” and ended it with “let’s take advantage of the 20 minutes we have left ...”

Mark’s actions to shift from one role to another stimulated students to engage actively in the learning process. They were excited to hear Mark’s hair story which encouraged them to participate in the discussion and talk about their experiences regarding dying and bleaching. Students were encouraged to use their language to involve and participate in discussing, arguing, and asking questions. Such involvement encouraged students to think how to relate what they had learned to their daily life experiences.

A student, for example, talked about how her father used kerosene to clean grease
on his hands after working on his car. Another student talked about how her sister's hair became green as a result of daily swimming in a pool. In the following sections, I endeavor to learn more about the roles that Mark, as a driver of the trip, could use in the classroom to help students enjoy science in their journey of learning chemistry.

**Mark As a Tour Guide**

Mark as the trip driver might act as a tour guide for participants to explore new routes, visit well-known destinations, or make appropriate stops or detours along the way. Usually, the trip driver has already visited the places of interest located along the way. Accordingly, he knows what the participants have to see and learn about during the trip.

Within the metaphor of a trip driver, Mark who has a broad knowledge base can act as a facilitator of learning through suggesting fundamental, as well as interesting steps in a science concept or topic (Ritchie, 1994). Gallagher (1993) emphasized the importance of instructors' facilitating or guiding the learning process in the classroom as:

> Both research and experience show that students are not very effective at either of these activities when left to do them individually, outside of class. Unguided, individual sense-making typically results in poor understanding and inability to apply knowledge. It is a source of many misconceptions that students develop. Also, it is a source of frustration to students because they are not able to understand and use scientific knowledge effectively. (p. 184)

Mark used his role as a guide to encourage students to explore new routes as well as visiting well-known destinations in their trip of learning.

It seemed that Mark's main goal as an instructor was to maximize the participation for his students and to enhance their learning with understanding. He
always was on the lookout for ways to stimulate active and varied ways of participation for all participants in the trip (Brush, 1993). Mark commented on his role as a facilitator to enhance students’ learning with understanding as follows:

My role is to facilitate that process. I have to find some reason that a student finds this material interesting or relevant and takes it that way. I can’t transfer my interest or my sense of relevance to other students. They have to construct that for themselves.

Mark’s role as a facilitator was clear in providing students with materials, such as balloons, nails, pennies, dry ice, liquid nitrogen, etc., and resources such as, handouts and worksheets, that are necessary to conduct activities and tasks for a specific topic. Throughout learning activities, Mark moved around, stimulating students to engage in such activities and helping them whenever someone needed help.

In Mark’s classes, students believed that a science instructor had to be the guide who could facilitate their learning in the classroom. Muna, for example, constructed the idea that science instructors are those:

... who also guide you along the way. They help you think for yourself. And they make sure that you are doing it right, and standing at your side. So they are the fountain plus the guide.

Students spent much of the class time working in groups to conduct activities, solve problems, and talk with peers about their ideas. Mark, as a facilitator, moved around facilitating interaction among students in each group and helping them whenever someone needed help. Mark aimed through using group activities to create co-operative learning environments that were likely to enhance the students’ learning of science. Tobin (1993 a) emphasized that “students should be given direct, hands-on experiences
to facilitate learning of science, and students ought to be able to discuss their experiences with peers in order to be a facilitator of learning” (p. 246).

Using the role of facilitator, each student was actively involved in the learning process by engaging in tasks and interacting with Mark and with other students. The student felt that Mark’s actions to facilitate her learning process helped her to learn with more understanding. Muna, one of the target students in the study, expressed her feeling about chemistry teaching and learning in Mark’s classes as follows:

I like Mark. I think he teaches well because he explains what you are doing, and he repeats it so you make sure you understand. And I think that what is important is to bring things in that you can see and make you understand better. Like when we went outside [to conduct the demonstration about the concept of an ‘atom’] and we did that whole thing where we had the balloons [the gas-inflated balloons activity] and you are showed the reactions and stuff like that. And when you go slow to make sure every one understands, because that is a lot of information.

Students, such as Muna, seem to like Mark because they think he is funny and explains the complex concepts in simple terms. Students appreciate their instructor when they feel they can access the language he uses in the classroom.

Through Mark’s facilitating the learning process, each student tried to use her prior experience and knowledge to construct meanings in new activities and situations. The driver of a trip, can expect participants to have their own experience and knowledge about the trip that has been constructed as a result reading, watching TV, or visiting certain locations on previous trips. The instructor, too, often find that students have their own prior experience and knowledge about science concepts. As a facilitator of learning, it was obvious that Mark endeavored to take account of what the students know, maximize social interactions between them such that they can negotiate meaning, and provide a variety of sensory experiences from which learning was built (Tobin &
Mark as a Learner

As a driver, Mark was one of the participants in the trip with more knowledge and experience about the trip route. In each trip, he learns more as a result of interactions with the participants of a particular trip. A science instructor, as a learner, is the person who already knows more about particular content (Tobin & Tippins, 1993) than the other participants in the classroom. Tobin and Tippins (1993) suggest that a science teacher, as a learner, can enhance learning by providing students with a scaffold to build knowledge in directions that would not be possible without the presence of the teacher.

The problem in many classes for prospective teachers is that the instructor and students are placed in different discourse communities with a wide gap between them (Griffiths, 1996; Lemke, 1990; Tobin & Roth, 1995). According to Tobin and Roth (1995), "It is hard to imagine two more disparate communities than the communities of science faculty and prospective elementary teachers."

The language used by the instructor creates a barrier that prevents members of the students' community from crossing the border into the instructor's world of science (Griffiths, 1996). Accordingly, most students tend to learn science probably without understanding, by memorizing facts, equations, definitions, and so on. Tobin and Roth (1995) emphasized that in order to bridge this gap and facilitate the students' learning of science "it is necessary for the teachers to employ a form of discourse that allows students to use their discursive resources in the process of building understandings of physics."

In the classroom, Mark believed that he was no more than an expert learner on
the trip of learning. Although Mark belongs to the community of science faculty, his
text and actions in the classroom gave students the impression that he was close to
each learner's community. As a driver on a journey of learning, Mark endeavored to
have students feel that he was the one who wanted to learn more, as well as the other
participants in the classroom. Students felt that they could learn with understanding
through talking, arguing, asking questions, and expressing their misunderstandings. A
student in the class, Muna, commented on Mark's style of teaching as:

I like [Mark] a lot more. ... He is just more down to earth. He is funny; he
explains it a little more in common terms.

Mark was an enthusiastic learner who took an interest in the students and their
learning. Use of the trip metaphor helped him to build a congenial classroom atmosphere
where students feel secure to speak before their peers. Mark was an approachable
teacher who did not intimidate. He should be commended for reaching out to the students
in a friendly, non-threatening manner. Students, such as Muna, did take an interest in
chemistry because they liked Mark. They appreciated the way he used to speak in the
classroom, by using simple terms and everyday examples that they could understand.

Mark's language in the classroom included many terms that were familiar to
students, such as 'that's cool' and 'oh, boy.' He always encouraged students to keep going
in making comments or asking questions through responding 'that's a good question,'
'that's really a great point,' or 'you've helped make my picture better.' He did not
hesitate to answer a student's question with 'I don't know, does somebody know?' or 'I
am not sure, but ...' to give students an impression that he was also a learner as well as
the other students in the class. The materials like balloons, nails, coins, water, and soap
that he used to conduct activities or demonstrations in the class were mostly familiar to students.

It appeared that Mark used such actions to increase students' involvement in the learning process. He commented on such actions as:

I think any time that we get people circulating among the students, getting them to talk, that is good thing. And my experience as the classroom instructor is that I always learn more than the students do. So getting involved and doing stuff with students is good.

Mark as an Entertainer

In the trip of chemistry teaching and learning, one of Mark's goals as a driver was to create a pleasant environment in which students participate in learning with interest. An instructor can create a pleasant environment by "fostering politeness, cooperation, mutual respect, shared responsibility, and humor" (Berliner, 1990, p. 89).

The teacher's role as an entertainer, described by Tobin (1990a) and Tobin and LaMaster (1995), is used by teachers to manage students in the classroom. Unlike this purpose, Mark used the role of entertainer to stimulate students to enjoy their trip of learning. The purpose of using different teaching strategies in Mark's classes was to create an exciting atmosphere for students to love science learning.

Many of Mark's actions in the classroom suggest that he used the entertainer role occasionally to create learning environments in which students enjoy science learning. For example Mark used the entertainer role in the class of radiation and radioactivity. He used a radiation detector to measure radioactivity in different materials he brought to the class. When he used the detector to measure radiation of his body, rings of the
instrument increased dramatically indicating that Mark's body had a high radioactivity. Students were excited about that and became more excited when Mark took out a package of hydroxides and nitrates of thorium from his pocket which caused the detector to ring loudly. Students learned that this substance which miners use to put in their lanterns is extremely radioactive.

In another class, while students were working on the dry ice and liquid nitrogen activity, Mark threw a racquetball, which previously had been immersed in liquid nitrogen against the wall. The ball shattered into many pieces, producing a loud explosion. Students became so excited and some of them searched the floor of the room looking for pieces of the ball. The gas-inflated balloons activity, which was conducted to help students learn about energy and chemical reactions, was another example in which Mark used the entertainer role as a referent for his actions. The students reacted excitedly to the loud and flaming explosion of balloons. Such action stimulated them to talk with each other and with Mark, to understand what happened to the exploding balloons.

Mark as entertainer sometimes socialized with students, such as talking about his wife in the clinic and the baby they were to have. In another class, students became excited when Mark told them about what happened to his hair as a result of dying and bleaching when he was a graduate student (the dialogue between Mark and students in this chapter). This action stimulated students to engage actively in discussing this issue and expressing their ideas and experience about it. One of Mark's goals, which was consistent with his beliefs, was to create an environment in which students learn science with interest.

Mark promoted an active engagement of his students 'or travelers in the trip' to
learn chemical concepts meaningfully in the classroom. It is clear that the students had
the autonomy to talk, ask and answer questions, and argue (Tobin, in press-1). In his
teaching, Mark very competently stimulated students' thinking and provided them with
opportunities to interact through asking questions, discussing, explaining, clarifying,
elaborating, arguing, evaluating, reconstructing, collaborating, and attempting to reach
consensus on what was learned in the classroom.

Mark as a Tour Controller

Most of the teacher metaphors, such as policeman, entertainer, and social
director, described in the previous studies (e.g., Berliner, 1990; Tobin, 1990a; Tobin
& Tippins, 1996; Tobin, Tippins, & Hook, 1994) focus on the teacher’s managerial
roles. Unlike these metaphors, the science teacher as a travel agent (Ritchie, 1994) or
a trip driver encompasses managerial roles as well as aspects of constructivist learning
theory (Ritchie, 1994).

Teaching and learning practices in Mark's classes can be described in terms of
the metaphor as a trip driver. Even though practices that seemed to be traditional in his
classes, such as controlling what is to be learned in the classroom according to the
syllabus of the course and the pace students would cover content, can also be described in
terms of this metaphor. The trip driver takes care of the trip schedule and endeavors to
conduct it on time, but being sure that all participants are enjoying their trip. The
instructor, too, can regulate and sequence activities in the classroom and allocate the
time students have to conduct tasks for particular topics.

The instructor as a controller to sequence events and activities was clear in most
of Mark's classes. Each class seemed to have its schedule for events. Mark announced at
the beginning of each class how much time they would spend in each task and activity in
that class. Some examples of Mark's announcements to control events in the classroom included "we got five minutes to do that" or “we are going to spend 15 minutes in this activity."

In the class of chromatography, for example, Mark spent 5 -10 minutes discussing tasks and homework for the next class, and 15 - 20 minutes lecturing about chromatography, 10 minutes demonstrating how a line of black ink in a piece of paper over a period of time being dipped in water was separated into other colors. Then he asked students to work for about 20 minutes with Chris (the teaching assistant) to conduct the chromatography activity. After the break, Mark spent around 10 minutes discussing the periodic table and chemical theory. Then he asked students to work in groups in an activity on conservation of mass until the end of class.

Mark's role as controller of the trip schedule was associated with beliefs that were compatible with constructivism. Within the trip metaphor, it was clear that Mark used this role to support learning in the class. However, Mark probably used this metaphor to adapt his practices to classroom and institutional constraints (Brickhouse & Bodner, 1992) which enforce traditional practices of instruction and evaluation in college science classes. According to Tobin and Tippins (1996), “the metaphors used by an individual to make sense of a particular teaching role have meanings that are saturated with the semantic networks associated with the culture in which the instructor lives.”

Conclusion

Using a constructivist epistemology as a referent to develop science teaching and
learning in college level classes is receiving increased consideration. This epistemology calls for a reconceptualization of what a science instructor is and what he or she does in the classroom (Herron, 1996). This epistemology can be used as an alternative referent to allow instructors to frame problems in different ways and ultimately to obtain different alternative solutions (Tobin & LaMaster, 1995). Using constructivism rather than objectivism as a referent for teaching helps a science instructor to think of appropriate ways to conceptualize his or her roles in the classroom. Metaphor is a way that the instructor can use to conceptualize his or her roles in re-presenting knowledge of teaching and learning. The term 'instructor's role' refers to how an instructor considers his or her position when he or she is teaching a particular concept in a particular context.

A science instructor in college classes can construct his/her own metaphors to describe aspects of teaching and learning. Using metaphors helps instructors to think about their roles and students' roles while teaching science. Tobin and Tippins (1996) reported three significant aspects of metaphors in terms of potential applications to science teacher education. First, metaphors can be used as a way to describe teaching. Second, metaphors can be used as a referent to constrain instructor and student actions in the classroom. Third, metaphors can be used as a generative tool to build new knowledge. Using metaphors as referents to understand teaching and learning has the potential to change what happens in classrooms (Tobin & Tippins, 1996).

Mark used constructivism as an alternative referent to describe science teaching and learning in his classes. Accordingly, he developed a new metaphor that was consistent with his beliefs to provide a rationale for teaching science in a different way. He described his teaching role in terms of the instructor as a trip driver who helps and
encourages travelers to enjoy knowing things and places on their trip. This metaphor is used as a referent for actions in Mark’s classes to create a student-centered approach to teaching and learning in the classroom.

Mark’s main goal as an instructor was to maximize the participation of his students, and he always was on the lookout for ways to establish exciting environments in which all participants enjoy the trip of learning. To be consistent with his beliefs and goals that students should enjoy their journey of learning chemistry, Mark used the metaphors of learner, controller, facilitator, and entertainer as referents to create exciting environments. He was able to switch his actions based on which of the constituent metaphors he used as a referent to frame his actions and interactions, and thereby, to create an exciting environment for learning.
CHAPTER 6
LEARNING ENVIRONMENTS IN CHEMISTRY CLASSES FOR ELEMENTARY PROSPECTIVE TEACHERS

Introduction

Background

The methods students use to learn science are related to the environments in which learning takes place. An individual's learning environment structures and constrains the construction of new knowledge (Bowen, 1993). Knowledge is always the result of constructive activity by an individual while he or she participates in a sociocultural environment. In many classes for prospective teachers, environments for learning are generally conceptualized in terms of a transmission-receiver model (Tobin, in press-1), in which instructors transmit facts and students receive them, or a workplace model (Marshall, 1990a), in which student/workers are supervised by instructor/managers.

Many science instructors, who are the creators or modifiers of learning environments (Bowen, 1993), use these models as a referent to modify learning environments in their classrooms. Lecturing or keeping students on-task is a key method of teaching and learning (Gallagher, 1993; Roth & Tobin, 1996) in such environments. When an instructor thinks about the classroom in terms of either a workplace or a transmission metaphors, he or she prefers to set up a teacher-centered,
work-oriented environment rather than a student-centered, learning-oriented environment.

When prospective teachers learn science in environments in which relatively little emphasis is placed on understanding knowledge and how to relate it to their daily lives, many of them tend to learn science through memorization (Edmondson & Novak, 1993). Furthermore, they are expected to create similar environments when they teach science in their own classes. This situation is inconsistent with the visions described in more than 400 national reports (Hurd, 1994) which demand reform for science education through improving the environments of science teaching and learning at the university level particularly in classes for prospective teachers.

Through using alternative metaphors to think about teaching and learning, a science instructor may realize the positive effects that can occur when students' interests are addressed in enacting a curriculum. The goal of such an instructor is to create an environment that is rich in interesting activities and topics which motivate students to attend and participate in the learning process. Fraser (1987) pointed out that outstanding science teachers include in their curriculum the same complex material as other science teachers, but they make it seem easier to learn by creating environments conducive to learning.

A conducive learning environment is a construction about the extent to which a given social setting constrains learning in the classroom (McRobbie & Tobin, 1997). It consists of "learners' beliefs about their roles as learners, beliefs about the roles of others in facilitating and inhibiting, and beliefs about the extent to which the social and physical milieu constrain learning" (McRobbie & Tobin, 1997, p. 194). Such an environment may be established by modifying "the context within which the subject
matter is taught so that it connects with what students know and is perceived to be relevant, yet in a manner that relates to the curriculum” (Collette & Chiappetta, 1994, p. 76).

The central purpose of this chapter is to understand how Mark’s roles within the ‘trip’ metaphor mediated the construction and maintenance of learning environments enriched with interesting activities, which motivated students to participate in meaningful learning. At the beginning, it is important to understand the practices of instructors and students involved with the construction of learning environments in science classes.

**Learning Environments**

In classes for prospective teachers whether students learn science in lectures or other activities, learning involves people participating in complex environments (Bowen, 1993), in which curriculum, students, teacher(s), the physical environment, and the emotional climate interact to construct sites for learning (Talton & Simpson, 1987). Science teaching and learning in these classes is part of a rich social milieu comprised of diverse interacting physical and social situations (Bowen, 1993).

To understand and describe learning environments, such an interaction has to be understood. Grundy (1987) commented on these interactions as:

> Educational practices, and the curriculum is one set of these, do not exist apart from beliefs about people and the way in which they do and ought to interact in the world. If we search the surface of educational practice, and that implies organizational as well as teaching and learning practices, we find, not universal laws, but beliefs and values. (p. 7)

The practices of teachers and students involved with the construction of learning environments can be described in term of Habermas' (1972) theory of human cognitive
Habermas (1972) identifies three basic cognitive interests: technical, practical, and emancipatory. These interests influence individual's endeavors to make sense of their world. Grundy (1987) adapted Habermas' (1972) theory of human cognitive interests to analyze the curricular conceptions of teachers who were engaged in pedagogical reform. Instructors "conceive of curriculum according to the nature of their dominant cognitive interests, and that each interest gives rise to a distinctive type of pedagogical rationality" (Taylor & Campbell-Williams, 1993, p. 6). Although the goal of these interests is to seek pleasure that is grounded in rationality, the manner in which each interest acts as a referent for individual's actions is different from one interest to another (Bowen, 1993).

The technical interest, which is associated with objectivism, underpins the actions of many instructors. This interest is rooted in the self-interest goal of survival and reproduction, and is manifested in a desire to control and exploit the environment (Taylor & Campbell-Williams, 1993). Grundy (1987) uses the concept of hegemony to describe the ideology that the technical interest constitutes. Hegemony refers to the dominance or imposition of the ideology of a powerful group in a culture, and its unquestioned acceptance by less powerful members. Instructors operating with a technical interest have a basic orientation toward controlling or managing learning environments.

The technically-informed curriculum is designed to be implemented in learning environments in which students' behaviors and learning are strongly controlled by the instructor (Grundy, 1987). In such an environment, students have little power to determine their own learning objectives and, together with the instructor, are caught up
in a seemingly inexorable process of attaining predetermined learning outcomes of a product-oriented curriculum. Within technical interests, knowledge is regarded as a commodity that can be delivered from an individual to others.

Contrasted with the technical interest is the practical interest that is concerned with understanding. The practical interest, which is rooted in social constructivism, arises out of a need to live in an environment as a constitutive part rather than in competition with and/or control of it (Grundy, 1987). A curriculum informed by practical interests is concerned with human interactions in which the instructor and students are regarded as subjects engaged in sense-making activities (Taylor & Campbell-Williams, 1993). However, the attainment of practical curricular interests constitutes a limited pedagogical reform goal which is likely to be frustrated by the predominance of teachers' extant technical curriculum interests (Taylor & Campbell-Williams, 1993).

Instructors guided by practical interests have a basic orientation to understand the environment and interact with it. Within the pursuit of practical interests, the instructor is "interested in developing the judgment-making skills of his/her students, as part of an overall goal of personal development and improvement" (Taylor & Campbell-Williams, 1993, p. 12). Knowledge is socially constructed through negotiation and consensus making by the participants.

Habermas' (1972) theory of human interests addresses the need to liberate humanity from the dis-empowering influence of technical cognitive interests through using the emancipatory interest as a referent for actions. Emancipatory interests reflect individuals' needs for autonomy and independence from all that is outside of them (Roth, 1995). Within this interest, knowledge is not just socially constructed, but also
requires the development of a critical consciousness that aids participants in understanding extra-cultural aspects that coerce their construction of knowledge (Grundy, 1987; Bowen, 1993). Habermas' recent notion of communicative action (Habermas, 1984) aimed to provide an environment for the emancipatory interest to flourish. According to Taylor and Campbell-Williams (1993), communicative action is:

a form of social reasoning that embodies a moral concern for the right of the individual to remain free from coercive and distorting influences while participating with others in a discourse that aims to attain genuine consensus. The attainment of communicative rationality requires the establishment of a social environment that is shaped by the moral principles of truth, justice, and freedom, ... In a social environment in which communicative action flourishes, the emphasis is on the inclusiveness of participants in the building of mutual trust and respect, self-disclosure of joys and frustrations, attentive and critical listening, truth-telling and the examination of warrants for truth claims, and negotiation aimed at generating genuine agreement. (p. 15)

In science classes framed by emancipatory interests, participants are empowered to engage in autonomous actions. Use of constructivism as a referent for actions in the classroom facilitates the emancipation of both teacher and students from the disempowering influence of the hegemony of technical-rationalist ideology. Within a learning environment informed by an emancipatory interest teachers and students share the locus of control of their inter-subjective knowledge, and struggle collaboratively to make sense of both the perceived world and the ideology that constrains their perceptions and actions (Taylor & Campbell-Williams, 1993, p. 13). In curricula bearing emancipatory interests, as Bowen (1993) noted, "the plan is constructed within the culture and has the goal of empowerment with an emphasis on free speech and equality of participation. ... The learning group (both student-teacher and teacher-student) is responsible for the formulation and implementation of the curricular plan
aimed toward empowerment in the emancipatory curriculum" (p. 226).

Both the practical and emancipatory interests, as noted by Taylor (1993), have a pedagogical orientation toward the cognitive state of the individual learner (whether teacher or student). They are concerned with enabling the learner to make sense of his or her learning experiences, in addition to, promoting his or her autonomy and responsibility.

Science instructors adapt their teaching practices in order to have learning environments whose characteristics reflect the instructor's cognitive interests. They use these interests as referents to conceptualize not only their roles, but also the roles of their students in the classroom. The main goal of instructors guided by technical interests is to create work-oriented environments for learning while the main goal of those guided by practical and emancipatory interests is to create learning-oriented environments.

**Work and Learning-Oriented Environments**

What happens in the classroom not only depends on how instructors conceptualize their roles, but also on how students perceive and conceptualize their learning and the roles of their teacher. Science instructors guided by technical interests use the role of managers to establish work settings (Marshall, 1990a) or teacher-centered learning environments in their classroom. In work-oriented classrooms, a science instructor tends to view his/her role as an effective manager while students need to do tasks properly and well in order to obtain high grades.

Although learning in work settings may occur, it is usually an unintended consequence of such settings. Students view themselves as workers who are rewarded for their academic products or performance regardless of whether what is produced is or is
not learned meaningfully. They are reacting to or motivated by external forces, such as reinforcement, to perform or produce products. Students can perform or produce products without actually learning. Many instructors in work settings view meaningful learning as secondary to maintaining the work system (Marshall, 1990a); and they imply that learning will occur automatically sometime in the future (Tobin & Roth, 1995).

Contrasted with the work-oriented settings are learning-oriented environments (Marshall, 1990a). Science instructors guided by practical or emancipatory interests use roles different from that of manager to establish learning settings or student centered environments. The major goal of learning oriented settings is “construction of knowledge or skills that are of benefit to the learner in terms of self-development or increased quality of life” (Marshall, 1990a, p. 98).

According to a social constructivist perspective, the instructor’s role is to mediate learning which includes diagnosing students’ misconceptions and current levels of thinking, creating conceptual conflict, and presenting content so as to guide students toward greater conceptual consistency (Vosniadou & Brewer, 1987). Instructors, as noted by Marshall (1990a), need to:

- assess areas or zones where students are ready to learn based on such factors as prior knowledge and interest or benefits to the individual. Learning tasks are analyzed in relation to the [student’s] current level of development as well as in terms of cognitive processes involved, so that teachers can use appropriate instructional techniques to support learning. (p. 97)

In a science classroom, learning and thinking are situated in social contexts “within which academic tasks are presented and within which cognitions are constructed” (Marshall, 1990a, p. 97). The instructor and students construct social
context in the classroom through their actions and interactions. According to Lorsbach (1995), learning environment is a construction of the individuals in a given social setting, which is "an individual's socially mediated beliefs about the opportunities [he or she] has to learn and the extent to which the social and physical milieu constrains learning" (Lorsbach, 1995, p. 3).

Conveying messages about what counts as learning, such as whether the product or the process is important, depends on the social context constructed in the classroom. In classrooms where the learning process is emphasized more than the product, students participate actively in the process of science learning and constructing knowledge in their social contexts rather than reacting to external rewards (Marshall, 1990a). Constructing knowledge on their own or in collaborative learning context fills students with pride, affecting their attitudes toward the subject and toward further learning (Roth, 1994). Brown, Collins, and Duguid (1989) suggested that for meaningful learning to occur, instructors need to provide "authentic activities" in the classroom in which students can participate in collaborative learning. Such a strategy links classroom tasks to the real world rather than assigning decontextual tasks.

Although individuals can learn without the aid of others, Marshall (1990a, p. 98) pointed out that when students work in groups, the cognitive functions and multiple roles required to carry out cognitive tasks can be displayed by different individuals and models for others to learn. Also, group members may be able to elicit and confront misconceptions and ineffective strategies that an individual teacher is unable to accomplish in a whole class setting. Furthermore, collaborative groups create group norms where effort and intention to learn are values, thereby enhancing learners' motivation to learn.
Learning environments in Mark's classes appeared to be shaped by practical and emancipatory interests. Most of Mark's actions in the classroom were consistent with his goal to facilitate the building of learning environments in which collaborative social interaction among participants can occur. Earlier research (Brush, 1993; Duffy, 1993) indicated that Mark used various instructional strategies and always was on the lookout for ways to stimulate active and varied ways of participation for his students.

Environments and Learning in Mark's Classes

Mark used the 'trip' metaphor to be consistent with his beliefs about teaching and learning and with his goal to create an active science classroom in which prospective teachers enjoy learning. It was obvious that Mark used this metaphor as a referent to consider the learning environments and opportunities to learn by providing materials, initiating verbal interactions, and adapting roles that encouraged students to engage actively in learning process (Tobin, in press-2). Within the trip metaphor, Mark could adapt his roles in particular situations to help in establishing social contexts in which students enjoy learning and develop positive feelings toward science.

One of Mark's strategies was to provide "authentic activities" (Roth & Tobin, 1996) in the classroom in which students can participate in collaborative learning. Such a strategy links classroom tasks to the real world rather than assign decontextual tasks. The intent of using such activities in science teaching and learning "would be to allow students to enter and participate in a new discourse community" (Roth & Tobin, 1996, p. 149). For instance, students worked in groups in the chromatography activity to learn about pure compounds or mixtures, and the activity of producing soap to learn
about organic chemistry. The following vignette describes a class taught by Mark in which the dry ice and liquid nitrogen were utilized. It is based on field notes, an analysis of the videotape and interviews, and a review of students' journals. The vignette provides insights into the learning environment that Mark endeavored to modify to maximize students' participation in science learning.

Smashing Up the Ball Against the Wall Caught Me off Guard!

It was Friday. Students and instructors were wearing heavy clothes because it was very cold. Two instructors and the two teaching assistants, Chris and myself, plus 21 students, all females, were in the class. Students were arranged in five groups, each group with four or five students. The physics instructor, Adam, finished his presentation about error in measurement at about 12:00 noon.

The chemistry professor, Mark, began talking about temperature and explained the connection between temperature and the concepts of density, volume, and mass which were explained by Adams in the first hour of the class. Then he gave them a short presentation, for about 15 minutes, about temperature, Fahrenheit scale, Celsius scale, Kelvin scale, and the boiling and freezing points of water in each scale. He used the chalkboard to draw three thermometers representing Celsius (°C), Fahrenheit (°F) and Kelvin (K). For each scale the students were shown both the boiling and freezing points of water.

At about 12:15 pm, Mark asked the students to start activities with liquid nitrogen and dry ice (solid carbon dioxide). He clarified to the students how liquid nitrogen and dry ice are very cold, their temperatures being -189.8 °C (-320 °F) and
-87.8 °C (-109 °F), respectively. Then he poured some liquid nitrogen into his hand, but it turned to gas as quickly as it reached his hand. He explained to them how this demonstration indicates that the temperature of the hand is very high compared to the temperature of the liquid nitrogen. The students became excited after this demonstration. When he showed them the dry ice, they were enthusiastic to see how these small pellets of carbon dioxide turn from a solid phase to gas without getting their hands or the table wet. Mark described the different uses of dry ice in our daily lives, such as keeping drugs or foods refrigerated when they are sent by mail.

After a short break, students came back to the class eager to start their activities. Before starting, Mark showed them how the volume of nitrogen gas can be measured by putting an amount of liquid nitrogen into a test tube, then immediately putting a balloon over the top of the test tube. The balloon began to inflate due to the liquid becoming a gas. Then Mark asked them to start group work and write down their observations and comments about what they observed. He gave each group some liquid nitrogen in a styrofoam cup while the teaching assistant distributed balloons and some dry ice to each of the groups. Each student worked in her group to perform the activity.

In their group work, some students moved away and put their hands on their ears while balloons were immersed into the liquid nitrogen on the first occasion. They expected the balloons to burst. Students showed their excitement as they worked, especially when Mark, who previously had immersed a racquetball in liquid nitrogen, threw it against the wall and it shattered into many pieces. Some students searched the floor of the room looking for pieces of the ball. One student, Nora, commented on these actions in an interview as:
That was neat. I liked playing with that. That was fun, to see [the ball] smash up against the wall, and the balloons with the air, and then the dry ice that we used and just threw on the table. I like doing crazy things like that. I didn’t expect him to throw the ball up against the wall. That caught me off guard.

Aisha wrote in her journal the following description of what her group did during the dry ice/liquid nitrogen/balloon activity in her group:

We experimented with small pellets of dry ice. ... We stuck one pellet of dry ice in the balloon and tied it up. The dry ice begins to blow the balloon up slowly and then eventually almost appears to stop until we pick it back up and shake it and bring the inside to motion. We also did some experiments with the liquid nitrogen. [Mark] stuck a racquetball into the liquid nitrogen and it immediately turned into a glass-like state. [He] then threw the ball against the wall and it shattered into many pieces. We stuck our balloons with the dry ice in it into our cup filled with liquid nitrogen. The balloon seemed to collapse and [shriveled] up when coming in contact with the nitrogen.

While work on the activity continued, students discussed with each other within groups what they observed and sought help from Mark when they needed assistance. Mark moved from one group to another to assist students with their work, participate in discussion, and help them to understand what to do.

A good question was asked by a student about “what will happen if we blow a balloon up using regular air and put it into the liquid nitrogen?” Mark asked each student to predict and discuss within each group what would happen in this example, and to record their predictions before putting balloons with air into the liquid nitrogen. When they finished recording their predictions they inflated their balloons with air. Aisha wrote in her journal about her predictions and observations as follows:

My prediction about blowing the balloon up with regular air instead of using the gas given off from dry ice is that it will burst under the pressure of the density
of air inside the regular balloon. My guess is that it will pop. The air balloon shriveled quickly after being immersed into the liquid nitrogen then went back to its normal state as it was before being blown up. Then, we tried the dry ice once again and it seemed to drip condensation.

After a while they were asked to look for whatever they could see inside the balloons filled with air, such as liquid, after putting them in the liquid nitrogen. The instructors tried to help students to observe liquid inside balloons. Some students could see a liquid while some of them could not. Huda, for example, wrote in her journal "I saw a liquid in the balloon for a second, but then it disappeared as the balloon got its shape back. I have no idea what it is." But Aisha wrote in her journal "Although we were asked to see something inside of the air-filled balloon many times, I never really saw anything worth noting. Nothing was inside of the balloon." Before ending the class, students, within each group discussed their observations and wrote what they thought in their journals.

It appeared that the purpose of conducting such activities in Mark's classes was to create an interesting environment for learning and to stimulate students' reactions and interactions in the classroom. Mark, who appeared to take an interest in the students and their learning, aimed to build a congenial classroom atmosphere where students feel secure to participate. He used his roles, such as an entertainer when he threw a racquetball against the wall, as a referent for actions to build classroom environments. In such environments, learning became an exciting activity for students.

Students liked exciting environments in which they were motivated to participate actively in the learning process. Furthermore, students' views of learning environments in Mark's classes indicated that there was consistency between what students
experienced in the classroom, and its importance in facilitating their learning in the classroom.

**Students' Views of Learning Environments**

I used the University/Community College Student Questionnaire (Appendix B) in my investigations of whether students' views related to what was happening in the chemistry component of the course were consistent with the perceived importance of each item. This survey was developed by Muire, Palmer, and Tobin (1996) from Florida State University; and was intended to provide evidence as to what is occurring in science and mathematics classrooms in Florida's Community Colleges and Universities. The purpose of this survey was to obtain quantitative and qualitative data to establish a baseline of information regarding the needs, concerns, opinions, attitudes, and beliefs of students in science and mathematics classes.

This questionnaire consists of 47 items, in addition to 5 open-ended questions, to provide information about teaching and learning in the classroom. Its main purpose is to elicit students' perceptions of what they experience in the classroom and its importance to facilitate their learning. Items in the questionnaire were developed with constructivism as a referent for thinking about teaching and learning. These items are designed to measure seven clusters, teaching techniques, structuring of learning environments in the classroom, standard resources utilized, technology resources utilized, connection to real world experience, out-of-class participation, and assessment techniques (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996).

Sixteen of 21 students (76%) in the class responded to the questionnaire at the
end of chemistry classes by indicating the extent to which an action took place in the
classroom on a five point scale, almost always, 4; often, 3; sometimes, 2; seldom, 1; and
never/almost never, 0. Students indicated the extent to which an action was important in
the classroom on three point scale, high, 3; medium, 2; and low, 1. Thus, quantitative
descriptions of what was happening and the perceived importance of what was happening
as well qualitative descriptions were obtained from students.

The questionnaire data were analyzed using SPSS (the Statistical Package for the
Social Sciences) statistical software. Appendix C summarizes the descriptive statistics
associated with students’ perceptions of the frequency of occurrence of each indicator in
the classroom and its importance to them to facilitate their learning. It shows the
clustering on questionnaire items and the median, minimum, and maximum of each item.
The questionnaire includes five items (# 10, 13, 14, 16, and 25) to measure the
quality of the learning environment in the classroom. In this study, I used these items to
show how students’ perceptions of what was happening in the chemistry component of the
course was consistent with the importance of each item. Table 1 shows the descriptive
statistics related to these five items. Table 2 shows the descriptive statistics related to
these five items in Mark's classes compared to the descriptive statistics for students’
perceptions from in Florida's Community Colleges (Elmesky, Muire, Griffiths, Taylor,
& Tobin, 1996).

In their response to the 10th item (In this class, the instructor arranges seating to
facilitate student discussion), there was a consistency between what students in Mark's
classroom experienced, and its importance to them (Table 1). The data suggest that Mark
often arranged seating to facilitate student discussion, and students perceived this seating
arrangement to be of medium importance. It is possible that use of the trip metaphor as a
Table 1

Summary Statistics of Prospective Teachers' Perception of Perceived Environments and Its Importance in Chemistry Classes

<table>
<thead>
<tr>
<th>Item</th>
<th>FREQUENCY</th>
<th>IMPORTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Med</td>
<td>Min</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. Med = Median; Min = Minimum; Max = Maximum

Frequency
4 = almost always
3 = often
2 = sometimes
1 = seldom
0 = never/almost never

Importance
3 = high
2 = medium
1 = low

Referent for actions helped Mark to build a congenial classroom atmosphere in which students felt secure to speak before their peers whether within their groups or the whole class. According to the median of responses, students in Florida's Community Colleges (Table 2) perceive this type of seating as never arranged, and regard seating to promote discussion to be of low importance (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996). Probably, students' perceptions that arranging seating to facilitate
Table 2

Summary Descriptive Statistics of Students' Perceptions of Experienced Environments and Its Importance in Mark's Classes

Comparing to Students' Perceptions in Florida's Community Colleges Study

<table>
<thead>
<tr>
<th>Item</th>
<th>Mark's Classroom</th>
<th>Florida's Community Colleges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Importance</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td>Min</td>
</tr>
<tr>
<td>10.</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>13.</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>14.</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>16.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>25.</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. Med = Median; Min = Minimum; Max = Maximum

Frequency  | Importance
4 = almost always | 3 = high
3 = often       | 2 = medium
2 = sometimes   | 1 = low
1 = seldom      |               
0 = never/almost never |
discussion among students was of medium importance in Mark's classes was related to a traditional view in which student-instructor discussion is considered more important than student-student interaction.

Students in most of Mark's classes worked in groups to conduct activities or to solve problems on work sheets related to chemical concepts they learned in class. Furthermore, students could work together to solve the problems in the chemistry quiz. Most of these problems were related to students' daily life experiences, such as the activity of producing soap to learn about organic chemistry, and about pure compounds or mixtures. Mark used group problem-solving work to stimulate students to participate actively in learning science through interaction among students in groups and the whole class.

Students liked the arrangement of group activities to promote discussion among students within each group and facilitate meaningful learning. Muna for instance, in her response to the open-ended question about (what did she like most about the course?) in the questionnaire expressed her feeling about group work as "I also like how we are able to work in groups and have open-note tests. This enhances learning a great deal."

Student responses to the 13th item (In this class, the instructor encourages us to ask questions) reveal a high consistency between its frequency in the classroom and its importance to students (Table 1). The data indicate that Mark almost always encouraged students to ask questions, and students perceived their questioning to be of high importance. The use of several instructional strategies in Mark's classes to establish an interesting atmosphere for learning helped students to feel secure and engage actively in the learning process. Within such an atmosphere, students were encouraged to use their own language in asking questions to learn meaningfully in the classroom.
Dialogues between Mark and students (Chapter 5 and this chapter) show how students were encouraged to argue, ask and answer questions in the classroom. The freedom to ask questions or to say “I don’t understand why ...” or “I am still not clear to explain ...” (the dialogue in this chapter), is an indicator that co-participation is possible in Mark’s classroom. Students in Florida’s Community Colleges (Table 2) also agree that they are almost always encouraged to ask questions, and perceive their questioning to be of high importance to them (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996).

Responses to the 14th item (In this class, the instructor encourages us to express our opinions) reveal a high consistency between what students experienced in Mark’s classroom and its importance to them (Table 1). This result indicates that Mark almost always encouraged students to express their own opinions, and students perceived the expression of personal opinions to be of high importance. Students were empowered to express their opinions whether verbally or in their journals. Fatima, for example, challenged Mark that she could prove to him (the dialogue in Chapter 5) that her hair became green without dying it green. Also, Nora expressed her opinion about one of the lectures in the journal “I think the lecture went way too fast and was confusing.”

When students feel secure and have the power to express their ideas using their own language, they can argue and ask for help when they did not understand (Tobin, in press-1). Again, the perception that the expression of personal opinions is possible and valued is an indicator that co-participation can occur. Students’ responses in Florida’s Community Colleges (Table 2) indicate that they are often encouraged, and perceive the expression of personal opinions to be of high importance (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996).
Students’ responses to the 16th item (In this class the instructor encourages us to consider alternative explanations) indicate a high consistency between what students experienced in the class and its perceived importance to them (Table 1). The data suggest that Mark almost always encouraged consideration of alternative explanations, and students perceived this action to be of high importance. One of Mark’s goals was to help students understand science knowledge and how to relate it to their daily lives by utilizing common products and materials, such as chlorox, soap, balloons, pennies, nails, and test tubes in the learning activities. Within this environment students could use their own language to think of alternative explanations and how to relate what they learned to what they experienced in their daily lives. According to the median of responses, students in Florida’s Community Colleges (Table 2) indicate that they are sometimes encouraged to consider alternative explanations, and perceive such encouragement to be of high importance (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996).

Student responses to the 25th item (In this class, the instructor allows for the different learning styles of students) indicate a relative consistency between what students experienced in the class, and its perceived importance to them to enhance their learning (Table 1). The scores suggest that although Mark used different instructional strategies to facilitate various learning styles, students perceived it as very important to have more learning styles in their classroom. This result might be related to students’ views of learning styles which were used in other courses in the university, such as copying notes and memorizing facts, which were rarely used in Mark’s classes. Data from field notes and videotapes suggest that students in chemistry classes could learn science through interacting with Mark while he was lecturing or demonstrating, with
other students while they were working in group activities, and with tasks while solving chemical problems. However, students’ responses in Florida’s Community Colleges (Table 2) also indicate that varying student learning styles are sometimes allowed for, and perceive it to be of medium importance (Elmesky, Muire, Griffiths, Taylor, & Tobin, 1996).

Responses to the open-ended questions in the questionnaire revealed that students enjoyed science learning, particularly through activities. Many students liked the informal nature of learning environments, hands-on experience, the closeness, the instructor’s real care, and comfortable atmosphere in the classroom. They felt that science was ‘fun’ and interesting, and mostly relevant to the experiences in their daily lives. For instance, Muna in her response to the question about (what did she like most about the course?), expressed her feeling as follows:

I liked how [the instructors] showed us experiments and used hands-on learning. I also like how we are able to work in groups and have open-note tests. This enhances learning a great deal. I think [Mark] is funny and is relatable. He always relates things to materials we use everyday or are at least available to us.

Another student explained why she liked to participate in collaborative learning in the classroom:

I liked when we do in-class labs because they are usually fun and the whole class gets involved and I usually learn a lot from these [activities].

Another student expressed her feeling about what she learned in the classroom:

[I learn from ] the lab experiments and demonstrations we do each day that are
applicable to our classroom strategies later on. Activities really help the student. What is actually going on, hands-on is the best teaching method for me.

Learning environments in a particular classroom shape the relationship between students and their instructor. Prospective teachers in many science classes act within the assumption that if an instructor is the authorized resource of science knowledge that they need to learn, then it makes sense for the instructor to have the power to set up environments for science learning (Tobin, 1995a). Analyzing student-instructor relationships in terms of authority and distributed power in the classroom is important to understand more about learning environments.

Authority and Power in Learning Environments

Relationships between students and many science instructors in classes for prospective teachers can be described in terms of authority and power. Students in many science classrooms view knowledge as existing independently from knowers. This knowledge can be transferred from authoritarian resources to students who accept such knowledge as passive agents. Accordingly, for many students, the voices of science, as represented by teachers, textbooks and other resources, such as TV and videotapes, can be more powerful than common sense and other forms of personal knowledge (Tobin, in press-2). Students use this view as a referent to think about the relationships in the classroom.

Authority relationships in work-oriented environments are based on the status and expertise held by the manager or executive (Marshall, 1990a). The major role of the authority figure in such classrooms is to assure efficient production. In many
science classrooms the norms include, as described by Roth (1994), teacher explanation of concepts and procedures for calculating word problems to the whole class. Such actions may be followed by student seat work that emphasizes completion over comprehension. If small group or laboratory activities are used, they are most often recipe-like or limited to data-collecting components to emphasize the verification of known laws and law-like relationships. Production in such environments is represented by completing work, getting the right answers, and receiving satisfactory grades.

Instructors in many science classrooms construct their roles as the main source of knowledge. These instructors, who are mostly guided by the hegemony of technical-rationalist ideology (Habermas, 1972; Grundy, 1987), have much power in the classroom while students seem relatively dis-empowered. Hegemony, as noted by Grundy (1987), refers to the dominance or imposition of the ideology of a powerful group in a culture, and its unquestioned acceptance by less powerful members. Power imbalances constrain interactions and the relationships between the instructor and students to establish environments for learning. Verbal interaction is very rare or missing in such settings, and when it occurs, it is oriented to disempower learners. The power of the instructor is constituted in a form of discourse that cannot be accessed or appropriated by students, leaving them with little recourse other than rote learning (Tobin, in press-2).

In contrast, authority relationships in learning-oriented environments are based on the instructor’s expertise and knowledge to be shared, together with his or her ability to support learners in construction of their own knowledge (Marshall, 1990a). In such environments learning is an interpretive process, as new knowledge is constructed by individuals, in a social process that connects new to prior knowledge.
Each student actively constructs and reconstructs his or her understanding rather than receiving it from a more authoritative source in the classroom (Roth, 94).

Instructors in learning settings can structure activities in which students engage such that they can use their existing knowledge to make sense of what is happening and build new understandings on a foundation of extant knowledge (Tobin, in press-2). An instructor in such a classroom, as noted by Marshall (1990a), must be able to:

- diagnose learner’s present level of development and knowledge, analyze learning materials for the cognitive process and the development level required, select authentic and developmentally appropriate activities, structure the environment for collaborative learning, and search for ways to help students continue constructing their own knowledge. The teacher must share control of the learning process with a learner who plays an active role in the construction of knowledge. Teachers have some opportunities they provide for students to learn. (pp. 99-100)

Power within a learning-oriented environment is more distributed such that all participants in the class, as a community of learners, have equitable access to resources to enhance their learning. Power is shared among individuals in this community where actions and interactions are mostly guided by practical or emancipatory interests. Participants have the autonomy to engage in empowering forms of actions and interactions, and to co-participate in the discourse in their community. The learner in the environment, in which the instructor and students can access a shared language, can be viewed as "an interactive co-constructor of [scientific] knowledge" (Taylor & Campbell-Williams, 1993, p. 12).

**Discourse in Learning-Oriented Environment**

Discourse refers to a "social activity of making meanings with language and other symbolic systems in some particular kind of situation or setting" (Lemke, 1995, p. 8).
Meaningful learning is considered to occur in classrooms through social interactions when the discursive practices, such as spoken or written language, of participants are constantly changing in response to social structures and power relations (Tobin, in press-2). The symbolism of communicated language "evokes subjective meaning in the hearer or reader that is dependent upon their prior knowledge of the conventions of language" (Taylor & Campbell-Williams, 1993, p. 12).

When student-instructor interaction in a science class is rare, it means that the instructor and students may belong to different discursive communities with a wide gap between them (Tobin & Roth, 1995). The language used by the instructor is inaccessible to the students. Furthermore, it may create a barrier that prevents members of the students' community from crossing the border into the instructor's world of science (Griffiths, 1996). In such an environment students might not become involved in social interactions, such as arguing or raising questions, because of a fear that they do not know enough to do so. Social interactions using a shared language enable the instructor and students to communicate and test the fit of their knowledge with others' representations (Tobin, in press-2).

Within the trip metaphor, which was used as a referent to actions and interactions to create learning-oriented environments in Mark's classes, power was distributed more evenly among all participants in the classroom community. Travellers and the trip driver can access the language of one another because there is a free flow of ideas among all participants on the trip. Practical and emancipatory interests characterize actions and interactions of the community of the travellers (learners) in the trip of learning more often than technical interests.

Developing more discursive practices among the community of learners provides
an environment for emancipatory interests to flourish. When such an environment is built, students and their instructor "move strategically towards sharing authority and control in relation to the social construction of their own subjective and intersubjective knowledge" (Taylor & Campbell-Williams, 1993, p. 14). Throughout the trip of learning, participants in Mark's classes were involved in discursive practices using spoken or written language.

**Verbal Discourse:** Oral discourse among the community of learners in the classroom is an important characteristic of learning-oriented environments. Promoting learners to be involved in oral discourse means to bridge the gap between the language of science and that of the students. It appeared that the purpose of using different teaching strategies in Mark's classes, such as problem solving, demonstrations, and group activities, was to bridge this gap. Working in activities or solving problems provided students with opportunities to argue and discuss with each other to decide on their procedures, observations, and analyses. The use of familiar materials and words, such as soap, water, gasoline, balloons, salt, nails, pennies, and so on, in these activities facilitated discourse or co-participation in the classroom.

Co-participation, as Tobin (in press-1) noted, "implies the presence of a shared language that can be accessed by all participants to communicate with one another such that meaningful learning occurs" (p. 1). In a class in which co-participation occurs among learners, students have the autonomy to ask and argue with others when they have a problem with understanding (Tobin, in press-1). From a social constructivist perspective, the intent of science learning and teaching is to help students to "develop discursive competence for talking about empirical phenomena" (Roth & Tobin, 1996, p. 149).
Mark used the trip metaphor as a referent for his actions to develop discursive practices in his classes. For instance, the dialogue about hair dying and bleaching (in the previous chapter) revealed that Mark used different roles to stimulate students' coparticipation. It was clear that the goal was to promote an active engagement of students through employing a form of discourse that allows them to use their discursive resources in the process of understanding that concept (Tobin & Roth, 1995).

The following dialogue between Mark and students about the ions and molecules in water revealed how students were empowered in Mark's classes to speak:

Mark: What do we know about solutions that have a lot of ions in them?
The TA: They conduct electricity.
Mark: They conduct electricity. They conduct electricity. Now, water, is water a good conductor of electricity or a poor conductor of electricity? (Some students replied that it was a good conductor and some said it was not a good conductor.)
Mark: Well, [when we tested it before] it wasn't really good, but it conducted a little bit, so that's one way of knowing. What about [compounds] that are salts? If you think of all the salt that you know of, they consist of all positive ions and all negative ions, cations and anions, do they tend to be liquids, or do they tend to be solids?
Student 1: Solids
Mark: Solids. Right. Because that ion-ion bonding is so strong, that it holds them together very tightly, and therefore they tend to be a solid. So, one thing we can do to fix this picture, to make it better is to change the ratio of hydrogen and oxygen. We're also going to have the molecules connected like this (a chemical structure of water molecule in the board.)
Student 2: I am still not clear to explain why they are connected.
Mark: Well, the reason the model we used in class tells us that they're connected is that we said that non-metals tend to share electrons. Experimentally,
the way we say they are connected, is because if they weren't connected, if it [water] was a liquid that existed and had a lot of ions in it, we'd say that mobile ions are good conductors of electricity like the salt water. So, why shouldn't it have lit up all the light bulbs, and it only lit up two of the light bulbs, in the pure water?

Also, most salts have this strong ion-ion attractive force, and all the salts that we talked about are solid. They don't become liquid until you dissolve them in water to make a solution. So both from the way we think about bonding and from the physical properties, we want these (Mark pointed to atoms in sketch of water molecule) to be connected.

Student 3: So are you saying molecules that stay bonded are not good conductors?
Mark: Unless you form ions in solution, they are not going to conduct electricity. Now we are going to have the molecules like this. (Mark continued writing on the board, discussing water molecules and how they are separated from each other.)

Student 4: Separated from each other? Separated from each other, is that what you are saying?
Mark: Yeah, because the water is such a good H-bonder and so polar. Now you've helped make my picture better. They [the H+ and the OH-] are going to be evenly distributed and not necessarily that far apart. I don't know about that one. I don't know if they are close or not. My guess is that they are fairly evenly spread out over each other. If they were really close, then they would react together to form water.

Student 4: I don't understand why those ones are separated and those ones don't? (Mark used the chalkboard to explain more about water molecules and the situation of their connection.)

Student 3: Ions means the H+ and OH-?
Mark: Yes, ions mean the H+ and the OH-.
Student 3: How does that happen if they don't want to bond to hydrogens very often?
Mark: Because it's this dynamic equilibrium ...

It is clear that the students had the autonomy to talk, ask and answer questions, and argue (Tobin, in press-1). In his teaching, Mark provided the students with opportunities to interact through asking questions, discussing, explaining, clarifying, elaborating, arguing, evaluating, reconstructing, collaborating, and attempting to reach consensus on what was learned in the classroom. As we see in the dialogue, the students 2 and 4 had the power to say "it is not clear" or "I don't understand" and the student 3 (Nora) argued with Mark in order to understand the relationship of ions in water molecules.

Journals or Written Language: Using the journals in science classes facilitates discourse between students and their instructor. A student's journal allows a non-threatening mode of discourse to develop between every student and the instructor in the classroom. It encourages students to show their frustrations and confusions, and to show what the students did and did not understand about science. Reading students' comments allowed Mark to see how students (mis)understood science knowledge in the classroom. Mark commented on the use of the journals to encourage students to express their ideas as follows:

The nice thing about the journal is that it is a very non-threatening way to extend that dialogue between student and instructor. If I say that "when I boil water I create [oxygen and hydrogen atoms]" and you go "No you don't, steam is still water molecules. It is just in a gaseous stage, they are far apart," and I read that, maybe I feel kind of stupid. But I don't feel like I am being embarrassed in front of the whole class. It is much easier then. If on the board I say "no, that is not right," then I think they sort of clam up. Journals are great for that reason.

It seems that the use of the journals in the classes for prospective teachers is
consistent with Mark's goal to maximize students' participation in the learning process. Mark explained the importance of the journal to create environments in which student-instructor interactions is promoted as:

I do try to keep them interested. I try to do things that engage the students. What I do depends on the class and the nature of the students. That is what makes the journals so useful. Anything that gets the students to put their ideas into words lets you see whether they understand what they are doing. You never know if what you are doing in class is working until you get the students to talk or write.

Mark believed that the student journal is an effective means of assessing students' learning. The use of examinations or tests in the classrooms may enable the instructor to determine whether students learn science with understanding or not. Oral or written interactions in the classrooms can be used by instructors to determine what students do understand and what they do not. Mark emphasized the importance of co-participation in the classroom to evaluate meaningful learning as follows:

Exams are not the best way to determine what someone knows. Exams don't have the 'give' and 'take' of a conversation. But if I talk to somebody, I can tell whether they understand the piece of science. And sometimes it is that conversation that leads to understanding. You can almost hear the "click" when someone gets it. "Oh! I got it. It is like so and so."

Recently, there has been considerable attention given to developing approaches to assessment, such as portfolios and journals, based on students displaying evidence of what they have learned (Duschl & Gitomer, 1991; Collins, 1991). The use of portfolios and journals as an alternative means of assessing students' learning enables the instructor to determine what students have learned in the classroom. Tobin and Tippins
(1993) suggested that the use of portfolios and journals enables students to show what they know, opens the opportunity for instructors to get in touch with what students know on an on-going basis, and can provide a basis for a learner-focused dialogue between students and their instructor.

Furthermore, Mark used the journals as a way to encourage the students to participate and ask questions whether through their journals or in the class. For instance, in his response to Muna, Mark reacted to her comments on the dry ice and liquid hydrogen activity as follows:

Muna, you are off a good start here. Keep writing- both assigned entries plus anything you like. It is hearing and reading your ideas that allows us to give the best feedback for each of you. And feel free to ask questions in class too.

Students used the journals to express their thoughts and questions about learning activities in the classroom. They could explain what they did understand and what they did not. Furthermore, they used the journals to write about their confusions, frustration, and their personal problems that might inhibit their learning.

Students found the journals an efficient tool to explain what they did while they were working in groups or individually to conduct activities in the classroom and to express their feeling toward such activities. In the balloon, wall, and water activity, for example, Nora wrote in her journal the following comments about the activity:

I rubbed the balloon against my hair and I got it statically charged. Then I held the balloon next to a steady stream of water, and the water went toward the balloon. I thought the water and balloon experiment was cool! I already knew about the balloon sticking to the wall after rubbing it on your head (although I didn't know until now), but I had never heard of the water and balloon experiment before.
Muna used her journal to explain what she learned in the balloon, wall and water activity as well as pose some questions that she constructed in the activity.

I blew up a balloon, rubbed it on my hair to gain statistic electricity and put next to the dripping water. When I put the balloon next to it, the water was drawn towards the balloon. The balloon gains excess electrons when rubbed on hair. When I put balloon on the wall, it sticks because there are (+) forces on the wall which can't move. Do all things have both (+) and (-) charges, except for single elements? So why doesn't the balloon stick to a pen? If you have one balloon stick to board, can you stick another balloon on the balloon to the board? Will it stay?

The journals allowed a channel through which the students could express their confusions or frustrations without being face to face with the instructor. Nora wrote the following when she had difficulty with Laws of Thermodynamics:

I understand all the laws of thermodynamics, but I'm just a little fuzzy when we get to the fridge, engine, and entropy. What that has to do with the second law ...?

In the class in which Carnot's Theorem was taught, Nora expressed her frustration in her journal as follows:

I don't understand Carnot's Theorem. I think the lecture went way too fast and was confusing. All of these formulas mean nothing to me because I don't know what they mean.

Mark responded to Nora's confusion about the thermodynamics' laws asking the student to reflect more about her understanding as follows:

A number of students expressed this. We have talked about this material since
this lecture. Does it make more sense now? Did the homework help?

Mark’s response encouraged Nora to reflect more by writing more in her journal or verbally by asking the instructors if she still did not understand the laws of thermodynamics.

Muna was confused if she could use the word ‘water’ for liquid water, as she learned in the Earth Science class, or water and steam. She wrote in her journal:

The liquid water stays as H₂O in liquid and steam because it is still H₂O. Our Earth Science teachers always had a fit when we just called it water. They said ‘liquid water.’ What’s the difference between (aq) and liquid?

Mark responded to Muna’s confusion as:

Both water and steam are H₂O. The only difference is the phase- but that is an important difference. (Aq) just means dissolved in water.

As a final note about the types of journal entries, the students used the journals as a way to communicate with the instructor about their personal problems, such as when they were sick or why they were absent. Fatima, for example, wrote in her journal to explain why she was absent:

I have been very sick lately. I had to go to the doctor and he told me to go to another doctor. ... I am trying my best to keep up with this class and all my other classes. I didn’t want to seem like I was just making up excuses. But I am really doing my best.

Mark responded to Fatima’s problem as “Fatima- This is serious. Please come talk to me about it.” Probably this discourse established a student-instructor relationship that
encouraged Fatima to respond in the questionnaire as:

The professors really cared. It isn’t fun if you know your professors don’t really care. But we knew from day 1 that they cared about us.

**Conclusion**

Learning science with understanding in classes for prospective teachers could be enhanced by creating classroom environments. To create a classroom environment means to encourage and stimulate students to learn science actively through student-teacher, student-student, and student-task interactions. Such interactions affect their beliefs and emotional responses toward science. A learning environment guided by a teacher who has high regard for all students in a class and has a concern about the context in which his or her students prefer to learn science may tip their attitude scale toward the positive end (Collette & Chiappetta, 1994). Students in a science class for prospective teachers would like to be more involved in the learning process. Also, they prefer science content to be more relevant to their daily life practices.

Studies (e.g., Fraser, 1990; Duffy, 1993) have shown that student achievement and satisfaction are greater in classrooms in which there is a closer match between the actual classroom environment and that preferred by students. Fraser (1987) pointed out that outstanding science teachers include in their curriculum the same complex material as the other science teachers, but they make it seem easier through creating a quality learning environment. When such an environment is provided, prospective teachers engage actively to learn science, and are not afraid of teaching science in their own classrooms. Duffy (1993) found in a chemistry course taught by Mark that there
was a relatively small difference between students' experienced and preferred classroom environments. He attributed this findings to the high degree of approachability demonstrated by the instructor in his study.

Findings of this study suggest that there was a consistency between what students experienced in Mark's classroom, and its importance to promote their learning. Mark used the trip metaphor as a referent for actions in the classroom to be consistent with his beliefs and goals that students should enjoy their journey of learning chemistry. In the trip of learning he was able to switch his actions within the roles of facilitator, entertainer, learner, and controller. Mark was able to use an appropriate role in a particular situation as a referent to frame his actions and interactions, and thereby, to create an exciting environment for learning.
CHAPTER 7
SUMMARY, CONCLUSION, AND IMPLICATIONS

Summary

Purpose

This interpretive research set out to investigate the characteristics of an exemplary college science instructor who endeavors to improve teaching and learning in classes for prospective teachers. It was undertaken in order to develop an in-depth understanding of science learning and teaching for prospective teachers. This study aimed to explore actions of a chemistry instructor, Mark, in classes for prospective teachers and how such actions related to his beliefs, goals, and teaching roles. Its central purpose is to understand the metaphors that Mark used as referents to conceptualize his roles and frame his actions and interactions, and thereby, to modify an exciting environment for learning.

The research questions focused on identifying how Mark, as a constructivist instructor, developed his own metaphor that 'learning is an exciting trip' to be a referent for teaching and learning practices and to constrain his roles and students' roles in the classroom. Discussion in the study presents accounts of Mark's reflecting on his endeavors to become an approachable instructor by utilizing innovative teaching strategies designed to enhance students' learning. To be consistent with his beliefs that students, who have negative attitudes toward science (Brush, 1993), should enjoy while
learning science meaningfully, Mark used the trip metaphor to conceptualize his roles as a facilitator, a controller, a learner, and an entertainer in the classroom. Mark was able to shift his actions based on which role he used as a referent for himself while teaching science.

Methodology

An interpretive research design, described by Erickson (1986), Guba and Lincoln (1989), and Gallagher (1991), is employed in the study. The main sources of data for this study were field notes, transcript analysis of interviews with the instructor and students, and analyses of videotaped excerpts. Additional data sources, such as student journals, and the results of students' responses for the University/Community College Student Questionnaire (Appendix B), were employed to ensure that the assertions I constructed were consistent with the variety of data.

Constructivism (Glasersfeld, 1989), human interests theory (Habermas, 1972) and co-participation (Lemke, 1995; Schon, 1985) are the main theoretical frameworks in this study. The basic tenet in constructivism is that knowledge is personally constructed but socially meditated (Tobin & Tippins, 1993). Knowledge is always the result of constructive activity by an individual while he or she exists in a socio-cultural sense. This epistemology enables us to make sense of how students learn and how the teacher works with them to create learning environments that enhance their learning.

Within a constructivist framework, participants in science classes are empowered and given opportunities to act and reflect on their actions through using the practical and emancipatory interests to frame such actions. When students have the freedom to co-participate in the learning process, they can negotiate meanings of actions
to arrive at a consensus on what has been learned. Co-participation implies, as stated by Tobin (in press-1), "the presence of a shared language that can be accessed by all participants to communicate with one another such that meaningful learning occurs."

The instructor(s) who know science assist students to learn by engaging in activities in which co-participation occurs (Roth, 1995). In such situations, students are empowered to engage actively in the process of knowledge construction, and have the autonomy to ask questions when they have problems (Tobin, in press-1).

This study is based on the physical science course, which was designed especially for prospective elementary teachers. The focus was on the actions in Mark's classes, the chemistry instructor in the course. His reading and reflection on the audiotape and videotaped transcriptions provide what Guba and Lincoln (1989) refer to as member checks. The researcher's prolonged and intensive engagement (Guba & Lincoln, 1989) in the class during the whole semester added to the credibility of the study.

Data analyses and interpretation in the study focused on identifying the aspects which Mark and the researcher might find useful in reflecting to understand what was happening and why that was happening in the classroom. Interactions between Mark, as a scientist, and me, as a science educator, about actions in the classroom were central to shape the assertions which represent viable interpretations or answers for the research questions which make sense to Mark and me.

The knowledge claims presented in the assertions, from a constructivist perspective, "cannot be viewed as a necessarily "true" or correct portrait of the constructions" (Briscoe, 1991, p. 150). These claims represent concepts which both Mark and I have agreed are feasible explanations of his beliefs, goals, and roles to frame his actions within the contexts of chemistry classes for prospective teachers.
Throughout this study, I endeavored to construct assertions to answer the following research questions that were formulated as the goals of the study:

• How are a teacher's roles in the classroom related to his beliefs and goals?
• How are the teacher's actions and his instructional strategies related to his roles in the classroom?
• How are the constructions of a teacher's roles in the classroom related to the contexts within which science learning and teaching take place?
• How do the metaphors that a science teacher uses in science teaching relate to his roles in the classroom?
• How is the creation of an effective learning environment in the classroom related to the teacher's roles?

In the following sections, I discuss what I have learned from this study through discussing the results and then address implications related to these questions.

Conclusions

Marks's Roles, Beliefs, and Goals

Mark used his beliefs about science teaching and learning as referents to think about his roles as an instructor in the classroom. It was clear that one of his essential beliefs, as a constructivist instructor, was to move from teacher-centered to learner-centered approaches in which alternative ways of science teaching and learning could be utilized. In a learner-centered classroom, in which students learn science with interest, meaningful learning can occur. To achieve this goal, Mark was looking for ways to stimulate active and varied ways of participation for his students.
Mark developed a 'trip' metaphor that was consistent with his beliefs to provide a rationale for creating a learner-centered or a learning oriented atmosphere in his classes. Accordingly, he conceptualized his teaching role in terms of the instructor as a trip driver who could help and encourage travelers to enjoy knowing things and places on their trip. Within the metaphor of a trip driver, Mark could use several roles in his classes, such as controller, facilitator, and entertainer. His goal of using several roles in the classroom was to maximize the participation of all participants in the trip.

Mark used his personal beliefs as essential consideration to decide whether or not a particular role is appropriate for use as a referent for a particular action in a specific context. If the role was consistent with his beliefs, the decision might be to adopt the role, but if not, the role might be considered inappropriate (Tobin, 1990b); therefore, he might need to use another appropriate role. For example, Mark adopted the role of entertainer in the first class of chemistry when he threw a racquetball, which previously had been immersed in liquid nitrogen against the wall. This role seemed to be consistent with his goal of creating an exciting environment for learning and with his belief that creating such an environment stimulates students to engage actively in learning chemistry.

**Mark's Roles and Actions in the Classroom**

The results of this study suggested that Mark's actions and his strategies for teaching were coherent with the roles he used in the classroom. An instructor's actions in a science classroom are a product of interactions between four elements: the goals of the instructor and students, the context in which an action occurs, beliefs that are referent for a given set of behaviors, and the behaviors that occur (McRobbie & Tobin, 1995).
To be consistent with his beliefs that students should enjoy while learning chemistry with understanding, Mark's actions were embedded in the metaphor that 'learning is an exciting trip' to construct a vision of the classroom in which actions can occur. Actions in Mark's classroom are intended to help prospective teachers be more interested in learning science and relating it to the elementary classroom rather than just fulfilling a science requirement. His endeavors to develop different techniques for teaching in which various roles can be used as referents for actions was consistent with achieving the goal of establishing a high quality atmosphere for learning.

It appeared that Mark's goal of using several roles within the trip metaphor as a referent for actions in the classroom was to stimulate students' interest to participate in the learning process. Using the trip metaphor helped him to build a congenial classroom atmosphere where students feel secure to speak before their peers. Mark's actions to shift from one role to another, such as from a facilitator in helping students to understand the ions and molecules in water to an entertainer in helping students to understand dying and bleaching, helped students to feel secure and develop discursive practices in the classroom. When students feel secure and have the power to express their ideas using their own language, they can engage actively in the learning process by arguing or asking for help when they do not understand (Tobin, in press-1).

Teacher's Roles and the Context of Teaching

Mark works within a context of teaching in which actions in classes for prospective teachers are mostly interpreted in terms of powerful cultural myths, such as myths of transmission, efficiency, and preparing students to obtain high grades (Tobin & McRobbie, 1996). Mark perceived that such myths structured not only instructors' actions in college classes, but also constrained his learning experiences.
when he was a college-level student. He commented on his learning experiences from liberal arts courses in college as follows:

[When] I think back to the electives I took, I hardly remember a thing from them. I mean, they may have shaped the way I think, they may have influenced me in some way, but I doubt it. The great liberal education experiment failed for me.

As a faculty member and a college science instructor, Mark's work in science laboratories helped Mark's beliefs about science teaching and learning to evolve. Furthermore, being involved in teaching chemistry for prospective teachers for several years, in which active engagement of students was encouraged, helped Mark to consider constructivism as an alternative referent to think about the instructor's roles and students' roles in the classroom. Teaching practices in Mark's classes for the last few years (Duffy, 1993; Brush, 1993) indicate that Mark used constructivism as a referent for his teaching practices. It was obvious that as soon as Mark used constructivism as a referent for his teaching he developed and considered alternative metaphors to be consistent with his beliefs. During this time Mark developed the trip metaphor to improve his style of teaching practices to be a more routine manner. Within this metaphor, Mark could conceptualize his roles in the classroom in different ways.

Although the main goal of using more than one role in the classroom was to create an atmosphere for active learning, it appeared that the construction of these roles in the classroom was influenced by the context within which science learning and teaching were performed. Mark used some of these roles, such as Mark as a controller, to adapt his teaching practices to the culture of teaching in the university. However, he worked hard to liberate his actions from such constraints and to set up a classroom in which each individual participates actively in meaningful learning. In a setting in which co-
participation is occurring "the focus is always on what students know and how they can re-present what they know" (Tobin, in press-1).

Metaphors As Referents for Marks's Roles

An important result that Mark and I learned from this study is that using metaphors is a productive way to think of teaching and learning. The use of metaphors to talk about actions in the classroom indicates a teacher's understanding of classroom life (Briscoe, 1991). Metaphors provide a way for instructors to interpret actions in the classroom in relation to their goals and beliefs about teaching and learning.

Many instructors in science classes for prospective teachers use the transmission-absorption metaphor (Roth & Tobin, 1996) to make sense of actions in their classrooms. They use this metaphor to frame science learning as teacher-centered, and they conceptualize their roles as transmitters of knowledge. As a consequence, students are viewed as empty vessels or receptacles for knowledge. In contrast, the constructivist instructors use a mediational metaphor (Glasersfeld, 1989) to conceptualize science learning as a learner-centered approach.

In a classroom, in which the instructor endeavors to mediate the learning processes, students who are actively involved in meaningful learning, use their prior experience and knowledge to construct meanings in new situations (Glasersfeld, 1989). In a learner-centered classroom, a science instructor uses constructivism as a referent to develop new metaphors for conceptualizing the roles he or she considers to have greatest salience for teaching (Tobin, Tippins, & Hook, 1994). To be consistent with his beliefs as a constructivist instructor, Mark developed the 'trip' metaphor to construct a vision of what science classes for prospective teachers could be like. Within this metaphor, he could conceptualize his role to be the driver with the ability to guide
teaching and learning practices during the trip of learning.

The driving analogy that Mark used to think of actions in his classes seemed to be consistent with his beliefs and goals for teaching science to prospective teachers. The main goal for Mark as a trip driver was to set up an exciting atmosphere in which all participants enjoy learning activities during their trip. Creating such an environment encourages students to engage as active participants in learning activities to achieve the goal of meaningful learning of science concepts in the course. To maximize participants' enjoyment and involvement in the learning process, the driver may need to use other roles or to conceptualize other metaphors during the trip, such as a tour guide, a controller, and an entertainer.

Teacher's Roles and Learning Environments

Mark used a driving analogy, consistent with his beliefs and goals, as a referent to conceptualize appropriate roles for setting up an active science classroom in which prospective teachers enjoy learning. Since a learning environment is a construction of the individuals in a given social setting (McRobbie & Tobin, 1997), Mark used the metaphor that 'learning is an exciting trip' to think about teaching and learning, and thereby, to conceptualize his roles and students' roles in the classroom in which an interesting environment could be modified. Underlying the trip metaphor was a more constructivist epistemology in which every participant in the trip was involved actively in the activities of the trip. Enjoyment was another important referent used by Mark to stimulate students' engagement in the learning process.

Mark's approach to teaching science was consistent with his beliefs and goals to create learning-oriented environments (Marshall, 1990a) and to maximize the participation of his students who are non-science majors and who frequently have
negative feelings about science (Brush, 1993). Since it usually is the first or second science course for these students, Mark's approach encourages them to engage actively in discussions and other activities intended to promote their interest in science learning (Brush, 1993). The use of different strategies for teaching indicated that Mark was always on the lookout for ways to stimulate active and varied ways of participation for students.

By using the trip and enjoyment metaphors to think about chemistry teaching and learning, Mark might realize the positive effects that could occur when students' interests are addressed in enacting the curriculum. To be consistent with his beliefs and goals that students should enjoy while learning science meaningfully, Mark used these metaphors to construct a vision of what science classes for prospective teachers could be like. In such a trip, the main goal becomes enriching the environment with interesting activities, demonstrations, and topics which motivate students to participate in the process of meaningful learning.

Data in the study reveal that Mark adapted his teaching practices in order to have learning environments whose characteristics reflect his preferred cognitive interests (Habermas, 1972). Learning environments in his classes appeared to be shaped by practical and emancipatory interests (Grundy, 1987; Habermas, 1972), which are associated with a constructivist epistemology. It was obvious that these interests were used as referents for actions and interactions in Mark's classes more often than technical interests. Such interests were used to conceptualize not only Mark's roles, but also the roles of students, and thereby, to frame actions and interactions in the classroom. Most of Mark's actions in the classroom were consistent with his goal to develop an exciting learning environment in which collaborative social interaction
among participants can occur.

Since the main goal of Mark as an instructor was to maximize the participation of his students, using the trip and enjoyment metaphors as referents for actions encouraged the development of collaborative social interactions among the class community. During the course the community developed a shared language that permitted all participants to co-participate. Co-participation implies that each of the participants shares a language and can understand what is happening to the extent that there is freedom to participate and learn with understanding (Schon, 1985). Such a language is negotiated and is constantly evolving as learning occurs. Co-participation among participants in Mark's classes was stimulated through the use of different instructional strategies. Mark always was on the lookout for ways to stimulate active and varied ways to attain co-participation. Students learned chemical concepts with understanding because they perceived they had the power to talk, ask and answer questions, and express their opinions.

As a driver, Mark viewed himself as no more than one of the other participants on the trip, but with more experience about the route. Since he was always driving in this way, he was an expert traveller with more knowledge about exciting things and places along the journey. In each trip, the driver learns more about activities that maximize participants' enjoyment and involvement, and the activities that do not work. His role as a trip driver was that all participants on the trip enjoy learning and knowing new and exciting places and things along the journey. Within the metaphors of the trip and enjoyment, students were active agents to achieve the goal of learning with understanding about topics and concepts in the course. Participants could use their prior knowledge built at home, via television, high school, and other organizations in the
community to construct new knowledge through watching, listening, asking questions, arguing with others, and reading carefully the brochures and posters about their journey. Learning by construction implies a change in prior knowledge, where change can mean replacement, addition, or modification of extant knowledge (Cobern, 1993).

When the goal of a trip driver is to create environments in which participants enjoy their trip, the driver needs to use other roles to maximize all participants' interests. Such a driver can change his role from a driver to a tour guide, or to an entertainer, for example, based on contexts and situations that arise during the journey. To be consistent with his beliefs and goals that prospective teachers should enjoy their journey of learning chemistry, Mark, the driver on the journey, used the metaphors of controller, facilitator, learner, and entertainer as referents to create conducive learning environments. He was able to switch his actions based on which of the constituent metaphors he used as a referent to frame his actions and interactions, and thereby, to create an exciting environment for learning.

Students' responses to the University/Community College Student Questionnaire (Appendix B) suggest that there was a consistency between what students experienced in Mark's classroom, and its importance to promote their learning. The results of the questionnaire indicate, for example, that Mark almost always encouraged students to express their own opinions and to ask questions in the classroom, and students perceived their questioning and the expression of personal opinions to be of high importance. Students were empowered to ask and answer questions and to express their opinions whether verbally or in their journals.

In conclusion, Mark was an enthusiastic learner who took an interest in the students and their learning. He should be commended for reaching out to the students in a
friendly, non-threatening manner. Students found Mark an approachable instructor who did not intimidate. Use of the trip metaphor helped him to build a congenial classroom atmosphere in which students feel secure to speak before their peers. Students did take an interest in chemistry because they liked Mark and appreciated the way he spoke in the classroom, by using simple terms and everyday examples they could understand.

**Implications for Improving Science Teaching**

**Teaching and Learning Enhancement**

This study points out the significance of employing a more constructivist approach (Glasersfeld, 1989) in science classes for prospective teachers, to create environments in which meaningful learning can take place. This recommendation is consistent with the visions described in many national reports (e.g., Rutherford & Ahlgren, 1990; National Science Teachers Association, 1992; Committee on Undergraduate Science Education, 1997), which demand major changes in what, when, and how science is taught in science classes for prospective elementary teachers. When science instructors in college classes use constructivism as an alternative epistemology to think about actions and interactions in the classroom, more learner-centered classrooms for science learning can be created. Such an epistemology will be a frame for the metaphors that science instructors can develop and use as referents for their practices in the classroom.

Within the developed metaphors, instructors can constrain their roles and students' roles while teaching science in classes for prospective teachers. Mark, the instructor in this study, who used constructivism as a referent to frame his actions and
interactions, used the trip and enjoyment metaphors to construct a vision of what science classes for prospective teachers could be like. Within these metaphors, and to be consistent with his beliefs about teaching and learning, Mark considered himself as a driver for the trip in which the participants wanted to enjoy and learn.

When the goal of a trip driver is to create environments in which participants enjoy their trip, the driver needs to use other roles to maximize travellers’ interests. Using constructivism to frame actions and interactions helped Mark to shift from one role to another within the trip metaphor. During the trip of learning, Mark was able to switch his role from a driver to a facilitator or to an entertainer to create learning environments in which students learn science with interest. Mark's actions shifted according to the metaphors he used as referents for a specific action in a particular situation to facilitate learning.

Mark related his developed images of classrooms to his past experiences as a science researcher and his involvement in cooperative work with science educators over a period of several years to design, review, and enact a curriculum for prospective elementary teachers (Brush, 1993; Duffy, 1993). Mark's experiences as a science researcher helped him to develop his beliefs that college students learn science meaningfully by doing, which means students should be actively involved in the learning process. These beliefs were enhanced by being a member of a group of science faculty and science educators to plan and implement the physical science course for prospective elementary teachers during the last six years (Barrow, 1993; Brush, 1993; Duffy, 1993).

Scientists and Science Educators: Cooperative Work

The cooperative project aimed to establish learning environments in classes for
prospective teachers in which students engage actively in the learning process through questioning, discussing, explaining, clarifying, elaborating, arguing, evaluating, reconstructing, collaborating, and reaching consensus on what was learned (Tobin & Roth, 1996). It seemed that Mark, as a member of the science faculty in the project, who were encouraged to use social constructivist approaches of teaching, developed his images of the classroom to be a referent for his own teaching practices.

Roth and Roychudhury (1994) commented on how such cooperative work between science faculty and science educators may help to improve science teaching and learning in college classrooms as follows:

Empirical work with college students made the claim that a constructivist position is a more mature form of knowing. Consequentially, many educators have accepted constructivism as a more appropriate set of beliefs to direct teaching and learning. However, to translate into classroom practice science educators' faith in a constructivist epistemology, teachers must recognize a need to change their views. Thus, science educators seek to help teachers in changing from world-views that are commensurable with objectivism to ones that are commensurable with constructivism. (p. 7)

When science faculty members have the opportunity to work with science educators to design and implement science courses for prospective teachers they become more aware about their roles in improving science teaching and learning for the future science teachers. Furthermore, science faculty members can make a substantial contribution to educational reform by sharing their most recent and prominent models of science teaching with future science teachers (Committee on Undergraduate Science Education, 1997).

The results of this study suggest that consideration should be given to the cooperative work between science faculty and science educators to plan and implement
science courses for prospective elementary teachers. The interaction and cooperation between the two groups may help science instructors to change their traditional views of teaching and learning, and thereby, develop their pedagogical knowledge and practices. In such a situation, the main goal will be how to develop a special classroom environment for future teachers in which they engage actively in learning science and learning how to teach science in their own classrooms.

Teacher Education

The results of this study also have implications for science teacher educators. Students who have spent 14 or more years of education in primarily traditional science teaching and learning environments are mostly in their freshmen year of college. Most of them came directly from high school and are not experienced as students at a university. Future elementary teachers in science courses frequently have negative feelings about science (Brush, 1993) because they are non-science majors and it is the first or the second time for most of them to attend college science classes.

While prospective teachers are involved in science courses, they are still trying to get used to the university scene and become more familiar with science learning and teaching these courses. Most of them come to science classes with traditional views about teaching and learning. They view lecturing as the main instructional style in college classes, and the instructor, who is the main source of knowledge, has the power to control instructional and evaluation practices. Also, they are involved in science courses with the purpose of obtaining high grades, so they can be accepted in the elementary teaching program.

When students and their instructor(s) have different views of teaching and learning, “teaching-learning process may disrupt because of different epistemological
commitments between teachers and students" (Roth & Roychudhury 1994).
Accordingly, science instructors need to be on the lookout for effective ways to help their
students change their traditional views about teaching and learning and stimulate them to
participate in learning science meaningfully and learning how to teach science
appropriately.

If science instructors and science educators expect to enhance science learning in
classes for prospective teachers and foster the development of their pedagogical skills,
effective teacher education programs have to be developed. The main goal of these
programs should be helping future teachers “to create new images” (Briscoe, 1991)
about teaching and learning and to construct a vision of what science classes in
elementary schools could be like. Briscoe (1991) emphasized that these programs
should focus on creating environments for science learning in which:

Future teachers must not only have opportunities to observe exemplary teachers,
and observe each other in teaching situations; they must be assisted to reflect on
their own images of teachers and learners. By assisting students to examine the
personal epistemologies, beliefs and metaphors which they hold about
teaching and learning, teacher educators can help students construct
pedagogical knowledge and pedagogical content knowledge which is consistent
with constructivist science teaching. (p. 169)

Questions for Further Learning

Enacting reform of science teaching for prospective teachers means establishing
learning-oriented or learner-centered classrooms. Such an environment for learning is
set up by the instructor who provides students with learning experiences that are likely
to facilitate learning. Since a science instructor plays an essential role in enhancing
students' learning, plans to enact reform need to take account of teachers and their styles of teaching in the classroom. Further action research needs to be conducted, especially in my home country, to understand how science teaching and learning can be improved in college-level classes in general and in classes for prospective teachers in particular.

Some of the questions that may emerge from findings in this study that need more action research to construct answers are:

How can we improve the culture of science teaching and learning in college-level classes?

How can science instructors recognize and begin to overcome constraints to teaching and learning which arise from beliefs associated with cultural myths?

To what extent can science instructors change their personal theories used as referents for their actions in classes for prospective teachers?

To what extent can the collaborative work between scientists and science educators to design and implement science courses help science instructors to improve their styles of teaching?

What are the other effective ways, rather than such cooperative work, to have science faculty re-think about teaching and learning in their classrooms?

What is the appropriate way to help instructors to reflect and give voice to the beliefs, images, roles through which sense of practices is made?

How can we assist science instructors to use alternative metaphors as referents for their actions, to improve learning environments in college level classes?

The use of constructivism as a referent to develop science teaching and learning in college level classes is receiving increased consideration. This epistemology calls for
a re-conceptualization of what a science instructor is and what he or she does in the classroom (Herron, 1996). This epistemology can be used as an alternative referent to allow instructors to frame problems in different ways and ultimately to obtain different alternative solutions (Tobin & LaMaster, 1995). Using constructivism rather than objectivism as a referent for teaching helps a science instructor to think of appropriate ways to conceptualize his or her roles in the classroom.

This study has highlighted how a science instructor in college level classes can construct his own metaphors to describe aspects of teaching and learning. Metaphor is a way that the instructor can use to conceptualize his or her roles in representing knowledge of teaching and learning. Using metaphors as referents to understand teaching and learning has the potential to change what happens in classrooms (Tobin & Tippins, 1996). Metaphors helps instructors to think about their roles and students' roles while teaching a particular concept in a particular context.
Today is Wednesday. The class is in 105 UPL (Undergraduate Physics Lab) in the Richard's Building. It is the time to start the class:

11:15 am: Adam, Mark, Chris and 19 students are in the class. Adam talks about the presentation that each student needs to do in the class. Each student can look for a science article in a newspaper or a magazine to present it for no longer than 10 minutes. Jennifer asks a question about the style of the presentation. His reply is "we are going to start with Chris on Friday and Abdullah on Monday." Another student asked about what kind of articles they should look for. She can pick up whatever science article she likes relates to the stuff of the course, and she can use transparencies and the overhead projector if she likes. Then Adams moved to the back of the class leaving Mark to begin the class.

It is good to encourage students doing presentations in the class. This will give each student the opportunity to talk about a science issue. Despite the short time of the presentation, this will help each student to be familiar with the class through talking, discussions, and interactions.

11:20 am: Mark sits on the table in front of the class. He says that he is going to talk for not more than 30 minutes. Then Chris is going to do some chromatography activities with students for about 20-25 minutes before the break then Mark will continue with them after the break. Mark talks with students for a while about the presentations that they are going to do. Then he clarifies some points related to the difference between pure substances and mixtures that he taught about last week. Then he talks for a while about chromatography and how it is related to what they learned about pure substances and mixtures. Chromatography is an important part of chemistry. We use it a lot in our lives. Mark clarifies to them how this kind of activity is good to be used with kids in elementary classes.

It is a good point that Mark is trying to help students using their previous knowledge about pure substances and mixtures to learn about chromatography. But his role in this short lecture seems as informer. Why doesn't he stimulate students to talk and interact? Compared to the first class of chemistry, there is a lack of co-participation among Mark and the students. His role would be an interactive informer if active discourse is created in the class. Probably there will be some activities later.
11:27am: Mark moves to the board and shows the class a piece of paper marked with a line of black ink was separated to other colors. He uses the board to explain how the black ink separated into the colors of blue, red, pink, and yellow over a period of time being in water. It is very interesting that Mark is using his body to clarify how color molecules move to separate from each other. From a standing position, he rotated himself along the length of the blackboard across the entire front of the room to show them how the mixture moves in the piece of filter paper as it is soaked in water.

Mark is trying to stimulate students through teaching with interest. In the short lecture, he uses his body's movements and language to help them understand concepts of chromatography. But his role is still as informer while students are passively looking to what he does and listening to what he says.

11:34am: Mark prepares a piece of paper and puts a purple line on it. He has some water in a dish. Students look with attention to what he is doing. Carefully, he puts the piece of paper in the dish in which the line is about 1 cm above the water. The paper is left for about two minutes while Mark continues his lecture about colors and chromatography. A student asks him how chromatography is used in industry. He clarifies how different pigments are used in industry for a long time. Then he goes back to the dish after about four minutes and picks up the piece of paper and show it to students. He asks them what they think about purple, is it a mixture or pure? A student says that it is still black, and probably it needs more time. Mark says "that really is a good point, it needs more time to say it is a mixture. But can we say it is pure?" The student replies "No, not yet." Mark replied that we need more time and experimental procedures to be sure that it is pure substances or mixture. Mark asks Chris to start activities with them. Chris asks students to begin work in chromatography activities.

Doing the demonstration of the piece of paper in the dish stimulates some students to talk and ask or answer questions. How does one encourage students to learn actively with lecturing? Is using demonstrations or activities the only way to stimulate the discourse in science classes?
APPENDIX B

UNIVERSITY/COMMUNITY COLLEGE STUDENT QUESTIONNAIRE

BELIEFS, ATTITUDES, AND PERCEPTIONS ABOUT SCIENCE, MATHEMATICS, AND TECHNOLOGY EDUCATION IN FLORIDA

This questionnaire is being sent to university and community college students throughout Florida. Your cooperation in completing this survey will assist our research team to understand what is happening with respect to science, mathematics, and technology education in Florida's universities and community colleges. The information you provide will in no way be used to evaluate you individually and will not affect your grade in this course. Furthermore, your responses will not be released or reproduced in any individually identifiable form. Please base your answers to the survey items on the course you are presently taking. This form should take approximately 30 minutes to complete.

BACKGROUND INFORMATION

A. Date: __________________________ B. Institution: __________________________

C. Please circle your gender: Male Female

D. Please circle the category that best describes your ethnic background:

- African American
- American Indian
- Asian
- Caucasian
- Hispanic
- Other

E. Please circle the number of college credits you've completed:

0-15 16-30 31-45 46-60 61-75 76-90 91-105 106-120+ post-baccalaureate

F. Please circle your current GPA (note: 1st-term students, please circle N/A):

184
Below 2.0  2.0 - 2.4  2.5 - 2.9  3.0 - 3.4  3.5 - 4.0  N/A

G. Please list your major or area of concentration:

H. Course # and name:

I. Please circle your approximate grade in this course:

Below 70  70 - 79  80 - 89  90 - 100

Directions for Parts A & B: Beside each phrase or sentence below, please circle the frequency of occurrence and the importance to you of this occurring in the classroom. There are no right or wrong answers. The correct responses are those that reflect your own personal beliefs, attitudes, and perceptions.

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<thead>
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<tbody>
<tr>
<td>A = almost always</td>
<td>H = high</td>
</tr>
<tr>
<td>O = often</td>
<td>M = medium</td>
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<tr>
<td>S = sometimes</td>
<td>L = low</td>
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<tr>
<td>R = rarely</td>
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<td>N = never</td>
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PART A. TEACHING AND LEARNING

In this class, the instructor:

1. encourages students to use their textbooks.  A  O  S  R  N  H  M  L
2. has students work in cooperative groups.  A  O  S  R  N  H  M  L
3. uses lecture to disseminate information.  A  O  S  R  N  H  M  L
4. encourages student-led discussions.  A  O  S  R  N  H  M  L
5. uses audio-visuals such as films and videos.  A  O  S  R  N  H  M  L
6. uses interactive media such as videodiscs and CDs.  A  O  S  R  N  H  M  L
7. encourages us to use computers and related technologies.  A  O  S  R  N  H  M  L
8. uses computers and related technologies.  A  O  S  R  N  H  M  L
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<td>R = rarely</td>
<td>N = never</td>
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9. arranges out-of-class learning experiences. | A O S R N H M L |
10. arranges seating to facilitate student discussions. | A O S R N H M L |
11. asks open-ended questions. | A O S R N H M L |
12. requires that we use evidence to support answers and claims. | A O S R N H M L |
13. encourages us to ask questions. | A O S R N H M L |
14. encourages us to express our own opinions. | A O S R N H M L |
15. allows us to work at our own pace. | A O S R N H M L |
16. encourages us to consider alternative explanations. | A O S R N H M L |
17. incorporates historical perspectives into lessons. | A O S R N H M L |
18. encourages us to relate topics to applications in society. | A O S R N H M L |
19. provides real-world applications for what we’ve learned. | A O S R N H M L |
20. uses the chalkboard. | A O S R N H M L |
21. integrates material from other subjects. | A O S R N H M L |
22. uses handouts. | A O S R N H M L |
23. provides lists of supplemental reading materials. | A O S R N H M L |
24. discusses learning expectations (i.e., what we are expected to learn). | A O S R N H M L |
25. allows for the different learning styles of students. | A O S R N H M L |
26. uses overheads. | A O S R N H M L |
Importance Frequency
A = almost always
O = often
S = sometimes
R = rarely
N = never
H = high
M = medium
L = low

27. provides extra sessions for those who need more help. A O S R N H M L
28. seems to fear losing control of the class. A O S R N H M L
29. is available for help outside of class. A O S R N H M L
30. uses hands-on experiences. A O S R N H M L

PART B. STUDENT ASSESSMENT

To assess our learning, the instructor uses:

31. multiple-choice questions on tests. A O S R N H M L
32. fill-in-the-blank questions on tests. A O S R N H M L
33. portfolios. A O S R N H M L
34. student self-assessments. A O S R N H M L
35. essay items on tests. A O S R N H M L
36. short-answer items on tests. A O S R N H M L
37. student research papers/projects. A O S R N H M L
38. homework problems/assignments. A O S R N H M L
39. student interviews. A O S R N H M L
40. student journals. A O S R N H M L
41. peer assessment. A O S R N H M L
42. student attendance. A O S R N H M L
43. student participation. A O S R N H M L
44. individual tests. A O S R N H M L
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45. group tests.  
46. in-class tests.  
47. take-home tests.

PART C. ADDITIONAL COMMENTS - Please answer each question below as completely as possible. You may write on the back of these pages if you need additional space.

48. What do you like most about this course? Why?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

49. What do you like least about this course? Why?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
50. What are the best policies, procedures, and activities for enhancing learning that currently exist in this course?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

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51. What policies, procedures, and activities currently exist in this course that you feel inhibit learning?

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52. How should this course be changed so that it improves learning and better meets the needs of students?

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APPENDIX C

Summary Statistics of Prospective Teachers' Perception of Perceived Actions and Its Importance in Chemistry Classes

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APPENDIX C. (Continued)

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Note. Med = Median; Min = Minimum; Max = Maximum; St = Standard resources utilized and/or advocated; TT = Teaching Techniques; Tech = Technology resources utilized and/or advocated; O-of-C = Out-of-Class provisions; Env = Structuring of learning Environment; RW = Connection to Real World; AT = Assessment Techniques.
APPENDIX D

NUDIST Tree

Level 1
  Level 2
    Level 3
      Level 4

Culture
  Context
    Beliefs
      Mark
      Students
  Strategies
    Demonstrations
    Group Work
    Lecture

Roles and Metaphors
  Metaphors
    The Trip Metaphor
    The Trip of Learning
  Roles
    Tour Guide
    Learner
    Entertainer
    Controller

Environments
  Learning-Oriented Env.
    Mark's View
    Students' Views

Discourse
  Verbal
  Written
APPENDIX E

HUMAN SUBJECTS COMMITTEE APPROVAL LETTER

Florida State UNIVERSITY
Office of the Vice President
for Research
Tallahassee, Florida 32306-3067
(904) 644-5260 FAX (904) 644-1464

APPROVAL MEMORANDUM
June 21, 1995

TO Abdullah O. Abbas
(Curriculum and Instruction)

FROM Betty Southern Chair
Human Subjects Committee (IRB)

Re: Use of Human Subjects in Research
Project entitled: The Teacher's Role in College Level Classes for Non-Science Majors: A Constructivist Approach for Teaching Prospective Science Teachers

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be exempt per 45 CFR § 46.101(b)(2) and has been approved by an accelerated review process. You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report in writing any unexpected problems causing risk to research subjects or others.

If the project has not been completed by June 21, 1997 you must request renewed approval for continuation of the project.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to ensure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is M1339.

BS/uh
cc: P. Gilmer/3006
human/exempts.asp
APPLICATION NO. 96.183
APPENDIX F

CONSENT FORM

I freely and voluntarily, and without any element of force or coercion, agree to participate in the research project entitled, "The Teacher's Role in College Level Classes for Non-Science Majors: A Constructivist Approach for Teaching Prospective Science Teachers." I understand that I can withdraw my consent/participation at any time without penalty and have the results of my participation, to the extent that it can be identified as my own, removed from the experimental records or destroyed.

I understand the following points with respect to this research study:

1. This research about science teaching and learning in the physical science course is being conducted by Abdullah O. Abbas, a graduate student at Florida State University, Department of Curriculum and Instruction, Science Education Program, 207 Milton Carothers Hall, Tallahassee, Florida, 32306, (904) 644-1263. The physical science classes have already been videotaped during the Spring, 1996 semester. Participation in the study will involve an initial audiotape recorded interview of between 30-60 minuets. Following the initial interview I will be provided with a transcribed copy of what was said. The purpose of providing the transcription is to allow me to correct errors or to make changes. When the researcher needs to obtain clarification on some points and elaboration on others, I agree to schedule additional interviews. I understand that the researcher will search for patterns of meaning in the interview transcripts which will become the data for the study. I may contact the researcher for answers to questions that I have now or during the course of the research.

2. The purpose of this research is to investigate the teaching and learning in a physical science course for prospective teachers. Possible benefits resulting from this study may include the formulation of guidelines for the reform of the teaching and learning of science in college level classes.

3. My participation will include:
   • Taking part in an audiotape recorded, in-person interview of approximately 30-60 minutes. During this interview, I will be asked to provide the following information about: (a) the teaching and learning of science in the classes of the physical science course; (b) teaching strategies or methods used by the instructors; (c) the ways of assessments used in the class; and (d) my subjective views of the teaching/learning activities and the instructors.
   • Checking/reviewing transcripts of my interview to verify their
correctness and to provide additional relevant information.

- Taking part in follow-up audiotape recorded interviews to obtain information on issues that emerged in earlier interviews. I understand that these interviews will be scheduled at my convenience.
- Signing and returning this consent form and my interview transcripts.

4. Participation entails only minimal foreseeable risks. And discomforts or stresses that I may face during this research are limited to uneasiness felt as a result of participating in interviews. Interviews will be scheduled at my convenience and will be conducted in person at Milton Carothers Hall on the Florida State University campus.

5. The result of participation in this research will be confidential and will not be released in any individually identifiable form without my prior consent. The use of pseudonyms and data coding will be employed in transcribed interviews, reports, journal articles, and other documentation to maintain confidentiality. All audiotapes, interview transcriptions will remain in possession of the researcher during the course of this project. The audiotapes and transcriptions will be stored in a locked filing cabinet. Upon project completion, which is expected to be done by August 1, 1997, all audiotapes will be erased, and all transcriptions will be destroyed.

__________________________________________  ______________________________________
Signature of Participant                        Signature of Witness

__________________________________________  ______________________________________
Date                                           Signature of Researcher
REFERENCES


Research in Science Teaching, 30(6), 547-559.


Erickson, F. (1986). Qualitative methods in research on teaching. In M.C. Wittrock (Ed.), Handbook of research on teaching. (3rd Ed.) (pp. 119-159). New York: Macmillan.


evaluation of myths. A paper presented in the annual meeting of the National Association for Research in Science Teaching, St. Louis, MO., 31 March - April. 1996.


201


Taylor, P. C. S. (1995). *College teaching of science and mathematics in Florida: A preliminary foray into the field.* A report was undertaken in the Florida State University and supported by the Florida Department of Education through the Dwight D. Eisenhower Program for Post-secondary Education.


Francisco, CA.


Abdullah O. Abbas was born in Taiz Governorate, the Republic of Yemen, on February 1, 1952. He completed secondary school on 1974, then he taught in an elementary school for one year. In 1976, Abdullah continued his education in the Faculty of Education at Sanaa University and received a B.S. in science education with major in biology in 1979. After graduation, he taught science in middle and high school for a year. He went back to the Faculty of Education in which he was appointed as a teaching assistant.

On September 1982, Abdullah left Yemen to the United States to study Master degree. He got admission from Indiana University to study in Health Education program. He obtained his Master degree on April 1984 and left back home. He worked in the School of Education at Sanaa University for about eight years. In addition to teaching science teaching methods and science curriculum for several semesters in science education department, he taught the health education course for about eight years. Furthermore, he supervised science students during their teaching practices in high and middle schools.

On the Fall of 1993, Abdullah was admitted to the Florida State University to study for the Ph. D. in science education. He was awarded the Ph. D. on 1997. Abdullah is currently employed as an Assistant Professor at Sanaa University.