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Personal Practical Theories, Self-Identity, and Astronomy Teachers' Interactive Decision Making

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Personal Practical Theories, Self-Identity, and Astronomy Teachers' Interactive Decision Making

by

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In Memoriam

Elanor Michelle Richmond

1978-1997

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My youngest daughter, Elanor Richmond, probably suffered my neglect the most. Since I entered graduate school about the time she entered her junior year of high school, I missed some things I should not have missed. I missed band functions and football games; I missed being a member of Band Parents and PTA. Mostly, I missed being there when Elanor needed me. A cell phone is a poor substitute. Whatever I missed, it is now too late to make amends. Elanor was killed in an automobile crash near Kingman, Arizona on July 13, 1997. My arms ache to hold her one more time. I will miss her so long as this life endures.

Personal Practical Theories, Self-Identity, and Astronomy Teachers' Interactive Decision Making

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Research has suggested that beliefs play a major role in selecting and defining teaching tasks and organizing the knowledge needed to perform those tasks. Teachers, consciously or unconsciously, depend on beliefs because they work in ill-structured domains where traditional problem solving techniques and academic knowledge do not work as well.

The goal of this project was to establish, if possible, a causal link between teacher beliefs and interactive decision making through empirical, qualitative research. The hypothesis was, that when faced with those sorts of situations, the participants would fall back on belief systems that did not necessarily have a rational basis.

The research focused on astronomy teachers in community colleges. Since most science reform efforts are directed toward primary and secondary schools, community college science teaching remains a neglected area of study. Yet community colleges are

predicted to play an increasingly important role in higher education in the near future. For many students, community college science classes may represent their last encounter with formal, academic, science programs.

The three participants were interviewed and observed in the classroom over an extended period. Initial interviews were conducted with each participant to capture stated beliefs. After the extensive classroom observations, stimulated recall interviews were held with each participant viewing short, edited segments of the classroom videotapes.

No direct causal link between beliefs (in the conventional sense of the word) and participant decision making is apparent from this empirical research. However, the construct of personal practical theories, which includes beliefs as one component, shows promise as a significant determining factor in interactive decision making. Themes have been developed that represent each participant's personal practical theories. The strongest theme, applicable to all participants, is based on the notion of extemporaneous lessons within a structured context of an implied contract between the students and the teachers. The terms of this implied contract are found in the administrative constraints, the systemic constraints, the personal restraints of the participant teachers, and the personal restraints of the students. The name assigned to this unifying theme is "planned spontaneity." While sounding like an oxymoron, it concisely suggests the kind of flexibility required of all teachers who are faced with an ever shifting classroom environment.

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Chapter One
Introduction and Background

The closely related ideas of personal practical theories, teacher's self-identity, teacher's perceptions of students, the variety of beliefs about pedagogy and effective instruction, and other beliefs held by teachers may all play a significant role in the complex daily interactive decisions required of in-service community college astronomy teachers. All of these various ideas can be gathered together as a single construct called in this paper simply "beliefs."

BELIEFS

Beliefs play a major role in selecting and defining teaching tasks and organizing the knowledge needed to perform those tasks (Munby, 1982; Nespor, 1987; Brickhouse, 1990). Jan Nespor (1987, p. 323) asserts that, "to understand teaching from teacher's perspectives, we have to understand the beliefs with which they define their work." Teachers, consciously or unconsciously, depend on beliefs because they work in ill-structured domains where traditional problem solving techniques and academic knowledge do not work as well (Nespor, 1987). How do teachers make decisions in these ill-structured domains? How do community college astronomy teachers decide how to proceed through a lesson, especially when unexpected events happen. Stated as a research question, this becomes "given a particular situation, how do teachers decide what to do?" (Munby, 1982, p. 203) It would appear that in order to answer this interesting question, teacher's beliefs must be examined.

When beliefs are examined, intriguing and sometimes contradictory results appear. For example, Nancy Brickhouse (1990) found striking differences between experienced and inexperienced teachers. The experienced teachers were consistent from day to day and expressed personal philosophies that were apparently consistent with their classroom actions. The inexperienced teachers were more unpredictable. Brickhouse states "Unlike the experienced teachers, [the inexperienced teacher] had not reconciled his own conflicting beliefs or the impact of institutional constraints on his teaching." (Brickhouse, 1990, p. 60) In another article drawn from the same study, Brickhouse states that science teacher's thinking about instruction and task selection is often separated from the teacher's knowledge of the discipline (Brickhouse & Bodner, 1992).

In contrast to the suggestion that beliefs are powerful predictors, some researchers have found glaring inconsistencies between beliefs and practice. For example, in research with teachers of English as a second language, Rebecca Herman found that teachers' stated beliefs were often at odds with classroom practice (Herman, 1995). According to Herman, many of the teachers asserted that music and song were the most effective ways to teach a new language. In addition, most observed classrooms had sound reproduction equipment and suitable recorded materials available. Yet no teacher was ever observed utilizing the materials. Nor was Herman ever able to determine any specific reason for this failure. She speculated it was due to administrative constraints and pressures of standardized testing (Herman, 1995). If science education reform, teacher development programs, and national curriculum efforts are going to be successful, we must examine how teachers make instructional decisions and what restraints, if any, prevent them from acting. We are not served well if these efforts overlook or neglect any factor teachers use in task selection and definition. Furthermore, if all of these change recommendations overlook the psychological foundations of teaching science, including teacher's beliefs, knowledge, and attitudes (Ernest, 1989), change is not likely to be effective or beneficial.

WHAT ARE BELIEFS?

Defining beliefs is problematic. This report uses the definition that teacher beliefs are notions that teachers accept as true without empirical evidence and without a compelling, non circular argument in support of the notion. Religious beliefs, such as belief in a divine being or belief in the efficacy of prayer, certainly fall into this category. (An example of a compelling but circular argument would be arguing that God exists based on evidence found in the Bible or the Qur'an.) Other notions teachers hold also fall into this category. In no particular order, these would include statements such as "some students just can't learn," "teachers teach as they have been taught," "education courses are a waste of time," and similar notions. Many of these ideas might be true, but have not been investigated. Others are demonstrably false, but teachers still hold on to the ideas.

Pajares (1992, p. 309) defines beliefs similarly as "fundamental assumptions that can be reasonably made." Pajares lists several characteristics of beliefs (primarily based on research with pre-service teachers):

- Beliefs about knowledge are well established by the time a student gets to college.
- The earlier a belief is incorporated, the more difficult it is to alter.
- Individuals develop a belief system that houses all beliefs acquired through the process of cultural transmission.
- Belief change during adulthood is a relatively rare phenomenon, the most common cause being a conversion from one authority to another or through a Gestalt shift.

Teacher beliefs are an important factor in designing and successfully implementing change in schools and colleges. Research has consistently shown replicable links between teacher beliefs and the success or failure of change efforts, especially as those efforts depend on changing teacher's thinking (Cooney & Hirsch, 1990; Gess-Newsome, Southerland, Johnston & Woodbury, 2003).

Teacher's Perceived State of the Learner

Englert and Semmel (1983), in an article on reading research. suggested that an important variable governing teacher behavior is the teacher's perceived state of the learner. This includes reading achievement, mathematics achievement, class participation, gender, and problematic behaviors. In community college classrooms, it is rare for instructors to have more than minimal background information on students. What information instructors do have is generally gathered through short surveys and misconceptions tests given early in the semester. The remainder of the teacher's perceptions of the students is built up through classroom interactions and responses to examination questions. In their study of elementary reading education, Englert and Semmel concluded that teachers form hypotheses about a student's ability based primarily on student miscues (Englert & Semmel, 1983). Teachers assessed the probable state of the learner when miscues indicated that students had lost track of the meaning of the lesson. They interrupted the lesson flow only when errors made by the students indicated significant misunderstanding. However, teachers often failed to redirect the students attention to the source of the error. They either lacked sufficient time to make decisions about appropriate treatments, or they lacked skill in matching treatments to errors.

Teacher Self-Identities

Drake and others examined the effect of teachers' identities (as teachers and learners) on their teaching and learning practices (Drake, Spillane & Hufferd-Ackles, 2001). Individual self identities or personal identities can be understood through the stories they tell (Bruner, 1990; McAdams, 1993). These stories help others understand how individuals know themselves and their social situation. Thinking about self-constructed identities has become a popular approach to research on teachers (Connelly & Clandinin, 1999a; Connelly & Clandinin, 1999b). Teacher's stories encompass many different beliefs and sets of beliefs and can possibly form a metaphorical lens through which a researcher can examine teacher decision making.

Participants' Perceptions of Self-efficacy

A teacher' belief of self-efficacy is a teacher's judgement about how capable he or she is to bring about certain educationally desirable outcomes. Albert Bandura first introduced the idea of self-efficacy in 1986 (Bandura, 1986) and has developed and expanded the ideas in several subsequent papers (Bandura, 1994; Bandura, 1997; Bandura, 1998; Bandura, 2001). Other researchers have attempted to apply Bandura's ideas in educational settings (Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Tschannen-Moran & Woolfolk Hoy, 2001; Shaughnessy, 2004). Several teacher efficacy scales have been developed, following the guidelines established by Bandura (Bandura, 2001). The number of participants in this study limit the usefulness of any quantitative measures, such as measures of self-efficacy, but it may be instructive to at least compare the self-efficacy of the participants using a standard form with other sample groups.

Personal Practical Theories

Julie Gess-Newsome and others studied the anatomy of change in college science teaching. They found that personal practical theories were the strongest influence on instructional practice. They state that "to create and sustain fundamental change, there must be specific and concentrated attention to the personal practical theories of the faculty involved. Change in practice requires dissatisfaction with the teaching and learning goals established for students, beliefs about students and how they learn, and beliefs about the effectiveness of instructional practices used to meet newly established goals." (Gess-Newsome, Southerland et al., 2003, p. 762)

NATIONAL CURRICULUM EFFORTS

Change is urged on teachers and schools because researchers, administrators, politicians, scientific societies, and other professional groups all criticize science education for various reasons. Researchers assert that teachers do not use the latest results of cognitive science in lesson design and teaching practice. Administrators are faced with pressure to keep test scores up and costs down. Politicians suggest that the United States is falling behind other countries in economic competitiveness (United States, 1984). The scientific societies assert that the curricula and textbooks are inadequate. Since all of these stakeholders are pushing for change, it may be a good time to see just what teachers are doing in the classroom, right or wrong. Most of the pressure for change is directed toward public schools. However, community colleges provide an important transition between secondary schools and other academic institutions and there have been several recent research efforts directed toward community college curriculum reform (Palmer, 2000; Allen, 2002; Taylor, 2002; Gess-Newsome, Southerland et al., 2003; Watts, 2003).

Whether the situation in science education is as abysmal as it is frequently characterized is a matter of debate. For a different viewpoint, David C. Berliner (1993) suggests the bleak picture of American education painted by the news media and others is in error. He counters that today's high school and college graduates are smarter, more productive, and have higher achievement scores than their counterparts of two decades ago. Berliner suggests that the United States actually has a surplus of trained scientists and engineers at the same time that the demand for highly qualified people is expected to continue to decrease (Berliner & Biddle, 1995. p. 102).

The Community College and Science Teaching

Community colleges are predicted to play an increasingly important role in higher education in the near future (Texas Higher Education Coordinating Board, 2001). In a certain mid-sized metropolitan area, the largest public university in the state serves around 50,000 students, while a local community college in the same area serves around 35,000 academic students. The Texas Higher Education Coordinating Board has recommended that 500,000 students be added to Texas higher education rolls by 2015 (Texas Higher Education Coordinating Board, 2001). Since it would appear to be unlikely that 10 major universities could be added to the state in a decade or so, it would appear to be impossible to add that many higher education students unless community colleges and other small colleges play a significant role (Texas Higher Education Coordinating Board, 2001; Roueche, 2003). The Texas Higher Education Coordinating Board expects 60% of the growth in higher education enrollment to be through public community colleges and technical colleges (Texas Higher Education Coordinating Board, 2001).

Many of the persons served by the community college are in programs that require only one or two semesters of science, thus community college science classes may represent their last encounter with formal, academic science programs. In spite of this, community college science teaching remains a neglected area of study. The great thrust of research in science teaching has been in secondary schools. Much work needs to be done in community colleges to improve instruction and to design curricula that fit the needs of both the academic and professional students.

Change and Science Education Reform

One reason for examining teacher's practice is the internal and external pressure for change in science teaching. Internal change efforts arise with science teacher organizations and science teachers who have long understood that the information dense, "final-form" science curricula of the past is no longer satisfactory or acceptable (Hilborn & Howes, 2003). External pressure originates from national and state legislatures and governors, major corporations and others who would like to blame America's declining competitiveness on the schools (Bracey, 1997). A different form of external pressure arises with national scientific organizations, such as the American Association for the Advancement of Science (AAAS), who are motivated by a genuine spirit of public service and by well-formed notions about how science should be taught. All of these stakeholders press for science education reform.

Pressure for change and curriculum reform efforts are also moving into community colleges. While community colleges have not been at the forefront of science education reform efforts, there has been some recent movement toward reform of college science teaching (Feldman, 2000; Gess-Newsome, Southerland et al., 2003). Recent publications, such as *College Pathways to the Science Education Standards* (Siebert & McIntosh, 2001) and efforts by the National Science Teachers Association both encourage and facilitate the adoption and incorporation of science standards-based teaching at the college level (Bowen, 2001; National Science Teachers Association, 2003).

TEACHER DEVELOPMENT PROGRAMS

Most secondary school teachers are prepared by graduate schools of education, including alternate certification programs. The University of Texas at Austin has initiated an innovative teacher certification program called UTeach that seeks to address the chronic shortage of science and mathematics teachers. This pathway to teacher certification allows students to complete a bachelor's degree in a discipline and obtain teacher certification within four years.

In contrast, most community college teachers receive little or no formal training (Roueche, 2003). Even when formal professional development programs are in place, research has shown that future teachers enter professional preparation programs with well-formed beliefs about education and leave with those beliefs intact (Pajares, 1992). No amount of classroom time, workshop time or other training will be effective unless teaching practice actually changes. Teachers may intend to change, may believe they have done so, yet still be teaching in an outmoded or ineffective way. In addition, there are many barriers that teachers must overcome, including administrative barriers, inadequate classrooms, inadequate training, inadequate textbooks, and others. Furthermore, teachers may not be aware that their teaching practice is apparently inconsistent with their stated beliefs about teaching (Gess-Newsome, Southerland et al., 2003). Nespor (1987) argues that these beliefs, unlike knowledge systems, do not require validation or consensus. They do not even require internal consistency. Teachers with similar knowledge backgrounds may teach in very different ways, apparently influenced by different beliefs (Ernest, 1989).

Several universities now offer professional degree programs leading to certificates in community college teaching (Iowa Community College, 2003; Watts, 2003). However, few community colleges require certificates or any other specialized training (Roueche, 2003). Only two states have any sort of state-wide certification program for community college instructors. Iowa requires a community college teaching certificate and has a state-wide program. Arizona ended its state community college certification program in March of 2002 and made each community college district responsible for certifying its own teachers (Pima Community College, 2003).

Consequently, community-college instructors often receive little specialized professional training (Roueche, 2003). Most of the training community college instructors receive is “on-the-job” or is through a local professional development program, through professional associations, or through the National Science Foundation Chautauqua programs. Since three or four years of instruction in pedagogy has little effect on secondary school teacher’s beliefs about education, it is unlikely that the informal training received by most community college instructors will have any significant impact on previously held beliefs.

Teacher development programs generally incorporate the latest findings of education research. So teachers in training should be well informed about the latest research. However, this may not be true for teachers in service, whether in secondary schools or community colleges. Mestre and Touger (1989), citing cognitive research, misconceptions research, and expert-novice research, characterize the state of research about physics teaching as sufficiently rich in findings that teachers may begin to benefit from the research. Efforts such as those by the American Association of Physics Teachers to train individual teachers throughout the United States to serve as resource agents are successful, yet most teachers do not benefit from these endeavors. For example, many physics teachers are not aware of misconceptions research in physics and may hold misconceptions themselves (Berg & Brouwer, 1991). The problem now, according to Mestre and Touger, is communication between researchers and teachers. This lack of communication between researchers and teachers continues. Recent conventions of the National Association for Research in Science Teaching (NARST) have been attended almost exclusively by researchers (Murray, 2002). Few secondary school teachers or community college instructors are interested in attending, unless they are actively participating in research. Few are able to attend even if they are interested due to lack of financial resources and lack of release time (Murray, 2002). Community college faculty are not interested in participating in professional development programs they perceive as irrelevant, inefficient, and unfocused. Articles discussing the findings of cognitive research are not read by teachers and the predominant audience at conferences and meetings is other researchers (Sligh, 2002). Since the 1970s, there have been efforts toward improving and increasing professional development opportunities for community college faculty (Murray, 2002; Outcalt, 2002). Nevertheless, not enough information is getting to the practicing classroom teacher. Curriculum support materials, textbooks, and ancillaries "remain essentially untouched by the research" (Mestre & Touger, 1989, p. 447). Enrolling the teacher as a co-researcher may serve as one method practicing teachers may gain access to research findings.

Investigation of teacher's beliefs is an important but little utilized approach to improving teacher development. Researchers have found that exploring the nature of beliefs is rewarding and the findings suggest powerful relationships between beliefs and planning, instructional decisions and classroom practices (Gess-Newsome, Southerland et al., 2003). However, beliefs remain a poorly defined construct (Pajares, 1992). Many researchers have suggested that qualitative research methods are the best and most promising approach (Munby, 1982; Munby, 1984; Schunk, 1991; Brookhart & Freeman, 1992).

Pajares states, "Little will have been accomplished if research into educational beliefs fails to provide insights into the relationship between beliefs, on the one hand, and teacher practices, teacher knowledge, and student outcomes on the other" (Pajares, 1992, p. 309). How are teacher preparation institutions to be effective in teacher preparation programs without research that identifies beliefs consistent with effective teaching practices?

Current research indicates strongly that effective change must originate with the teachers and in the schools themselves. In order to produce change, teachers must be given the tools and techniques necessary to become change agents. Traditional research models, with an independent and presumably dispassionate researcher objectively observing the classroom and writing recommendations in various professional journals, do not provoke effective change in the classroom. To change, teachers must themselves become researchers. If teachers are able to identify problem areas and at the same time develop an active research stance, change may be possible. From the viewpoint of critical theory (Carr & Kemmis, 1986), teachers must move beyond empirical-causal and hermeneutic-interpretive forms of knowledge to emancipatory knowledge. This is only possible when teachers become aware of knowledge distortions (Freire, 1970).

PURPOSE OF STUDY

> A field worker who approaches a strange people soon perceives that these people are saying and doing things which they understand but he does not understand. One of the strangers may make a particular gesture, whereupon all the other strangers laugh. They share in the understanding of what the gesture means but the field worker does not. When he does share, he begins to understand. He possesses a part of the "insiders view" (Wax, 1971, p. 11).

The purpose of this study is to gain an "insider's view" of how teachers' beliefs affect their decision making and task definition and selection. Unlike the people referred to in the quote, astronomy teachers are not a strange people, at least not very strange, and the participants in this study speak the language and understand the gestures of the other participants. Nevertheless, deeper understanding of the processes teachers use to make decisions in the classroom is possible. Like all studies of this type, the purpose, in Wax's language, is to "understand" teaching and teachers, to gain an "insider's view." In particular, the purpose of this study is to elicit the beliefs of in-service astronomy teachers about effective astronomy instruction, beliefs about the purpose of astronomy instruction, and beliefs about the purposes of instruction in general, while at the same time observing the practice of these teachers in classroom settings. From these two sets of data, it may be possible to gain insight into the relationships between beliefs and behaviors, while recognizing that beliefs are very hard to identify and are at the same time powerful determinants of behavior (Dewey, 1933; Rokeach, 1968; Nisbett & Ross, 1980; Bandura, 1986). Individual teacher's stated or actual beliefs about good astronomy instruction, the purpose of astronomy instruction, the role of astronomy teachers, and the value of recent educational research may or may not be obviously revealed in the teacher's classroom practice.

By working directly with the researcher in a close collaboration with common goals, the participants will themselves become researchers, learning to be self-reflective, and learning to be practitioners guided not by the pursuit of fixed goals and the certainties of known techniques, but guided instead by "criteria for the process itself: criteria based on experience and learning which distinguishes educational processes from non-educational processes and which separate good from indifferent or bad practice" (Carr & Kemmis, 1986, p. 37).

In my years of teaching high school physics and astronomy, I had few opportunities to stop and reflect on practice. Creating opportunities for self-reflection is is a significant lack in teacher in-service training and professional development. Staff development never addressed this problem and even served to reduce the amount of time potentially available for self reflection.. Other teachers have expressed similar concerns (Tomanek, 1994). While trying to shape or change teacher's beliefs "from the outside" would be ineffective and contrary to my own personal convictions, helping teachers become self-reflective and conscious of their own beliefs would be an appropriate response. So encouraging and enabling myself and other teachers to become more self-reflective is the other and possibly more significant goal of this study.

The research will focus on astronomy teachers in community colleges in Central Texas. As stated in a previous paragraph, most of the science reform efforts are directed toward secondary schools and lower, yet the community colleges play an increasingly important role in providing a transition between high school and college or providing professional preparation for a wide variety of different fields from commercial art to industrial welding. An additional reason for using community college teachers is purely practical. Access to a classroom of primarily adults is significantly easier than a classroom of public school children. Since community college astronomy classes are generally elective courses that stand apart from the rest of the curriculum, a third reason is to possibly avoid the curricular and administrative restraints that could obscure other more interesting relationships that might emerge when comparing beliefs to practice. As an example, in a course that is part of a sequence where a standardized curriculum is imposed, there might be fewer opportunities for an instructor to deviate from a lesson plan. For instance, most students that take Engineering Physics I will go on to take Engineering Physics II. Consequently, the core curriculum of Engineering Physics I takes up most of the available class time.

While one of the suggestions of this paper is that community college instructors should become participant researchers who examine their own practice, at present astronomy instructors and other community college instructors are primarily classroom teachers, not academic researchers, administrators, coaches, or other dual role holders. Therefore, the fourth reason is that most community college instructors are focused on the classroom task.

Fifth, I am a community college astronomy instructor, I have been a community college astronomy instructor in the past, and probably will continue to be in the future. Thus I have a particular insight into the community college teaching environment while at the same time I have a special interest in the outcomes of this research beyond completion of degree requirements.

A final reason for studying astronomy teachers is the nature of the discipline itself. Astronomy is in many respects like physics, a structured discipline with a well defined set of problems and relatively well defined rules for solving those problems. On the other hand astronomy courses normally include many literary and humanistic elements, especially as they are taught at the introductory level with emphasis on the history of astronomy and the personalities and lives of well known astronomers. In this respect, astronomy may be more like an ill-structured domain. The types of models about thinking used in well-structured domains are significantly different from the models used in ill-structured domains (Donald, 1992). Thus astronomy, with its combination of well- and ill-structured components may offer insights into teacher decision making not available in a more well-structured domain like physics.

RESEARCH QUESTIONS

According to Pajares (1992), the investigation of beliefs is a necessary and valuable avenue of educational inquiry, but it is lightly traveled. While Pajares emphasizes the importance of investigating the beliefs of beginning and pre-service teachers, beliefs of practicing teachers also deserve study. Especially since research shows teachers apparently graduate from teacher preparation institutions with liberal ideas about education that gradually return to more conservative notions during service (Veenman, 1984).

The goals for this study can be stated in the form of six closely related questions:

1. What are teachers' stated beliefs about the nature of effective astronomy instruction?
2. What are teachers' perceptions of the purpose of teaching?

3. What teacher beliefs about the nature and purpose of effective astronomy instruction can be extracted from observed teacher behaviors?
4. What specific classroom practices do teachers use?
5. Is it possible to identify a relationship between specific classroom practices and stated or implicit belief systems?
6. Does teaching practice change when teachers begin to reflect on their own beliefs and practice?

ORGANIZATION

This dissertation is divided into three main parts. The first three chapters cover the background, theoretical basis, and methods used in the research. Chapter One is an introduction. Chapter Two defines the study and discusses related research, the theoretical framework, and the physical and human environment in which the research was conducted. Chapter Three describes the research processes used.

The second part of the dissertation is Chapter Four, which describes, compares, and contrasts the three participants, including educational background, professional training, and other pertinent information.

The third and last part of this dissertation includes Chapters Five and Six. Chapter Five is an analysis of the collected data. Chapter Six proposes a theoretical structure for interpreting the data and concludes with suggestions for further research.

Chapter Two
Defining the Study: Working With Teachers

The body of research concerning science teaching reform is enormous. However, little research exists about the current practice of classroom teachers observed in context, especially the contrast between stated or implied beliefs and actual classroom practice. There is little or no information concerning how the classroom decision-making of community college instructors might be related to their beliefs. People are frequently required to make important decisions based on insufficient information, that is information about all of the possible consequences of their decisions. Teachers must make many decisions in the classroom, while engaged in teaching, with only scanty information about the possible outcomes. Community college astronomy teachers are no different.

RELATED RESEARCH

The literature review has long been considered to be central to the research process. However, in recent years, debate has arisen over where this literature review should be placed and when it should occur. For example, Barney Glaser asserts, "There is a need *not* to review any of the literature in the substantive area under study" (emphasis added) (Glaser, 1992, p. 22). This dictum arises from Glaser's conception of true grounded theory and is based on the notion that too much knowledge of the substantive area will lead to a forcing of theory, rather than allowing the theory to grow out of the data. This possibly wise course has obviously not been followed here, primarily because (unlike a field sociologist) the participants already had an intimate knowledge of many aspects of the subject area and preconceived notions of how to proceed.

The use of technology has changed the process of literature review. Bibliographic references for the literature related to this project have been stored in a commercially available electronic database. This software also simplifies the placement of citations in the text and automatically formats the bibliography based on the in-text citations. This makes it possible to keep the bibliographic data base constantly up-to-date, since new references can be added at any time, even at the last minute. With this or similar technology, it is no longer necessary or even desirable to make the literature review a discrete research phase. Instead, researchers are now free to use an integrated approach to literature review. This is especially useful in qualitative studies where emerging theories are the goal, rather than hypothesis testing.

The way literature is used has also changed. Alexander Massey writes, "[O]ne cannot sensibly say what a literature review is, what it is for, where to put it, or whether to have one at all, until one has thoroughly explored why . . . we might even want to refer to what others have said and done. . . . What counts as authority? Where can it be found? Why do we need it?" (Massey, 1996, About the title ¶ 2) This newer approach to the literature review also changes how referenced literature is presented in the report. Instead of being collected into a single chapter, references to pertinent literature may be distributed throughout the report where they can be placed in context and directly related to emerging ideas. However, it is still good practice to start with an overview of relevant literature.

Nancy Brickhouse (1989) studied teachers' subject matter knowledge and its relationship to classroom practice. Hewson, Kerby, and Cook (1995) describe a process of determining a teacher's conception of teaching science by using an interview task. Jan Nespor, as part of the *Teacher Beliefs Study* (Nespor, McCuller & Campos, 1984; Nespor, 1984a; Nespor, 1984b; Nespor, 1985; Nespor, 1987), used preliminary interviews, classroom observations, and stimulated recall interviews to examine the relationships between beliefs and task definition, memory processes, and problem solving in ill structured domains (Nespor, 1987).

Some information about the process of observing physics classes is available in a study done by Jonathan Keister (1990). Mr. Keister documents and analyzes teachers' and students' activities during physics practicals in order to gain critical insights into why students did not acquire the expected practical skills and how theory and practice interacted in the context of teaching. Data obtained included observations from four physics lessons, five physics practical classes, and one laboratory demonstration, as well as from nine interviews. Data were analyzed and discussed in light of the teaching methods and barriers that seemed to inhibit students' understanding of scientific concepts.

Wolff-Michael Roth (1990) develops models about how beliefs in fundamental philosophies, such as collaboration and constructivist teaching, might be reflected in classroom practice. Roth provides some examples of teaching practices that are compatible with the constructivist view of learning in a social and collaborative context and discusses basic beliefs and central metaphors of teaching, sources of case materials, teaching events, and reflections from a semiotic perspective.

THEORETICAL FRAMEWORK

The complexity of the interaction between teachers, students, and astronomy curriculum in the classroom suggests that a qualitative approach is most appropriate for this study (Marshall & Rossman, 1999). A teacher must draw on knowledge from multiple domains in order to be successful (Leinhardt & Greeno, 1986). What a teacher needs to know to teach and how that knowledge should be acquired and applied has been a central theme of education research and philosophy since the time of John Dewey.

Teachers as Study Subjects

There has been a tremendous increase recently of interest in how teachers think and what they know. The perception of teachers has partially changed to one of practicing professionals whose thought processes are worthy of study (Clark & Peterson, 1986). This changing perception has resulted in a number of different studies revealing aspects of teacher's knowledge. For example, Shulman (1986) classifies teacher's knowledge into:

- subject matter knowledge, including facts, concepts, and relative importance of each
- pedagogical content knowledge, including understanding of what makes certain concepts and topics difficult
- curricular knowledge, including alternatives and connections to other areas of knowledge.

Although this study will focus on pedagogical content knowledge and beliefs, Wilson, Shulman, and Richert (1987) emphasize that these are not separate blocks of knowledge. All are interrelated in many different ways. The description of teacher knowledge that results from these and other studies portrays teacher knowledge as fluid, contextualized, drawing from many different sources, and used for a variety of different purposes.

Teacher Thinking

Clark and Peterson (Clark & Peterson, 1986) have conducted research into teacher thought process. They assign teacher thought process to three separate categories: teacher planning, teacher's interactive thoughts and decisions, and teacher's theories and beliefs.

The last two categories and any possible connection between them are the focus of this research.

A number of different methods exist for identifying and evaluating teacher thinking. Kagan (1990) identified five different types of methods, direct assessment, analysis of teacher's descriptive language, taxonomies, teacher constructed concept maps, and methods combining questionnaires with interviews and tasks. This research combines analysis of teacher's descriptive language with interview tasks and stimulated recall interviews.

It seems obvious that teacher thought processes determine teachers' behavior and that is the fundamental assumption of all research into teacher behaviors. An equally obvious corollary is that to change teacher behaviors requires changing teacher thought processes. It is not so obvious that observing teacher behaviors will unambiguously reveal teacher thought process. Before identifying and evaluating teacher thinking two models of teacher thinking currently popular in the literature should be discussed. These are the decision making model and the information processing model.

The Decision Making Model

This model was first described by Shavelson (1976; 1979; 1981). It contains four parts, alternative acts, states of nature (student cognitive states, affective states, and environmental conditions), teacher utility (in terms of student learning), and student goals. In the 1976 paper, Shavelson acknowledges the problems associated with the model.

To what extent can teachers identify alternative acts? Can they estimate accurately the probability that each state of nature characterizes the learner? Can they estimate the probable outcomes of a particular teaching act under a particular state of nature? (Shavelson, 1976, p. 386)

Shavelson goes on to state, "Inconsistencies in goal setting may arise from inconsistencies in teacher's beliefs about the nature of children, beliefs about themselves and their roles as teachers, and beliefs about the aims of education and how to achieve them." (Shavelson, 1976, p. 404)

The Information Processing Model

The information-processing model postulates that there are three distinct structures in the human information-processing system: an intake register or sensory system that receives the information, a working memory, and a long term memory (Romberg & Carpenter, 1986). In this model, all information enters through the intake register, but can only remain there for a relatively short time. Unless the information moves to working memory, it will be lost. In working memory, new information is combined with information from long term memory. Working memory is the seat of consciousness. However, working memory is limited in capacity. Current models of information processing suggest that humans have a limited capacity to process new information. When too much information is received at the same time, working memory becomes overloaded.

According to Barak Rosenshine and Robert Stevens (1986), there is a close correspondence between the results of research on information processing, and research on effective teaching. The results from information processing research relate to the limits of working memory, the importance of elaboration and practice, and the importance of additional practice to achieve fluency (to assure storage in long term memory).

There have been several different models proposed to explain interactive decision making by teachers in terms of information processing (Peterson & Clark, 1978; Shavelson & Stern, 1981). More recently, Clark and Peterson have suggested a revision of teacher's interactive decision making models (Clark & Peterson, 1986). Their new model is based on two assumptions: (1) Teachers are not choosing between two or more alternatives, but rather are choosing whether or not to implement a specific action. (2) The decision is preceded by factors other than judgements made about the students or about the classroom situation. These factors include judgements about the teaching environment, the teacher's state of mind, or the appropriateness of a particular strategy. While teachers' decisions do seem to depend on student behavior, failure to consider these other factors would lead to inaccurate portrayals of teacher decision making.

Teacher Beliefs

Not all agree on the best way to teach science or even on what sciences should be taught. Norman G. Lederman (1992) has examined both teacher and student beliefs about the nature of science and found that many teachers as well as students hold a fixed, authoritarian, text-book oriented, and final-form view of science. Gess-Newsome and Lederman (1993) found that many biology teacher's knowledge structures were fragmented and incomplete. Hewson and Hewson (1989) found that both beginning and experienced teachers held a variety of different conceptions of teaching science, some of which might limit their capacity for professional development and result in ineffective teaching practices. On the other hand, it is not reasonable to assume that teachers with ten or more years of experience are working from the same set of beliefs about science teaching they formed during their college years. Their philosophies of science and science teaching are likely to have been shaped and altered by the years of teaching science (Brickhouse, 1990).

All of these findings suggest that teachers do hold different views of teaching science and strongly suggest that these views might influence the way they teach or will teach (Hewson, Kerby et al., 1995). This study extends this recent research trend (Lederman & Zeidler, 1987; Brickhouse, 1990; Gess-Newsome & Lederman, 1991; Pajares, 1992) by examining the beliefs and practices of astronomy teachers through classroom observation, task based interviews, and stimulated recall interviews. Belief inventories are not sufficient because they cannot encompass the "myriad of contexts under which specific beliefs become attitudes or values that give fruition to intention and behavior" (Pajares, 1992, p. 309).

The examination of teacher beliefs is particularly important because teachers enter graduate schools of education with well-formed beliefs about education and leave with those beliefs intact (Pajares, 1992). Brown and Clooney (1982) suggest that beliefs have their roots in cultural transmission, including thousands of hours spent in the classroom as students. Based on this information, Frank Pajares asserts that, "It is for [this reason] that investigating the educational beliefs of teachers and teacher candidates should become a focus of . . . educational research and . . . teacher preparation programs can ill afford to ignore the entering beliefs of pre-service teachers (Pajares, 1992, p. 322). Furthermore, these beliefs are resistant to change, even in the face of contradictory evidence. Nisbett and Ross suggest that theories and beliefs tend to persist because lay persons have few of the formal social scientist's skeptical or disconfirmatory skills (Nisbett & Ross, 1980, p. 10). Furthermore, substantial research exists to substantiate the claim that behavior is related to judgmental errors based on faulty beliefs (Nisbett & Ross, 1980, p. 11).

Teacher's beliefs about the nature of science affect the way they teach. Pajares (1992) suggests that teacher beliefs are the most powerful predictor of their success or failure as a teacher because beliefs are the best indicator of the decisions individuals make throughout their lives (Bandura, 1986). Belief systems are more inflexible, more disputable and less dynamic than knowledge systems. Knowledge is advanced by informed scholarship; beliefs remain unchanged. Yet, beliefs are a more powerful influence on task organization and decision making (Nespor, 1987).

However, it is difficult to develop a consistent and useful definition of beliefs that is clearly distinguishable from other forms of knowledge (Pajares, 1992). Part of the problem is that every research field defines belief in a way most suitable for that field. The community, according to Pajares, has not been able to consistently choose which definition of belief to use. This report uses the definition that teacher beliefs are notions that teachers accept as true without empirical evidence and without a compelling, non circular argument in support of the notion. It is unavoidable that, for the purposes of investigation, beliefs must be inferred. Nisbett and Ross state, "We also say little about how people's judgments affect their behavior. . . . We . . . acknowledge that we share our field's inability to bridge the gap between cognition and behavior." (Nisbett & Ross, 1980, p. 11)

Research in science education has for some time now indicated a link between teachers views of scientific knowledge, including their beliefs about scientific knowledge, and classroom practice (Duschl & Wright, 1989). A distinction is made in the literature between substantive and syntactic knowledge. Substantive knowledge refers to the explanatory frameworks or paradigms that are used both to guide inquiry in the field and to make sense of data. Syntactical knowledge refers to the methods used to acquire or construct knowledge (Schwab, 1968).

Nancy Brickhouse (1990) states that teachers syntactical knowledge plays a role in classroom instruction but then goes on to assert that we lack descriptions of how this knowledge influences classroom instruction. Brickhouse also examined the relationship between teachers views of the growth of scientific knowledge and teacher's classroom practice (Brickhouse, 1990). She summarizes the results as showing that the two experienced teachers who had a well-formed and internally consistent view of the growth of scientific knowledge were remarkably consistent from day-to-day, and were guided by their belief system in making instructional decisions. The inexperienced teacher was more unpredictable. According to Brickhouse, this was because the inexperienced teacher felt constrained by what he felt was possible rather than attempting what was desirable. The inexperienced teacher encountered many obstacles that prevented him from using the instructional strategies congruent with his beliefs (Brickhouse, 1990; Brickhouse & Bodner, 1992).

It is worth mentioning however, that Brickhouse observes and notes an apparent contradiction in one of the experienced teacher's practices. This teacher had stated that he liked the text, *ISCS Physical Science*, because it was activity based and emphasized scientific discovery. Yet the emphasis in classroom instructions was on following instructions, not on the scientific discovery implicit in an activity-based approach (Brickhouse, 1990, p. 56).

This study will extend Brickhouse's study by both broadening and narrowing the focus. All sorts of beliefs will be considered such as religious beliefs, beliefs about how science should be taught, beliefs about the nature of science, beliefs about how students learn science, beliefs and stereotypes about the students, and beliefs about the relationship between teachers and students. At the same time, whether other teachers feel the same sort of institutional constraints as the inexperienced teacher in Brickhouse's paper will be investigated. The emphasis will be on community college astronomy teachers and their beliefs about the nature of effective instruction.

The Structure of Beliefs

Beliefs can be distinguished from other forms of knowledge by certain characteristics, identified by Nespor as existential presumption, alternatively, affective and evaluative loading, and episodic structure (Nespor, 1987). While these characteristics give clues about how to relate beliefs to practice, there are still no definite connections. The following categories of beliefs may suggest a strategy for classifying behaviors, but the danger of this sort of classification scheme is always to avoid forcing data into categories.

The Assumption of Shared Perceptions

> The gods did not reveal, from the beginning, All things to us; but in the course of time, Through seeking we may learn, and know things better...These things are, we conjecture, like the truth. But as for certain truth, no man has known it, Nor will he know it; neither of the gods, Nor yet of all the things of which I speak. And even if perchance he were to utter the final truth, he would himself not know it: For all is but a woven web of guesses.
>
> Xenophanes (circa 550 BCE)

Fundamental to much research in teacher thinking and beliefs is the implicit assumption that teachers and researchers share common perceptions. But we know all human perception is influenced by the perceiver's schema, constructs, beliefs, and understandings (Nisbett & Ross, 1980). According to Munby (1982), a researcher might interpret a cue as important according to the way the researcher looks at the world, while the teacher might ignore that cue and focus on something quite different. Unfortunately, the assumption of shared perception is at the heart of much research that depends on interviews, especially stimulated recall interviews. Munby puts it succinctly, . . . we assume that when we code an utterance to a class as a management one, then it was delivered as one and heard as one; and we traditionally accept that the meaning we retrieve from a statement in a transcribed interview is consistent with . . . the meaning intended by its author." (Munby, 1982, p. 207)

This philosophical stance is essentially the same as that known as constructivism. Teachers, then, are constructing meaning from their perceptions of classroom experiences just as students construct meaning from their own perception of those same classroom experiences. The students are intended to be constructing meaning about the subject matter and there are elaborate systems in place to assure that at least some of the meanings constructed by the students are consistent with what the teacher intended. At the same time, the teacher is constructing meaning from student utterances, curriculum design, subject matter content, and personal beliefs and there is no mechanism the teacher can use to compare those constructions to any standards, nor any standards to compare to. It is up to the teacher to become reflective. The participants in this study were encouraged to keep daily journals or at least to record thoughts about their lessons. All did keep some sort of journal or notes. One participant wrote extensively about the lessons and science education in general. All of the journals and notes became an important data source.

Existential Presumption

Beliefs may be characterized by assumptions about the existence or non existence of entities. (Abelson, 1979, p. 357) For example, some teachers may assume that some students are unable to comprehend certain material, are lazy, or are immature. These types of assumptions tend be viewed as immutable—beyond the teacher's control.

Alternativity

Beliefs often include ideas about alternate worlds or realities (Abelson, 1979, p. 357-358). These may be gleaned from books or workshops and be implemented in the classroom without true understanding of the notion or training in its implementation.

Affective and Evaluative Aspects

Beliefs rely much more on affective domain components (Abelson, 1979, p. 358). Feelings, moods, and personal preference may be used as a means of task selection and choice of instructional strategy.

Episodic Storage

This term is used to refer to the manner in which certain bits of information are gleaned from personal experience, readings, workshops, or other sources. These episodes or anecdotes are then used to buttress particular beliefs (Tversky & Kahneman, 1973; Ayeroff & Abelson, 1976; Nisbett, Borgida, Crandall & Reed, 1976).

Disputability

Beliefs and belief systems differ from other knowledge in the way holders of beliefs are willing to allow, in fact expect, others to disagree . Knowledge accumulates and changes according to well defined rules for the particular area of knowledge in question (Kuhn, 1970; Toulmin, 1972; Kuhn, 1977; Feyerabend, 1978). Beliefs change by epiphanies (real or perceived), gestalt shifts, and the like. People who hold certain beliefs (religious beliefs are only one example) expect others to disagree. While other types of knowledge operate on consensus, beliefs are willing to tolerate non-consensus.

Unboundedness

The rules connecting events, situations, and other types of knowledge to belief systems are loose and ill-defined (Abelson, 1979). To one not holding a particular belief, the connections might seem unlikely or impossible

Self-efficacy

Any investigation of teacher's beliefs must include some consideration of one particular category of teachers' beliefs — perceptions of self-efficacy. Nearly three decades ago, Albert Bandura introduced the concept of self-efficacy perceptions. He defined these as "beliefs in one's capacity to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). Since Bandura initially introduced the concept of self-efficacy perceptions, research in many different areas has demonstrated the power of this construct to predict human behavior, learning, performance, and motivation. According to Bandura, there is a growing body of evidence that human accomplishments and positive well-being require an optimistic sense of self-efficacy (Bandura, 1998). Since there are so many obstacles to completion, people must believe they are capable of accomplishing the task at hand before attempting it. Teacher's self-efficacy perceptions are so closely linked with teacher beliefs, that it seemed important to include at least a brief and tentative estimate of self efficacy perceptions as part of this study.

In the last few years, research has revealed strong links between student achievement and three versions of perceived efficacy beliefs (Goddard, Hoy & Woolfolk Hoy, 2000). Two of these constructs are not used in this research—the self-efficacy judgements of students (Pajares, 1994; Pajares, 1997) and teachers' perception of collective efficacy (Goddard, Hoy et al., 2000). The third construct, teacher's perceived self efficacy (Tschannen-Moran, Woolfolk Hoy et al., 1998), is pertinent.

Research has shown that teacher's perceived self efficacy is a powerful predictor of many educational outcomes such as teacher's persistence, enthusiasm, commitment, and instructional behavior. Teacher efficacy is also related to student outcomes, such as achievement, motivation, and self-efficacy beliefs. However, persistent measurement problems have plagued the construct (Tschannen-Moran, Woolfolk Hoy et al., 1998).

Despite the problems, many researchers have devised ways to measure teacher's perceptions of self-efficacy (Tschannen-Moran & Woolfolk Hoy, 2001). Albert Bandura has written extensively on the subject (Bandura, 1994; Bandura, 1997; Bandura, 1998) and has prepared a comprehensive guide for constructing self-efficacy scales (Bandura, 2001). These scales produce numerical measures of self-efficacy. While it may seem inconsistent to introduce quantitative data into a qualitative paper, there are many researchers now using mixed methods research (Bell & Lederman, 2003; Johnson & Onwuegbuzie, 2004).

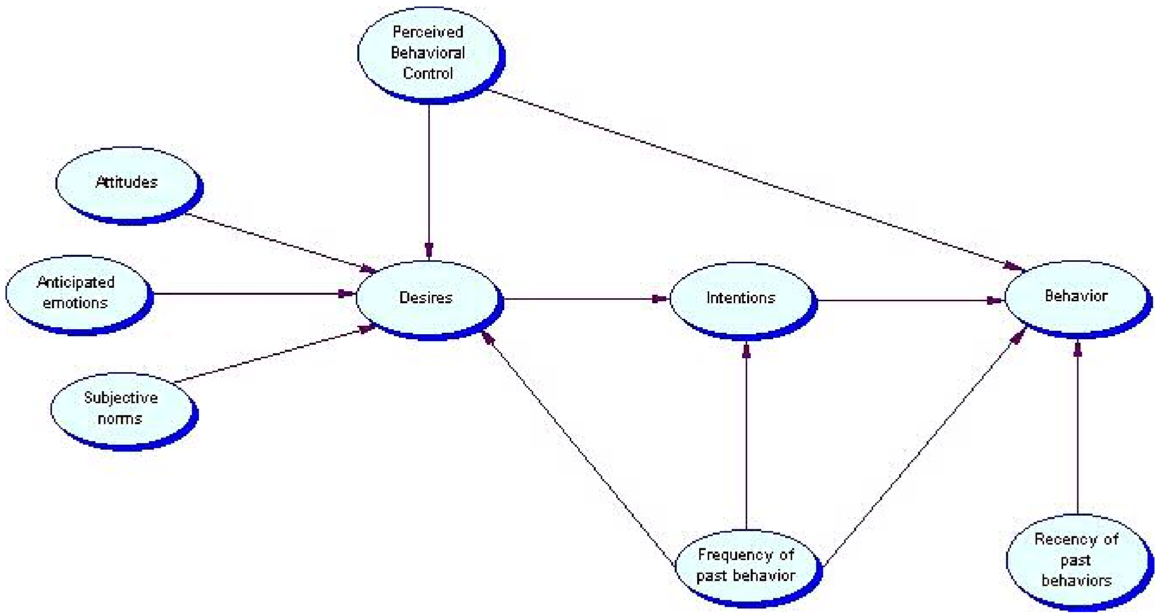
Collective efficacy beliefs (Goddard, Hoy et al., 2000; Goddard, Hoy & Woolfolk Hoy, 2004) are a logical extension of the self-efficacy concept. Within an organization, perceived collective efficacy represents the beliefs group members have concerning the capabilities of the social system as a whole (Bandura, 1997). Collective efficacy beliefs would include notions community college instructors hold about the collective efficacy of their schools, including the belief that the faculty of the college can organize and execute the courses of action necessary for instructional improvement (Goddard, Hoy et al., 2004).

Theory of Planned Behavior

An idea closely related to the notion of self-efficacy is the theory of planned behavior (TPB). This construct is widely used in nursing studies, psychology of health, exercise studies, and related fields. It is beginning to show up in general education-related research (Davis, Ajzen, Saunders & Williams, 2002), and in science education related research (Crawley, 1990; Crawley & Black, 1992; Crawley & Koballa, 1992). Some studies have investigated teacher beliefs using the construct (Haney, Czerniak & Lumpe, 1996). The theory of planned behavior (TPB) grew out of the theory of reasoned action (TRA) (Fishbein & Ajzen, 1975). Both have been important tools in social psychology for many years. One advantage of the theories is their parsimony; that is, a simple construct has great explanatory power.

There are many variations of TPB and many researchers have suggested modifications. Figure 1 is a chart that represents a recent version of the construct (Perugini & Bagozzi, 2001). Research using the theory of planned behavior typically involves rather large sample sizes and sophisticated statistical analysis (Ajzen, 2002). So this construct was not pursued in this study, but there are certainly possibilities for future research in how beliefs might play a role within the theory.

Figure 1: Theory of Planned Behavior



Emic and Etic, Nomothetic and Idiographic

Each potential research stance and possible theoretical construct falls somewhere along two different spectra. One is the spectrum of an emic or an etic perspective. An emic viewpoint is somewhat like an "insider's" viewpoint. Emic approaches often involve participatory inquiry. The etic perspective is, in contrast, formal, structural, and external. It might be called the viewpoint of an informed "outsider." However, many researchers question whether a true etic perspective is possible.

The other is the nomothetic--idiographic spectrum. Nomothetic implies related to a law or to the philosophy of law. Nomothetic theoretical constructs involve at least "lawlike" statements. On the other end of the spectrum, idiographic constructs are local, unique, and related to discrete facts or events.

These two continua of research characteristics could be displayed on a chart that had four quadrants, as in Figure 2. This is not to suggest that each "axis" has only two values. It is better to think of each as a continuum of possibilities.

Figure 2: Two Dimensions of Research

	Emic	**Etic**
Idiographic	Personal theories Paradoxes Misconceptions	Social theories Prejudices Spirituality
Nomothetic	Law-like statements about personal experience, e.g. "That always happens!"	Law-like statements about social situations

"Orthodox" social research (Giddens, 1982) would fall in the lower right quadrant. By the same token, orthodox social researchers who seek positivist-type statements about generalizable social theories would reject social constructs or theories that fell in the upper left quadrant. But that is exactly where much current social research falls.

SUMMARY

Little recent research exists about the current practice of classroom teachers observed in context, especially the contrast between stated or implied beliefs and actual classroom practice. Nancy Brickhouse (1989) studied teachers' subject matter knowledge and its relationship to classroom practice. Hewson, Kerby, and Cook (1995) describe a process of determining a teacher's conception of teaching science by using an interview task. Jan Nespor (1987) used preliminary interviews, classroom observations, and stimulated recall interviews to examine the relationships between beliefs and task definition, memory processes, and problem solving in ill structured domains. Jonathan Keister (1990) documented and analyzed teachers' and students' activities during physics practicals in order to gain critical insights into why students did not acquire the expected practical skills and how theory and practice interacted in the context of teaching. Wolff-Michael Roth (1990) developed models about how beliefs in fundamental philosophies, such as collaboration and constructivist teaching, might be reflected in classroom practice.

Clark and Peterson (1986) have conducted research into teacher thought process. They assign teacher thought process to three separate categories: planning, interactive thoughts and decisions, and theories or beliefs. A number of different methods exist for identifying and evaluating teacher thinking. Kagan (1990) identified five different types of methods, direct assessment, analysis of teacher's language, taxonomies, teacher constructed concept maps, and questionnaires combined with interviews and tasks.

In this paper, the information processing model (Peterson & Clark, 1978; Shavelson & Stern, 1981) as modified by Clark and Peterson (1986) is the model used to understand teacher decision making. Their new model is based on two assumptions: (1) Teachers are not choosing between two or more alternatives, but rather are choosing whether or not to implement a specific action. (2) The decision is preceded by factors other than judgements made about the students or about the classroom situation.

Much research indicates that teachers do hold different views of teaching science and strongly suggest that these views do influence the way they teach (Hewson, Kerby et al., 1995). This study extends this recent research trend (Lederman & Zeidler, 1987; Brickhouse, 1990; Gess-Newsome & Lederman, 1991; Pajares, 1992) by examining the beliefs and practices of astronomy teachers through classroom observation, task based interviews, and stimulated recall interviews.

Chapter Three
The Research Process

I'd rather learn from one bird how to sing
than teach ten thousand stars how not to dance.
—e. e. cummins

Michael Crotty suggests (1998, p. 2) that there are four questions to be answered in this chapter:

- What *methods* do we propose to use?
- What *methodology* governs our choice and use of methods?
- What *theoretical perspective* lies behind the methodology in question?
- What *epistemology* informs this theoretical perspective?

This chapter will address each of these questions in turn. However, this chapter is not an attempt to provide a comprehensive review or even a survey of the theory of methods. Instead, the idea here is to proceed as directly as possible to the method of analysis used while providing only the background in methodology necessary to understand the rationale.

The question being asked often dictates the choice of methods. The questions being asked here suggest a qualitative approach. Douglas Ezzy gives an example of which kinds of question are best answered by which approach (Ezzy, 2002). Suppose someone decides to empirically test the often heard remark that women make terrible drivers. Testing this hypothesis is a straightforward process that does not appear to involve extracting meaning from texts. Rather, in traditional research of this kind, the hypothesis would take the form "There is no correlation between the gender of the driver and the likelihood of being in an accident." This hypothesis is easily tested using widely available accident statistics. On the other hand, suppose we ask the question "Why does our society label women as bad drivers?" This is a completely different sort of question that would require a very different approach, such as a qualitative approach perhaps using labeling theory as its research stance (Becker, 1963).

METHODS

Aristotle suggested there were three categories of knowledge: theoretical, practical, and productive knowledge or knowledge of how to make things (Ackermann, 1965). Knowledge that is true independent of human desires and hopes is called theoretical knowledge. The pursuit of theoretical knowledge can be considered knowledge for its own sake. Practical knowledge, or *praxis*, includes knowledge of how to deal with social situations. Teaching is precisely the type of social situation Aristotle had in mind because teaching is a complex endeavor with many uncontrolled and uncontrollable variables. Many researchers and practitioners feel that the best way of approaching understanding of humans in these complex settings is through some form of interpretive research method, guided by *praxis*.

Interpretive research may be qualitative or may include at least some quantitative component. The sorts of questions best answered through interpretive research are related to individuals acting in social settings (Erickson, 1986).

- What are the actions of the people in this setting?
- What do these actions mean to the actor at the time the action took place?

The first of these questions concerns classroom practice, the second concerns implied beliefs about classroom practice. The only effective way to take a measure of classroom practice and beliefs is by extended classroom observation and extended interviews. Therefore, the primary data for this research consists of interviews, video tapes, field notes, personal journals, and reflective journals of practicing astronomy teachers. The cooperating teachers were first extensively interviewed to determine perceived teaching philosophy and their judgement of various classroom practices.

Project Timeline

I recruited participants and arranged the initial interviews in September of 1996. Following the initial interviews, I conducted classroom observations, made field notes, videotaped classes (including my own), and along with the other participants began keeping a journal. This activity continued through the remainder of 1996 and well into 1997. I had just begun transcribing interviews and developing an analysis structure when I faced a personal tragedy (see Appendix L: Personal Biography). The emotional trauma caused by this personal tragedy forced me to stop work on this project as well as most other activities. During this period, I also changed jobs twice and had significant health problems. When I was finally able to begin work on the project again, I felt it was necessary to return to the classroom for a second round of observations to see if classroom practices had changed significantly in the interim. At this time, one participant dropped out. I observed classes and had a number of informal conversations with the remaining participants beginning in June, 2000. The participants and I had our second round of interviews, the stimulated recall interviews, between early September of 2000 and March of 2001. Late in 2001, I was able to continue with analysis of the data with a slightly different approach due to the added dimension of the extended time period of observation. Consistent with good practice in qualitative analysis, the participants continued to keep journals and I continued to make some limited field notes through the spring of 2002 while analyzing the data and beginning to write. Again following generally accepted good practice in qualitative research, I blended writing and data analysis.

Initial Interview Procedure

The first portion of the initial interview was based on an interview task as described by Hewson and others (Hewson & Hewson, 1989) (Hewson, Kerby et al., 1995) The interview consists of a series of ten events that include presumed instances and non-instances of science teaching. The events were either used in the form as described in the articles or were slightly modified to substitute astronomy content if that substitution did not change the sense of the task. The tasks are not typical classroom events. Rather, they are intended to encourage participants to think about teaching in ways different from usual classroom situations. The interviewees are shown a written description of each event, and asked to respond to three questions:

1. In your view, is science teaching happening here?
2. If you cannot tell whether science teaching is happening, what other information would you need to know in order to be able to tell? Please give reasons for your answer.
3. Whether you answered yes or no to question 1, explain what tells you that this is the case? Please give reasons for your answer.

The events used were

1. Handing out crystals

   A teacher in a middle school class (ages 11 to 14) beginning a unit on crystals has passed out samples of various crystals and has asked the class "What can you tell me about the crystals I've passed around?
2. Watching television

   A student is sitting at home watching a popular television show on astronomy.
3. Students in library

Two students are working together in the library, calculating distances to nearby stars from parallaxes and magnitudes given in a table.

4. College professor and first graders

   A college professor is lecturing on the origin and evolution of the solar system to a group of first graders..

5. Teacher describes algorithm

   A teacher in front of a ninth grade earth science class is describing the steps used in solving for units when working numerical problems involving measurements.

6. Teacher questioning student

   A teacher reads a 10th grade astronomy student's statement that "ideal gases have no volume" and asks "Were you referring to the gas particles or to the gas as a whole?"

7. Teacher asks student to label diagram

   A teacher draws the Hertzsprung-Russell diagram on the board and asks a student to label the various regions of the diagram from memory.

8. Student question

   A junior-high student (age 13) in class, watching a demonstration of the electrolysis of water which has been going for some time asks the teacher "Do you think you've got all the oxygen out of there yet?"

9. Student at home making muffins

   A student is at home, preparing blueberry muffins according to the recipe.

10 Teacher at home

   A teacher is at home writing a self-study resource center program on determining the spectral classes of stars.

Following the model developed by Hewson and Hewson (Hewson & Hewson, 1989) no new terms or ideas were introduced during the first (structured) part of the interview, but teachers were asked to expand on their ideas and follow up their line of thought.

The second portion of the initial interview was completely open-ended. The interview questions were drawn from several general areas of interest, rather than a series of predetermined questions. A list of "cue words" was used for devising questions any time the flow of ideas seemed to lag. Some cue words were developed in advance of the interviews and more words were added during the structured part of the interview.

Interviews were audio taped and notes were kept during each interview. Additional notes were added after the interviews. The tapes and notes were labeled and stored in a manner that preserves anonymity of the interviewee.

Journal

Participating teachers were asked to keep a journal during the time covered by the interviews and observations. While teachers were given basic guidelines (in the form of questions, see Appendix G) about what to include in the journal, they were also encouraged to record all thoughts, observations, and reflections that might be pertinent to each day's experiences. This journal served several purposes. It allowed teachers the opportunity to reflect on their teaching practice, it provided a cross-check for the interview data, and it provided an additional source of information about teacher's perceived classroom practice that could be compared to the observed classroom practice. Teachers may never think about their practice. Keeping a diary or journal encourages them to do so. They were especially encouraged to record and reflect on the classroom events that had transpired and what they felt would have been accomplished by each event.

The journal was most important when classroom observations were compared to stated beliefs. Teachers were asked to relate the journal entries to particular classroom practices. Thus the journal entries became an important source of data when the two areas are compared. Relationships between observed classroom practice and stated beliefs were likely to be revealed through the reflective journals.

The journals also allowed the participating teachers to be more active in their own professional growth during the study period. Hewson and Olsen (Hewson & Olsen, 1993) describe knowledge-in-action as a teacher's form of inherently knowing one's actions in the context of daily teaching activities. Allan Feldman (Feldman, 1994) examined ways in which teachers can use their own experiences to become better teachers. By reflecting each day on what transpired in the classroom, teachers should have been able to amend their practices to be more in line with beliefs. Thus the reflective journals added an action research dimension to the study.

However, the most important function of the reflective journals was intended to allow the teachers to tell their own stories, in their own words. Stories have been used for thousands of years to enable us to extract significant truths from complex human interactions. There are few human interactions more complex than the interaction between the teacher and the students. By combining the teacher's words and thoughts with the classroom observations and interviews, the teachers own stories are revealed.

I also kept a journal during the entire study period. This journal allowed me to model a behavior I wished the participants to emulate, to track my decision making process during the development of a research program, and to track the building and development of theoretical constructs that grew out of the study.

Classroom Observations

The initial interviews were followed by extended classroom observations using a naturalistic inquiry model (Lincoln & Guba, 1985; Patton, 1990). (See Figure 3 on page 59 for a graphical representation of the research process.) Such a model requires that the observer not look for any specific activities or behaviors, but rather tries to record everything of interest. Initially, the observations were purely naturalistic, with no manipulation of the situation (other than the unavoidable, intrusive presence of the observer) and placing no constraints on the possible outcomes. When observation revealed interesting patterns and significant ideas (such as a tendency to look at only one side of the room or perceptions of administrative constraints), the inquiry became more deductive as hypotheses were built, validated, and altered (Brickhouse, 1989). These observations took place over an extended period of time and covered several different class periods (to avoid a "dog-and-pony" show and also avoid class "freeze-up"). The research design called for a two-hour preliminary interview followed by eight or more classroom visits, with an option to extend the classroom observation time if needed so that an entire unit of study was included. The observations were followed by another interview to discuss the classroom events and interpretations.

There are several options for collecting data in a classroom, varying in intrusiveness and richness of data. The richest data collection procedure is using video taped recordings (Bottoroff, 1994; Spiers, Costantino & Faucett, 2000). The video camera records all of the words and movements, facial expressions, blackboard style, body language, and other aspects of teacher behaviors. One limitation of video taped recordings (VTR) are the lack of context or the inability of the video camera to capture the whole scene. This limitation can be overcome by the use of detailed field notes in conjunction with VTR. When coupled with detailed field notes, VTR provide the densest possible set of data. VTR are also a permanent record of the classroom events. They can be viewed and reviewed many times. When appropriate, the video tapes can be viewed in slow motion or even frame by frame.

Video also serves a role in educational intervention. The capacity to record multimedia, multi-sensory information about complex behavior makes VTR an ideal choice in self-reflection. Participants who view themselves in the act of teaching are able to see things they were unaware of before. They can spot eccentricities of eye movement, idiosyncratic gestures or behaviors, or bias in questioning with great ease. They can also recognize instances of miscommunication, unanswered questions, and failed strategies. Video is the only medium that can allow close interpretation of complex behaviors, because video can be viewed repeatedly (Spiers, Costantino et al., 2000).

While the density of data obtained using VTR is greater than all other methods, no record is ever complete. Microphones may miss important words. A camera recording a particular behavior may mean that some other behavior is overlooked. The camera cannot reveal subjective meanings guiding behaviors. The camera is unaware of the context, especially the historical context of particular behaviors. Any attempt to achieve more complete coverage by adding additional cameras or microphones may cause so much intrusion that more information is lost than gained. Nevertheless, VTR will typically produce more information than can easily be handled (Bottoroff, 1994).

Video recordings are relatively free of bias, but different observers may focus on different aspects of an interaction (Spiers, Costantino et al., 2000). When the camera position is fixed, events that occur close to the center of the screen or that occur closer to the camera are likely to receive greater attention. A wide angle lens takes in the whole picture but gives up detail.

People often change their behavior when they know they are being observed. Thus the act of observing and recording may alter the behavior of interest (Spiers, Costantino et al., 2000). The intrusiveness of the researcher or the presence of even one video camera was confirmed by the journal comments of one of the participants, "As I think back to the events of the class period, I was certainly aware that the videotaping was being conducted during the class. It made me feel a bit uneasy, realizing that any mistake that would be made would be recorded. . . . I was especially aware of the error in units which was made on the board." However, in the same sentence, this participant seemed to recognize the inherent value of videotaping,

> [P]erhaps a review of the tape would be helpful in improving my presentation of the material to the class. . . . [A]s I looked at the student's expressions, I am not sure that they were grasping the concept of luminosity and how it is dependent upon the temperature to the fourth power. I suppose that will become apparent when I ask for questions on homework during the next class meeting.

Participant anonymity becomes a problem when videotapes are used. Personal identification of both participants and students would be possible. For this reason, videotaping was to be used only if the participant was completely comfortable with it. In addition, the students in the classes were informed that videotaping was being used. While the participant was the focus of the research, students inevitably appear in the tapes. All of the participants in the study were willing to tolerate videotaping, so it was used extensively. However, for logistical and other reasons, some classes were observed with field notes only. The videotapes will be stored in a secure place during the duration of the study and will be destroyed when their research potential has been exhausted.

After videotapes, next in richness of data is audio taping with detailed field notes. This technique was used for the interview portions, since it would have been awkward or impossible to use a video camera in some of the interview situations. For example, one of the interviews was conducted in a restaurant over a long lunch. This created a comfortable, conversational interview situation, but videotaping would have been out of the question.

While field notes alone may seem a poor third choice, most essential information can be captured and recorded this way. Field notes are the traditional method of recording ethnographic data. One danger lies in assuming field notes are not necessary when videotape is used. They are still an essential part of the process.

Classroom observations were treated in the same way as interview data. The analysis was independent of but informed by the interview analysis. That is, all data were analyzed, identifiable units were coded, and common themes were sought. However, if there was a clear connection between observation and interview data, this was reflected in the coding.

Follow-Up Interviews

Follow-up interviews were also conducted, which gave teachers an opportunity to explain their perceptions of classroom events. During these interviews, participants were shown edited portions of the videotapes of their classrooms and asked to describe and comment on the activity being done. During these stimulated recall interviews (Munby, 1982; Clark & Peterson, 1986), comments could be drawn from journal entries or from memory. A disadvantage of this type of interview procedure is that it tends to make the teacher somewhat uncomfortable to be put on the spot. The alternative, a verbal description of a teacher behavior taken from field notes or videotape, has the disadvantage of an additional layer of interpretation or misinterpretation (the researcher's) between the event and the description, rather than allowing the event to speak for itself.

Of course, many researchers contend that events never speak for themselves; there is always some sort of interpretation occurring.

Each participant was given a copy of the transcript of the follow-up interview and was encouraged to review it for accuracy and completeness of thought. Participants were also asked to view all videotapes beyond the edited portions and were encouraged to comment on any additional interesting events or anything else they considered to be important. These participant comments were also included in the data set.

Observing Myself

In this paper, I will occasionally use a first person voice. These occasions arise when I am speaking about myself as researcher or as both researcher and participant. In those situations, to use other than first person becomes unacceptably awkward and stilted. As a "participant observer" my research position lies somewhere between "pure observation" and action research. I want to be a responsive and illuminative researcher, recognizing that my observation alters the situation, but still leaving the power for change with the participants (the community college instructors, including me). The unique position of being able to be one of my own study subjects, gave me a perspective that allowed me to accomplish several things:

- I learned just how obtrusive the camera is.
- I was better able to characterize the degree of obtrusiveness and judge how it affects the participant
- I learned just how difficult is the task I have assigned the other participants.
- I have improved my own teaching through intensive review of the videotapes and self reflection.

- My ability to be hold both an insider perspective and an outsider perspective was possibly enhanced by being a participant.

Summary

This research seeks to develop practical knowledge about what the actions of teachers means to the teachers, developed through interpretive research. This was developed using an initial interview with analysis of teaching tasks, journals, classroom observations with videotaping and field notes, and a stimulated recall follow-up interview.

METHODOLOGY

Aristotle's categories of knowledge are: theoretical, practical, and productive knowledge (knowledge of how to make things) (Ackermann, 1965). Knowledge that is true independent of human desires and hopes is called theoretical knowledge. The pursuit of theoretical knowledge can be considered knowledge for its own sake. Practical knowledge, or *praxis*, includes knowledge of how to deal with social situations. Unlike theoretical knowledge, practical knowledge is not required to be demonstrably true in every situation in order to be useful. However, *praxis* must be guided by *phronesis*, a moral disposition to act truly and justly. *Praxis* is the type of knowledge that applies to the study of teachers in the classroom and *phronesis* applies to both the teacher and the researcher. In *praxis*, theory and practice are mutually constitutive. They are continually reconstructed in every real social situation. Neither thought nor action is pre-eminent. The ideas that guide action are just as subject to change as action is. The only constant is the moral disposition to act truly and justly (Carr & Kemmis, 1986). This research, therefore, seeks practical knowledge. Specifically, the goal is to discover practical knowledge applicable to the particular social situation of interactive decision making by a teacher as guided by the beliefs of that teacher.

It is always risky to assign a label to a research design, because people are distracted by the label. The label may cause people to mistakenly include or exclude particular elements based on the label rather than the design itself. Nevertheless, this design is perhaps closest to that branch of interpretivism known as hermeneutic phenomenological research (Polkinghorne, 1989; Crotty, 1998; Cohen, Kahn & Steves, 2000; Ezzy, 2002). Hermeneutics is the art and science of interpretation. The name comes from the Greek god Hermes, who was the messenger and interpreter for the other gods. Originally, hermeneutics implied interpretation of biblical texts but was later expanded to include all texts. More recently, the definition has expanded even further to include all communication using any form of language (Ödman & Kerdeman, 1999). Hermeneutics provides a sophisticated philosophical background for many different forms of qualitative research.

Phenomenology is the term used for a group of related philosophical movements that have as their common theme, "to the things themselves." (Husserl, 1964) This means that phenomenology attempts to investigate phenomena as they are consciously experienced, without unexamined preconceptions. The phenomenologist "brackets" any notions about the real world, even questions about its existence. Instead, phenomenology seeks to understand how knowledge of the world comes about.

Hermeneutic phenomenology arose through the work of Martin Heidegger. He defined hermeneutics as:

- The attempt to understand the phenomena of the world as they are presented to us.
- The attempt to understand how we go about understanding the world as it is presented to us.

- The attempt to understand being itself.

Qualitative Interviews

David Kahn suggests that the hermeneutic phenomenological method elicits narrative data through interviews that are more like conversations (Kahn, 2000, p. 61). Robert Weiss lists several reasons for using this kind of interview (in-depth interviews) in qualitative research (Weiss, 1994).

- Detailed Descriptions—Qualitative interviews can produce detailed descriptions of events or situations not obtainable through survey techniques or other methods.
- Multiple perspectives—Qualitative interviews with more than one respondent also allow multiple perspectives no single individual could reveal.
- Describing process—This type of interview is especially useful when the purpose is to describe a process.
- Holistic descriptions—Quantitative research tries to focus on a single variable. The point of qualitative research is to examine and describe the whole phenomenon as thoroughly as possible.
- Interpreting events—This is critical to understanding how teachers make decisions.
- Bridging intersubjectives—Qualitative interviews allow the development of an "insider's" view.
- Identifying variables—Sometimes, qualitative research can identify the variables of significance in complex situations.

Kahn also distinguishes between participant observation (in the ethnographic sense) with participation and observation (as in the hermeneutic phenomenological method) (Kahn, 2000). Observation of the social world is impossible without some social interaction and participation in that same world. Two different kinds of observations are made: observations of the social interaction and observations of the setting in which those social interactions took place.

A "Typical" Interview Segment

To illustrate some of the points in the previous paragraph, a complete interview segment is presented here, without analysis. This transcript is close to the original words of the interviewer and one of the participants, although false starts and other verbal eccentricities have been revised to make reading the material easier. This is from the second interview, where the participants were shown edited portions of the videotapes of their classrooms and asked to describe and comment on the activity being done. In the segment discussed, the participant had spent some time discussing mythology. The line beginning with ID indicates the videotape segment content, IQ is the interviewer question and follow-up, and JACK marks the responses.

> ID: Callisto myth, Leda, the Swan, Gemini, etc.
>
> IQ: My question was why that particular myth? Why not another culture? Native American, Hawaiian, Celtic, African, etc. We also discussed this in segment 42.
>
> JACK: Well, the moons of Jupiter are named after characters from Greek mythology, so that's why I wanted to make that connection. As to why that particular myth, it's because I think the myth of Callisto is the most vibrant of the myths that revolve around Jupiter's moons. The myth of Ganymede has overtones of homosexuality that I really didn't want to get into. The myths of Io and Europa are just not very exciting. A woman rides on the back of a bull and stuff. I think Callisto is one the students can relate to the most. There's also the connection with the Big and Little Dipper in the sky. There's a lot of astronomy in that particular myth, not only the name of the moon but also the name of the constellations, the Great Bear. I think it's illustrative of the Zeus the philandering husband myths of which there are many. It's simply the most vibrant and the one that I think the students will understand and relate to the most. I also sometimes, if I have time, tell the myth of Amalthea. Amalthea was the closest of Jupiter's moons before we discovered some closer. Amalthea was his nanny. So, I try to tell them a bit of that story as well, when I have time. And why not another

culture, well simply because the names come from Greek culture. I try to talk about Native American myths and Viking myths if I have the time. In other contexts. The Callisto myth is also the one I personally find most interesting.

IQ: So a variety.

JACK: Yes. When we're talking about the constellations, I tell them the story of Black Mask. He put the constellations in the sky he started with the brighter stars first and after he put the brighter stars in, he laid down to take a nap and Coyote came along and started scattering stars around randomly. I do that to drive home the point that the myth is half right, all the stars are random. It's just that our mind wants to put a pattern in. So I don't try to force multi-culturalism. I don't think you need to. Most of the myths I do tell are Greek. But there's also other opportunities as appropriate. I try not to force it.

IQ: I do exactly the same thing. I try to bring in African and Native American and Indian and whatever myths at every opportunity I can. But I also tell them right at the beginning that I make no apology for the fact that the astronomy we are studying is essentially from the descent of western science and it draws from the western cultural tradition. That's just the way it is.

JACK: The advantage the Greeks had was they promoted each other. They really, really promoted each other through the centuries. They had a system of scholarship, very much like our own today, where the previous generation was promoted by the current generation and so legends built up and the traditions. Scientific and philosophical traditions built up and so the tradition was kept around.

It takes a little bit of luck. I try to drive these things home to students. It takes the right set of conditions. It's not that one culture is superior to another, the Greeks did all the things right that are required for a legacy. And they got lucky.

IQ: Yes. The fact that ancient Chinese apparently discovered something similar to Newton's first law a thousand years or so before Newton, that's significant and interesting, but it didn't begin any sort of scientific tradition that was maintained throughout the ages. It was an idea that came up but was lost. Unlike Newton's ideas, which have never been lost. They began a tradition of science that continues to this day.

JACK: Just like I tell my students about the Renaissance. How many Galileos and Copernicuses were there? How many people were beheaded or hung or burned at the stake or simply humiliated into silence during that time? How many great minds were there that simply weren’t there at the right time or in the right situation? There have probably been millions from generation to generation, but it was Sir Isaac Newton that was in the right place at the right time with the right amount of intellectual energy. So much of it depends on luck. Being well positioned to make your mark in history. Tesla is an example of somebody that just wasn't in the right place at the right time.

IQ: Yeah. Fine mind. Brilliant mind. All kinds of great ideas, plus some really weird ones. But never went anywhere with them. He just didn't know how to make it happen. Unlike Edison, who really didn't have very many good ideas, but he sure knew how to take advantage of what he had.

JACK: There are a lot of factors that go into legacy and a big part of it is luck. I tell my students that you shouldn't get too haughty about Western culture because Western culture came about as a result of a great number of fortunate accidents. Under any other set of circumstances, the Greeks would have been consigned to the ash heap of history and we might be talking about Persians.

The conversational style of this segment is typical of all the interviews. While the interviewer may seem to be rambling at times, this is deliberate in the hope that it will encourage the respondent to talk freely. The interviewer also seems to introduce new ideas into the conversation at times. Often, these new ideas were ones that were discussed previously or that came from notes or journals. However, the interviewer did not hesitate to bring up interesting new ideas if the context seemed appropriate.

Transcription

Qualitative reports will often contain some variation of the phrase “The interviews were transcribed verbatim.” Brief reflection and an examination of the transcribed interview included above will quickly suggest that this statement cannot possibly be true. Even in the field of conversation analysis, where elaborate codes are used to represent all verbal and non verbal parts of conversations, practitioners admit that the conversion is only approximate. (ten Have, 1999). Many researchers have suggested different sets of uniform standards for transcription that would still preserve the readability of the transcript (Mergenthaler & Stinson, 1992). The goals of transcription are morphological wholeness (standard word forms and standard punctuation), naturalness, and staying as close to the raw data as possible while still producing a readable text (Mergenthaler & Stinson, 1992).

The product of transcription is a document, called the "transcript." In this project, all interviews were transcribed and some classroom video segments were transcribed. In other fields, such as transcripts of courtroom procedures, transcripts are considered to be the official record of what transpired. They have documentary veracity (Becker, 1986) and may have some official status. On the other hand, converting oral speech into printed copy can only be partially representative of and not isomorphic with the original (Sandelowski, 1994). That is the sense in which "transcription" is used here. It is not an exact, one-to-one copy, but is a slightly edited form of the original data that is still intended to meet the goals stated by Merganthaler (Mergenthaler & Stinson, 1992).

This must happen, because the researcher chooses what parts of the interview to preserve in print. Certain features of speech, such as changes in pitch, volume, stress, and speed are difficult to represent in print without some sort of elaborate coding scheme, such as that used in conversation analysis. If these codes were included, the text would become exceedingly difficult to read. The researcher also decides which non linguistic and non verbal features are included. If every "uh" and false start is included, the text becomes confusing. Decisions about punctuation can clarify what was said, but can also change the meaning of the text.

The ontology of the transcript is, therefore, both realist and constructed (Sandelowski, 1994). Once the interview has been converted into a transcript, the transcript itself becomes the focus of analysis. However, during analysis in this project, continual reference was made to the original audio tapes and videotapes to keep the analysis as closely tied to the original as possible. Even with these precaution, it is still inevitable that transcription alters our perceptions of reality. A gap exists between the event as lived and the event as narrated (Sandelowski, 1994). By the time the transcript is made, the original experience has been further altered by the telling. Nevertheless, for the purposes of this project, the assumption has been made that the necessary information about beliefs and their relationships to actual practices can be inferred from the transcripts themselves, with reference to other written materials such as journals.

Computer-aided Coding and Analysis of Data

The interviews, classroom observations, text documents, and reflective journals accumulated for this project were first transcribed into a common computer text form. These transcriptions, along with the original video and audio tapes are the raw data for this study. The data was analyzed using standard qualitative research techniques (Wolcott, 1990; Wolcott, 1994). A computer program designed to support qualitative data analysis and retrieval was utilized to aid in data analysis.

Although the choice of computer program should have no bearing on the value of a research project, choosing a computer program is still a critical step. A good data analysis and retrieval program can make the tasks much easier. However, computer-aided data analysis programs must always be "kept in their place" and not allowed to drive, unduly shape, or control the research. This is especially important, since each of the various programs tend to support one particular approach to data analysis more than the others.

Computer-aided qualitative data analysis programs of this type allow qualitative data to be manipulated in several different ways, including arranging identifiable units in interviews, notes, videotapes, audio tapes, or observations; assigning codes to these units; attaching memos to the text units or the codes; arranging codes in hierarchies; using multiple codes for given text units; and other tools. All field notes, audio tapes, videotapes, transcripts, journals, and other information, whether computer based (on-line) or existing separately (off-line), can be referenced. Some programs, by using a special interface, include an option that allows a particular section of an audio tape or video tape to be retrieved and played back.

For this project, the program chosen was *NUD*IST* (Numerical Unstructured Data Information STorage), partly because of its support of theory building (Richards & Richards, 1995). Further information about the choice of software and documentation of the selection process is included in Appendix D. All transcripts and other documents were first coded using paper copies. This coding was transferred into the *NUD*IST* computer program and subsequent analysis and coding then took place directly within *NUD*IST*. This-software only facilitates the management and analysis of data. *NUD*IST* does not conduct analysis for the researcher, but provides a convenient and versatile means for managing and analyzing data. Additional information about *NUD*IST* and how data is managed is included in Appendices C and D.

Step 1: Coding the Data

The process of coding involves going through the data looking for things of interest. The data consists of written text and may include transcripts of interviews, transcripts of field notes, journal entries, and other documents. At first, everything of interest can be identified. Later, as the emerging ideas become more clear, information that is more closely related to the evolving research question will become more clear. With a specific and concrete research question, identifying chunks of text related to the question may be a straightforward process. However, if the research question is broader, such as one that might be typical of qualitative research "what is going on here?" then the chunks of text will be anything of interest. The code or label need not be precise. It can always be changed later. At this stage, the codes or labels are drawn from the text itself, not from outside literature. Each code must be accompanied with a memo or annotation describing why the chunk of text is interesting and what about the text is important. This is where a qualitative analysis program becomes most useful. They all have the ability to store the codes, memos, and chunks of text as related to each other and can also keep a chronological record of the process.

During the coding stage, it is also important to avoid "coding traps." Because of the ease of coding and retrieval provided by computer aided analysis software, there is a temptation to code everything. While the software allows the researcher to get very close to the data and do fine analysis, it is also important to step back occasionally, like a painter does when executing a work of art, to get the "big picture." The looking time is at least as important as the painting time. Qualitative researchers must do the same thing, metaphorically speaking. Software can aid this process as well, by allowing the codes and their relationships to be displayed graphically in a tree or other form. Another coding trap to avoid is bringing in theories from the literature that seem pertinent. The idea is to be tied to the data, to find out what the data says, not to be looking for support for some preconceived notion.

Writing is an important part of the analysis and begins during the coding and memoing stage. Writing memos related to the codes can become the basis for the analysis stages to come later. Memos are an early form of writing about the analysis. Silvana di Gregorio (di Gregorio, 2003) suggests switching back and forth between coding and memoing and using visual representations as themes emerge. This was done.

Another useful tool at this stage in the process (coding and writing memos) is suggested by the Grounded Theory methods of Glaser and Strauss (Glaser & Strauss, 1967). Writing memos and the chronological record they provide helps the researcher to see when it is important to go back to the field and gather more observations in order to check out hunches or tentative hypotheses. Eventually, what Glaser and Strauss call "data saturation" (Glaser & Strauss, 1967) will reveal when sufficient information has been collected. The approach used in this study is not grounded theory, but the notion of data saturation and other ideas from Glaser and Strauss have been used in data analysis.

Step 2: Developing Themes

There are several ways to develop themes from coded data. The traditional way is to print out two copies of the coded data and physically cut out each coded chunk of text from one copy. The other copy is used to keep track of where the data chunk came from so that context is preserved. The coded data is sorted into various piles according to related ideas or topics. Data chunks with the same code or a closely related code are stacked together. Then a label or a new code is created for each stack. The same process can be used in software analysis, except that the software does the cutting and stacking electronically.

While identification of key themes is critical, the themes must be supported by the data. Corroborating detail must accompany the themes. This is another place where qualitative analysis software becomes so useful, because the software keeps the coded chunks of text linked to the codes and also linked to the memos supporting the labeling. The software also allows any given chunk of text to be expanded to include surrounding text, so that the context can always be made clear. It may also become clear that themes must be reorganized. The software makes this easy and also keeps tracks of where and when the nodes were moved so one can always backtrack.

Step 3: Connecting the Themes

The next step is to tie the data together. This is the stage where the research questions take their final form and answers to the research question are developed. The conceptual scheme developed in this stage should go beyond the obvious and should be coherent. This is another place where the graphical display capabilities of qualitative analysis software can be useful. For example, the "nodes" (essentially the same as codes or themes) of *NUD*IST* can be exported to a program such as *Inspiration* (Helfgott & Westhaver, 1999) that can display the same nodes and relationships graphically.

To connect the themes in a conceptual scheme, the themes have to be placed in the proper conceptual relation to each other. Some themes are more important than others. Their position in a conceptual scheme will reflect their importance. It is possible that the themes tell a story (narrative) or can be represented by a metaphor. This is the stage where every step must be carefully documented because the conceptual scheme must be defensible. Writing memos can help with documentation, creating an "audit trail" for the process.

A central theme or core variable will have certain characteristics (Glaser, 1978, p. 95-96):

- It will be central
- It will recur frequently or the context will emphasize its importance.
- It will relate easily and meaningfully to other categories
- It will have clear implications for developing theory
- Have carry through
- Be seen in all relations

The process of creating codes and developing themes is explained in more detail in Appendix C. Table 9 in Appendix C lists all of the codes used in this project and shows the broader categories and relating themes into which the codes are collected.

Step 4: Writing the Analysis

This completes the process. Here, a narrative is created that places each of the original coded chunks of text into the conceptual scheme. The original text supports the conceptual scheme. Here is where other literature and other theoretical notions can be used to support the new conceptual scheme, but they are not the heart of the scheme. The data is allowed to speak for itself.

Analysis of Documents

Transcripts of interviews were analyzed by looking for ideas, thoughts, statements, or whatever coherent units exist, to develop initial codes. Then these were reorganized to look for themes, connecting ideas, and beliefs. It is possible that different teachers will share common themes or beliefs and these can be combined. However, generalizing across different teachers is not the primary purpose of this study. As Patton states, “Naturalistic inquiry assumes an ever changing world. This perspective is nicely captured by the observation of the ancient Chinese proverb that one never steps in the same river twice. Change is a natural, expected and inevitable part of human experience” (Patton, 1990, p. 53). The purpose of this research is formative evaluation, that is, evaluation of the program, and applies only to the teachers in the context being studied.

Data from observations, journals, tests, syllabi, teaching narratives, and other sources will be independently analyzed. It is hoped that the journals will reveal teacher intentions and the follow-up interviews will allow teachers to analyze their own instructional practices in view of their stated beliefs about teaching science. The computer-aided software makes it possible to easily connect observations, interview segments, journals, and other text units that are related to the same teaching event.

Sample Size

The amount of data collected per teacher, including hours of interviews, reflective journals, follow-up interviews, and field notes, limited the sample size to no more than a few community college instructors. Janice Morse has recommended a small sample size of around six cases for research that seeks to discern the meaning of experiences (Morse, 1994). That was the target sample size for this study, but due to attrition over the lengthy study period, only three active participants remained by the end. (See Appendix L for the explanation of the unavoidable length of the study period.) While a small sample size is not unusual in qualitative research, sample size is still an important consideration (Sandelowski, 1995). Numbers do count, but large sample size is replaced in qualitative research by purposeful sampling (Patton, 2002) with in-depth conversations, extensive observations, and active participation by the study subjects. Qualitative analysis is primarily about maximizing understanding of the individual case in all its diversity; it is case oriented, not variable oriented (Ragin & Becker, 1992). Sample size in qualitative research may refer to numbers of individual persons, but may also refer to number and length of interviews, length and depth of field observations, and number and variety of sampled events. Any one case offers a variety of different kinds of data that must be thoroughly sampled to illuminate the case (Sandelowski, 1995). More information about this and other characteristics of qualitative research are included in Appendices A and B.

Duration

The original research plan called for intensive observation of each teacher during an entire unit of study, from introduction to evaluation. This involved observation in the classroom for four or five weeks or eight to ten class periods of 75 to 90 minutes each. This length of time was necessary to allow the teacher and students to become accustomed to the presence of the observer in the classroom and to allow time for a variety of teaching activities to occur.

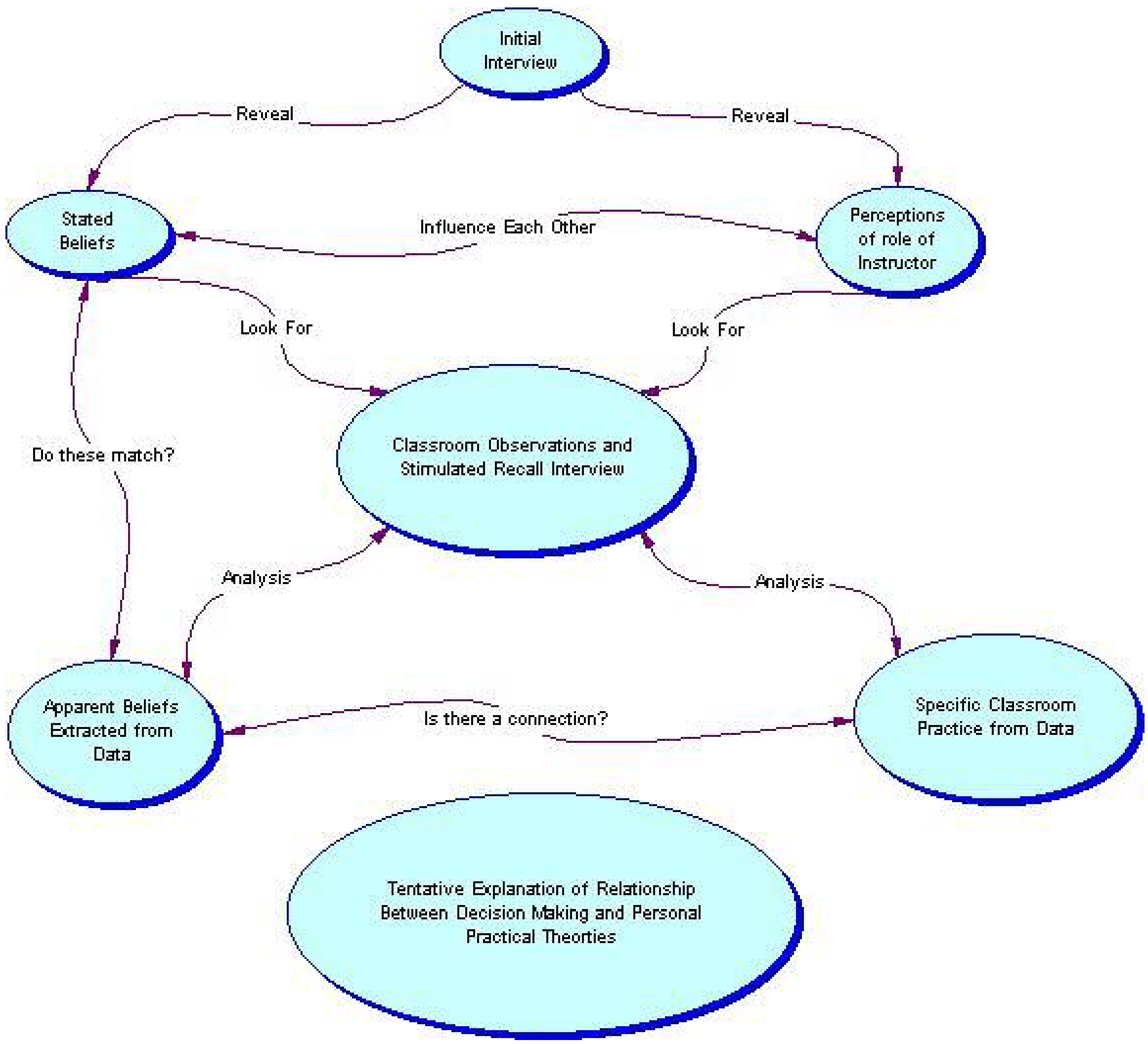
After the initial period of observations, the original research design called for the videotapes to be edited and a single tape created containing interesting events, interruptions, "teachable moments," unusual questions, and other events that caused the teacher to deviate in any way from a pre-planned lesson. Due to unforeseen circumstances (see Appendix L), so much time passed before the original videotapes could be edited that some question arose as to how well the teachers would remember these events. This made it necessary to go back into each classroom and complete a second round of observations. During the second round, some classes were videotaped and some were observed and the events were "scripted" without videotaping. Then events from the original round of videotaping, the second round of videotaping, and the scripted classes were compiled and presented to the participants. Each teacher was asked to comment on what was happening. These comments were recorded and added to the data set.

In a study of this type, it is hard to predict beforehand how much observation time will be needed. Instead of a fixed amount of time spent with each participant, the researcher must judge when new information becomes sparse and when the time spent is no longer adding anything of interest to the body of data (Weiss, 1994). Preliminary interviews ran about one and one-half hours, and each participant was observed in the classroom for at least six and up to nine hours. These observations were spread over eight to eleven class periods. For all participants, the observations included at least two different semesters. Follow up interviews required an additional two or three hours.

Counting additional telephone conversations and other interactions, contact with each participant ranged from 12 hours to around 17 hours. This amount of time spent in observation is comparable to the time spent in interview and observation by other researchers in similar studies (Brickhouse, 1989).

The process of data acquisition and analysis leading to tentative answers to these questions can be represented by an interconnected diagram as shown in Figure 3. The preliminary interviews revealed specific beliefs held by the participants and also revealed the participants perception of the role of a classroom instructor. These stated beliefs and role perceptions suggest things to look for during the observation phase and the stimulated recall interview. Analysis of the information gathered during the observations and stimulated recall interview reveals apparent beliefs and specific classroom practice. The beliefs as revealed by the stimulated recall interview can be compared with stated beliefs. The observed classroom practices can also be compared to stated and revealed beliefs about teaching. This leads to a suggested explanation of the relationship between belief and practice.

Figure 3: Data Acquisition and Analysis



Summary

While labels can be misleading, this research most closely resembles a form of hermeneutic phenomenology, that is an attempt to understand the phenomena of the world as they are presented to us in conscious experience through interpretation of texts. The primary data source comes through qualitative or unstructured interviews along with detailed classroom observations, field notes, and journals. Analysis of the emerging theoretical structure was aided using qualitative data analysis software.

METHODOLOGICAL PERSPECTIVE

The theoretical perspective or methodological framework used in this study drew from several different closely related traditions. Observation techniques used an ethnographic approach, treating astronomy instructors as a distinct culture (whether they are or not is not important to the process of observation). Since everything has been reduced to text and the texts become the primary data, analysis is primarily hermeneutic. Finally, elements similar to participant action research have been included in the follow-up interviews and other later steps.

Ethnography and Culture

While an ethnographic approach is being used for some data acquisition in this study, it must be pointed out that such an approach implies a specific "culture" to study. There are many cultures and types of cultures. What most often comes to mind when people think of anthropology and culture is an image of "native" peoples of some foreign land. As Harry Wolcott (1988) describes it, "Yet I confess that whenever I conjure up an image of an ideal ethnographer, I always envision him or her pulling a canoe up on a beach and stepping into the center of a small group of huts among lightly clad villagers in an exotic tropical setting." (Wolcott, 1988, p. 189) Yet ethnographers and anthropologists study corporations, urban gangs, rural school systems, crisis intervention programs, bureaucracies, dairy farmers, high-energy particle physicists, school principals, movie moguls, top-level executives, night club patrons, motorcycle riders, health care professionals, and many other cultures. These diverse groups share the characteristics of cultures, as the term is used by modern anthropologists. That is, they possess a common set of tools including the knowledge, beliefs, arts, customs, morals, and ethics required to allow them to function as a member of a group; to make a living. The cultural tool kit also includes ideas about how things should be done and what things should be done. A culture is a historically developed, distinct way of life. It includes beliefs and ideologies, interrelationships between persons and groups, and material goods and technologies (Dobbert, 1982). These tools or characteristics are acquired through membership in a *society* (Kottak, 1978, p. 543).

Some would reject the notion that small subsets of a culture constitute a culture in themselves. Spradley and McCurry (Spradley, 1972) suggest instead using the term "cultural scene." A cultural scene is the information shared by two or more people that defines some aspect of their experience. A cultural scene is the knowledge that actors employ in a social situation. The social situation consists of the persons, interactions, locale, and objects.

Do astronomy teachers constitute a culture or a cultural scene? Is there a society of astronomy teachers? According to Gess-Newsome et al. (Gess-Newsome, Southerland et al., 2003, p. 735), a teaching culture consists of "taken-as-shared patterns of thoughts and behavior" and is "defined by the beliefs, values, habits, and assumed ways of doing things among communities of teachers." There are certainly professional societies to which astronomy teachers have access, but to the extent that they work independently of each other with little or no contact, they possibly fail the definition of a culture as a group. The teachers in this study group seemed to have little contact with other astronomy teachers. However, astronomy teachers somehow acquire the skills and knowledge required to teach astronomy, and in the process were certainly parts of a distinct academic society, since each of the subjects in this study and most astronomy teachers have taken a number of college classes in astronomy and physics where there was at least the possibility of assimilating a distinct culture. They possess a common set of tools, including knowledge about the content of astronomy, what subjects should be taught, and how those subjects should be taught. Their material goods and technologies include textbooks with remarkably uniform content, computer programs, overhead transparencies, and classrooms. All of these aspects of culture are present, but the extent to which they are common characteristics of the participants varies. For example, the textbooks are either similar or identical but the classrooms are distinctly different and create quite different environments for the teacher and students.

The teachers studied may also be integral parts of other communities within their own campuses and thus may represent different cultures at different times. For example, in reference to administrative restraints, teachers may be representing the viewpoint of their campus culture. When referring to the lack of preparation of today's students, they may be stating a characteristic viewpoint of the community of all teachers or the broader society to which we all belong In describing a particular approach to teaching astronomy, they may be acting as a member of the society of astronomy teachers. As the tendency arises to think of each of these individuals as representing a culture, one must be very cautious in thinking about just which subculture they represent at any given moment. Of course, they are all inescapably members of a larger American society, carrying all of the cultural baggage that implies.

Comparison of Belief and Practice

Comparing belief and practice was the most difficult part of the study. The study was not designed as a correlational study because the variables to be correlated are not known and there is no way to establish *a priori* that a comparison is even possible.

Models for this study may be drawn from the work on teacher beliefs and practices done by Jan Nespor (1987). She suggests that beliefs have stronger affective and evaluative components than knowledge components and this effect operates separately from the cognition associated with knowledge. She gives an example of Ms. Skylark, who attempted to implement a sort of fantasized teaching environment based on her experiences as a child, but since her teaching practices were inconsistent with effective classroom procedures, her lessons were frequently incomplete or interrupted (Nespor, 1987) .

One technique may be to draw comparisons between the classifications of interview data and field notes. Another procedure might be to classify each type of observed behavior using previously established categories. The second technique may expose insufficiencies of classroom practice, but may also exclude useful information that does not fit into a category. It should be possible to examine the data from classroom observations and develop categories based on the information available, using all information. Then these categories can possibly be matched with stated beliefs. Or, the categories can be developed from the interview data and the classroom observations examined for matches and mismatches. A combination of all of these techniques were used as appropriate.

The most powerful technique for comparing belief and practice will be the teacher's own statements as revealed by the reflective journals and follow-up interviews. Teaching, a complex social activity, requires *praxis* guided by *phronesis*: practical knowledge guided by a moral disposition to act truly and justly. It is hoped that the journals and follow-up interviews will give teachers an opportunity for deep self-reflection and allow them to analyze their own classroom behaviors from a new and fresh viewpoint. At the same time, the journals should allow me to be a responsive and illuminative researcher, recognizing that my observation alters the situation, but still leaving the power for change with the participants (teachers).

Research Stance

If teachers are to be enrolled as cooperative researchers, then their participation must be more than a superficial review of materials or "member checks" in follow-up interviews. Once entry into a classroom has been negotiated and fellow researcher-teachers have been recruited the nature of the teacher's involvement can begin to take shape. Certainly, extensive journal writing is the type of legitimate, self-reflective participation needed for effective change, but it is very difficult to achieve unless participants are genuinely committed to the research program. Another possibility is to encourage teachers to code sections of their own or of other teachers interview transcripts or of the field notes. If teachers are willing to participate in this way, unique insights and alternate viewpoints will be provided.

In addition to the degree of teacher involvement, the nature of participation by the researcher must be thought through and negotiated. There are ranges of possibilities of participation that must be considered by any researcher. At one extreme is the position of dispassionate observer, who records observations without bias and without perturbing the observed situation in any way. Most researchers now reject this extreme position as fictitious. The presence of the observer perturbs the situation in rather unpredictable ways and the observations are always filtered through biases, preconceptions, and theories. Action research, on the other hand, implies a high degree of participation by the researcher. The intent of action research is to change practice in a collaboration between participant and observer (Carr & Kemmis, 1986).

A model for highly involved research has been demonstrated by Tom Russell in two papers at recent meetings of the American Educational Research Association (Russell, 1992; Russell, 1993) examining his work with bridging the worlds of theory and practice. Russell traded classes with a high school physics teacher, and had his own methods students observe and criticize his teaching practice. Students at both schools accepted the situation well. University students, invited to observe their university teacher at the high school, found it difficult to claim his expectations were unrealistic, since he was out teaching high school every day. Some students felt free to criticize his teaching since they had been asked to observe; others hesitated because they were not used to criticizing teacher's work. He decided that teaching one class a day while also teaching beginning teachers shifted his expectations for in-service education. He rethought the structure of pre-service teacher education to make it more applicable to future classroom teaching. The high school teacher also found student comments helpful and was able to bring a different perspective to the university classroom.

In a variation of Russell's approach, I continued to teach astronomy during the period of this research and I included myself as part of the study. This included videotaping myself, recording self-interviews, taking extensive notes about teaching astronomy during the last two or three semesters of teaching, and taking extensive notes about my experiences as a student in a summer astronomy course. Thus, my perspective will be simultaneously that of researcher, participant, and student.

It is hoped that some of the teachers will be interested in examining the results of the interview and observation and collaborating to adjust their classroom practice or teaching philosophy to more closely match their beliefs (Carr & Kemmis, 1986), using a model similar to Russell's or another model. If this turns out to be the case, follow up interviews and observations, collaborative teaching, and extended self-reflection would be necessary. This is beyond the scope of the current proposed study. (See Appendix K: Central Community College Now.)

Generalization

Generalization in qualitative research is always a thorny problem. Many, perhaps most, qualitative researchers reject generalization across populations as a viable construct. While some researchers see the lack of generalizability as a flaw, others prefer to focus on the strengths of this type of research. Marshall and Rossman state, "The generalization of a qualitative study to other populations, settings, and treatment arrangements—that is, its external validity—is seen by traditional canons as a weakness in the approach. To counter challenges, the researcher can refer back to the original theoretical framework to show how data collection and analysis will be guided by concepts and models" (Marshall & Rossman, 1999, p. 146). This approach establishes the theoretical parameters of the research. Other researchers or consumers of research can decide if those parameters apply in a particular situation. Erickson states, "The locus of judgment about what generalizes from one setting to the next lies with the *reader* of the report rather than the writer of it. The questions the *reader* must ask are: How does the situation the author describes resemble what is going on around here? What is similar and what is different in my situation?" (Erickson, 1992, p. 9)

Patton quotes a number of different speakers at length on this same subject (Patton, 1990, 487-491). Cronbach (reported in Patton, 1990, p. 488) asserts that generalizations are always of limited usefulness because they "decay." He suggests attending to whatever variables exist in a given situation. As the researcher moves from situation to situation, generalizations develop, but always as "working hypotheses." Guba suggests attempting to establish generalizability, at least by defining the "limiting cases."

(Guba & Lincoln, 1999) In contrast, Schofield (1990) argues for increased generalizability but defines generalizability in terms of “fit” or as providing a potential for action. This view of generalizability may be the most useful. The reader must ask, “how can I use this information to improve my practice?”

Summary

The research model draws from several theoretical perspectives. The classroom observations followed an ethnographic model that views teaching from a cultural perspective. The theoretical analysis of the relationship between belief and practice depends on various information processing models. Active involvement by the participants roughly approximated a model of participant action research.

EPISTEMOLOGY

Epistemology is the study of the nature and validity of knowledge. Epistemology attempts to explain how we know what we know. There are many different epistemological stances possible. Objectivism is the name of the epistemological position that asserts reality and the meanings assigned to reality exist apart from any consciousness. Constructionism holds that meaning is constructed and arises from interaction of a consciousness with the realities of the world. There is no meaning without a consciousness where that meaning resides. Subjectivism stands in opposition to objectivism and holds that meaning is created independently and is imposed on objects. The object itself makes no contribution to the creation of meaning.

There are many other variations and subdivisions in epistemological stances. Many thick books have been written concerning each of the many subdivisions of this branch of philosophy. While labels are always suspect and are potentially misleading, for the purposes of this research constructionism seems to be the closest to what is actually happening as participants struggle to understand why they made the decisions they made.

Ontology

Those familiar with the divisions of philosophy will recognize that there is one more category of thought, ontology, which is the study of the structure and nature of reality itself. However, in hermeneutic phenomenological research, questions about the nature and existence of reality are "bracketed" or set aside. It seems preferable to stop here and reserve discussion of ontology for some future time.

Summary

This research seeks to develop practical knowledge about what the actions of teachers means to the teachers, developed through a variety of interpretive research. While labels can be misleading, this research most closely resembles a form of hermeneutic phenomenology, that is an attempt to understand the phenomena of the world as they are presented to us in conscious experience through interpretation of texts. The primary data source comes through qualitative or unstructured interviews along with detailed classroom observations, field notes, journals, and a stimulated recall follow-up interview. Analysis of the emerging theoretical structure was aided using qualitative data analysis software.

The research model draws from several theoretical perspectives. The classroom observations followed an ethnographic model that views teaching from a cultural perspective. The theoretical analysis of the relationship between belief and practice depends on various information processing models. Active involvement by the participants roughly approximated a model of participant action research. The epistemological basis most closely resembles constructionism.

Chapter Four
The College and the Participants

All of the active participants are on the faculty of a large, metropolitan community college, referred to in this document as Central Community College (not its real name). This chapter has two parts, the physical setting of Central Community College and a description of the participants. The goal of both parts is to bring the college and the participants "to life" and to give the reader a real sense of what it is like to teach at Central Community College.

COMMUNITY COLLEGE ASTRONOMY CLASSES

According to LeCompte et al., "The basic goal of ethnography is to create a vivid reconstruction of the culture studied." (LeCompte, Goetz & Tesch., 1993, p. 235) The content of this section represents an attempt to reconstruct the culture or cultural scene of astronomy teachers in their classrooms through a description of the students, the classrooms, and the teacher behaviors observed in these classrooms.

Astronomy classes at all levels share many characteristics beyond the common subject matter. But, there are several significant characteristics of a community college astronomy class that distinguish these classes from astronomy classes at four year colleges or universities. There are also significant differences between different community college classrooms that challenge instructors' abilities to adapt. Several different community college astronomy classes and astronomy classes in small liberal arts colleges and teacher preparation colleges have been observed while gathering data for this research project and at other times before and after formal data collection. In addition, several different university-level astronomy classes have been observed. This chapter presents "snap shots" of community college astronomy classes to illuminate the similarities and differences.

The Physical Environment

The participants in this study are all faculty members at a large, metropolitan community college, referred to in this paper as Central Community College (CCC). This is not its real name. CCC has several main campuses and many satellite locations throughout the multiple county area it serves. A community college is best defined as any institution accredited to award the associate in arts or science as its highest degree. According to an ERIC Digest on community colleges, in 1995 there were 1,024 publicly supported community colleges in the United States and 445 private two-year institutions (ERIC Clearing House for Community Colleges, 1995). Community colleges offer a comprehensive curriculum that may include vocational and occupational programs leading to a certificate or an associate degree in applied science, liberal arts programs designed for students who plan to transfer to a four year college or university, community education and personal interest courses which do not award academic credit, and remedial programs designed to help prepare students for college.

Central Community College has a policy of discouraging dedicated classrooms, except for laboratory classes. So there are a variety of classroom setups that both adjunct and full-time faculty must deal with. For adjunct faculty, the situation is even more difficult, because an adjunct faculty member might be required to teach at two or three different campuses during the week. Full time faculty are often assigned to a specific campus, but may still be required to use several different classrooms. Each classroom is shared with other classes and instructors, both astronomy and other natural sciences as well as mathematics, philosophy, and other subjects.

Each campus of CCC is self contained, with learning resource centers, video equipment for the rooms that do not have permanent installations, computer labs for the students to use, and food service facilities. The computer labs as well as many other computers on the campuses have high-speed Internet access.

In one classroom used often by Jack and Edward, students sit around fixed laboratory tables. There are cabinets of supplies along the walls containing equipment for physics, geology, astronomy, and other classes. Additional equipment, including some celestial globes, sits on top of these cabinets. There is a chalkboard, an overhead projector, and a videocassette system with a large screen television mounted high on the wall, although not quite high enough to eliminate the risk of running in to it. The room has a periodic table and some astronomical related posters on the walls. It is packed full of the paraphernalia of science teaching including bicycle wheels, bowling balls, low friction rotating stools, and rocks. There is a computer on each laboratory table and air track blowers are positioned on the floor between the tables. Overall, the room is crowded and cluttered. When students are sitting in the chairs, it is very difficult to move around the room (for example, while distributing graded papers). There is a small lectern and a table at the front of the room.

Another room at the same campus often used by Edward during the study period is a conventional classroom with free standing student desks and a chalk board at the front. The chalk board is very low quality and has a large bulge in the center that makes it difficult to write on. There is an old desk at the front of the room and a small lectern that can be placed on the desk if desired. Edward rarely used the lectern. There is a periodic table on the wall, but no other posters or wall decoration.

One classroom used by Jack and Edward is in an older building close to downtown. This room is much more spacious and is used mostly for physics and astronomy classes. The room has the usual clutter of teaching paraphernalia and physics demonstration equipment, but the students sit at desks and the room is much larger so it does not seem as crowded. There is a raised dais across the front of the room with a lecture and demonstration table extending most of the width of the room. Behind the demonstration table is a well-lit whiteboard or dry-erase board. The building dates back to times when school rooms were not air conditioned, so there are many windows along one side and across the back of the room that are covered with slat-style blinds. Some of the rooms at this campus are individually air conditioned, and the unit in this room is rather noisy and somewhat ineffective, especially when the late afternoon sun leaks through the blinds. The ceiling tiles are stained and sagging. The room is equipped with a periodic table and several astronomy and physics related posters.

Gene usually teaches at a much newer campus in the suburbs. The difference between this new, suburban campus and the old downtown campus is striking. The newer campus has several separate buildings, although some adjunct faculty must still maintain office hours in portable buildings. One classroom Gene uses is neat, quiet, carpeted, has new seating and pleasant, diffused lighting. There are no windows. The central air conditioning system is quiet and effective. However, the room lacks a permanent video system, so Gene must roll a portable unit into the classroom each time he wants to show a video tape (which is often). The room lacks a periodic table or any other equipment or materials related to science. Another classroom used by Gene during a summer class at this campus was similar: new, well-lighted, carpeted, and well-air conditioned. This classroom had several computers on tables all around the sides of the room. One time during class, a technician came in and started working on one of the computers. This obviously distracted everyone.

Edward often teaches at a suburban campus that occupies a converted office building. This facility has pleasant, well-lighted rooms and fairly new furniture. It is also a self-contained campus, having an on site food service, a library, and a computer lab for student use. The floors are mostly vinyl tile. Some rooms have chalkboards and some have dry-erase boards. Many rooms have permanently installed video systems. All rooms have screens and overhead projectors. However, since it is a converted office building, many more persons are trying to use the facility at any one time than it was designed to accommodate. So the campus has a severe parking shortage and limited elevator access. The elevators are so crowded that many students and faculty use the stair wells. Unfortunately, they were primarily designed for emergency and occasional use, so they are not very attractive. The concrete stair risers are somewhat uneven. Older faculty and staff with even minor mobility impairment have difficulty using these stairs.

One problem common to all the classrooms at all of the campuses is a lack of writing materials. The tray on the chalkboard often contains several pieces of chalk, most too small to be used. In rooms with whiteboards (dry erase boards) markers are often barely useable. One instructor in the study finally resorted to obtaining a private supply of chalk, erasers, and dry erase markers that he carried around in his briefcase.

Most astronomy classes at Central Community College are held in the daytime or early evening on weekdays. Classes may meet twice a week, for 75 minute periods. One or two sections may meet three times a week in 50 minute periods. A section may also be offered that meets only once a week in a marathon 150 minute period. Community college astronomy classes usually do not have a formal laboratory component, although some community colleges are starting to offer a separate laboratory section. Except for the laboratory section, the classes are assigned three lecture equivalent hours (LEH). Descriptions in the course catalog imply that the courses are primarily descriptive survey courses. (See Appendix J: Course Guidelines for Central Community College Astronomy.)

To provide a baseline for comparison, classes at a small liberal arts college and a large state university were also observed. At the small liberal arts college, the class was taught in the late evening and a high-quality, large aperture telescope was available for use. There was ample storage available for the telescope and other equipment. The room was a traditional classroom with a desk at the front, chalkboards, and video playback equipment available. Moreover, this room was apparently used only by this instructor (albeit for several different subjects). So equipment and supplies were at hand or were readily available. A significant portion of the period was regularly spent outside in observation. The conditions were not ideal, but the ease of use of the telescope and the skill of the instructor combined to allow the students to see several objects of interest.

The introductory level university class was quite different from any of the other classes. It was an activity oriented, self-paced class. The classroom was used only for astronomy classes and all the equipment needed was readily available, including specialized solar observation equipment and other laboratory equipment. Much of the class period was spent on the roof of the building, where several small telescopes were made available to the students. Other observational activities could be completed on the roof as well. While the situation was still not ideal — there was much back ground light — at least the horizon was relatively free of obstructions.

Student and Teacher demographics

While this report is about astronomy teachers, some observations about the community college student population are pertinent. According to a recent ERIC Digest on community colleges (ERIC Clearing House for Community Colleges, 1995), approximately 42% of the first-time, first-year students in the U.S. enroll in a community college. So community colleges are the first higher education experience for a large portion of the student population. Of this group, the great majority are part time students. The modal age of the population is 19, but the mean age is 32. So the community college population includes many older students. The ethnic breakdown of the community college population is similar to the overall population: 72.2% of community college students are Caucasian, 9.2% are African-American, 8.3% are Hispanic, 4.5% are Asian, and 1.1% are Native American. Approximately 1% are nonresident aliens. Approximately 46.7% of all minorities enrolled in higher education are attending two-year colleges.

Central Community College students are often older students attempting to start or restart a program of college study or seeking professional certification. Many are married with full time jobs and responsibilities. Central Community College has some sort of educational contact with over 70,000 community members, either in workforce programs, in academic programs, in professional certificate programs, or in adult and continuing education. The college is committed to reaching traditionally under served populations and offers a wide variety of subjects at many different campuses and satellite locations at many different times during the day. Night and weekend classes are widely available in many subjects, especially vocational preparation. The college offers distance learning classes and telecourses in many subjects.

According to a recent audit (Strayhorn 2003), 63% of CCC students are part time students. One in ten CCC students are over 40 years old and this age group is the fastest growing group of students.

The ethnic breakdown at CCC is shown in Table 1. (Office of Institutional Effectiveness, 2003):

Table 1 Ethnic Breakdown of CCC Students

White	60.7%
Hispanic	21.8%
African-American	6.6%
Asian/Pacific Islander	5.9%
American Indian/Alaskan Native	1.0%

The ethnic breakdown of the faculty includes a somewhat higher proportion of those self identified as White, and lower percentages of other ethnic groups (Office of Institutional Effectiveness, 2003):

Table 2 Ethnic Breakdown of CCC Faculty

White	72%
Hispanic	15%
African-American	6%
Asian/Pacific Islander	3%
American Indian/Alaskan Native	2%
International	2%

The Teaching Environment

All three instructors use some variation of lecture-style instruction. The instructor stands or sits in front of the room and lectures through much of the material while using notes, referring to material in the textbook, and possibly showing an overhead transparency or two. At Central Community College, astronomy is not a laboratory course so activities other than demonstrations are relatively uncommon. Some instructors are able to schedule observing sessions, but it is difficult for most community college students to participate outside of regular class times because of transportation problems, child care, job conflicts, or other conflicts. Hands-on activities are sometimes included as part of the regular class. For example, the students may be asked to use a table of stellar color and magnitude to plot a Hertzsprung-Russell diagram, or use distance and galactic longitude information to plot spiral arm structure in our local galaxy. One instructor has the students determine the distance to a familiar young star cluster by the technique of "main-sequence fitting." There may also be a few activities using small, hand held spectroscopes and gas discharge tubes. Students are sometimes required to complete one or more outside-of-class projects using simple measuring instruments..

Astronomical observations using a telescope or other traditional equipment during regular class times are difficult and depend on the skills and motivation of the instructor and the students. Most classes meet during the day and class activities are by necessity limited to observation of such things as solar phenomena, the north-south motion of the sun during the seasons, solstice determinations, and some lunar observations. Evening classes can do some outside observation, but these sessions are generally restricted to parking lots or other areas where outside lighting limits observation to the brighter constellations and bright planets. Activities may still include mapping constellations and motions of the moon and planets. However, the limited time in a period and lack of a scheduled laboratory session limits the amount of class time that can be spent in this sort of activity.

During a semester there may be several opportunities for students to attend "star parties" sponsored by the local astronomical society or to attend public observing sessions sponsored by a local planetarium or university. However, most community college students work at least part time to help support a family or to help pay their way through school. So scheduling observations at times other than regular class time is difficult.

Summary

The content of community college astronomy classes is similar to the content of introductory level astronomy classes at four-year colleges and universities. However, the demographics of the community college population, the physical environment including multiple campuses, the dependence on adjunct faculty, and the variety of students enrolled in community college classes make them distinct from equivalent classes at four-year colleges and universities.

THE PARTICIPANTS

The names used for the participants in this and subsequent chapters are also not their real names. One participant dropped out after the initial interview and classroom observations were complete, but before the follow-up interview could be completed. The active participants all use the same textbook and have very similar syllabi. This is partly due to the requirements that have been set by the college and the astronomy department for grading standards, course content, test frequencies, and administrative requirements. However, there is room for much variation in test design and which course content to emphasize. For example, one instructor does not use multiple choice questions on exams at all, while the others use a mixture of multiple choice, constructed response, and other kinds of questions.

All of the participants use some variation of a lecture style of teaching. This is partly due to the structure of the astronomy courses. According to the course descriptions in the college catalog, both courses are survey courses. At the beginning of the study period, Central Community College offered Solar System Astronomy, Physics 1312, and Stellar Astronomy, Physics 1311. (The course numbers conform to a common course numbering system widely used in the state by most community colleges.) After the initial interviews and observations for this study were completed but before final submission of this report, Central Community College added an astronomy laboratory course. (See Appendix K: Central Community College Now.)

Gene

Gene has the fewest years of teaching experience. His teaching experience includes community colleges and as a teaching assistant while in college.

Personal Background

Gene teaches part-time at Central Community College. He also works full time for a government agency. Since his full time job is during the day, Gene is limited to late afternoon and evening classes. Unlike the other participants, Gene teaches only stellar astronomy. At the time of the first interview, Gene was 39 years old. He has a Master of Science degree with a double major in mathematics and physics. He does not have any hours beyond the master's degree, or any other specialized or professional training.

Gene's long term aspirations are to possibly obtain a full-time community college teaching position. He said, "Well. I tell you, there was a position that opened up full-time, a physics faculty position that was full-time that's getting close to my salary during the day, so I'm kind of toying with the idea maybe going to full-time." Several times during the first and second interviews, Gene expressed dissatisfaction with his day job. In his journal, Gene said "I had applied for my boss's job at work and expected to get it, but they gave it to someone else. I was angry about that. I found out about this on Monday." Later in his journal he remarks, "This is a stressful time in my life. Tuesday, [a company] called and I have an interview over there on Friday." It seems apparent that Gene does not get much satisfaction from his day job. However, during the first interview Gene commented, "I really enjoy teaching a lot." The love of teaching is common to all the participants.

Teaching Style

Gene's lecture style is perfectly straightforward. He carefully prepares notes, tries to anticipate student questions, and presents the material in a logical sequence. While Gene uses extensive notes that are coordinated with the textbook, the other participants use lecture notes that are somewhat independent of the textbook. Gene's lecture delivery can only be described as dry. He often appears to be reading from his notes and speaks in a near monotone with little variation in volume, timbre, or inflection.

Gene does not appear to use active questioning techniques and seems to discourage student questions. He feels this is important to maintaining an orderly and productive class. In response to a question about encouraging questioning techniques, Gene said, "they may not even notice, but I make it a point at the beginning of every class—and most of the time they'll ask questions throughout the class, and then I'll answer." However, there are limits to how much of this unstructured questioning Gene will tolerate. He said, "Recently, the last few semesters, there's been some classes where I don't know what the psychology of their behavior is or anything, but it just seems like every time I've said something, there's a question. . . . That was on the point of being annoying, and so I try to probably use some body language or something to discourage that." Gene's overarching desire for control and the need to exert authority also influences his questioning style. He said, "Then a lot of times questions will come up. . . . I like it when they raise their hand and ask instead of just blurting out, interrupting me. I might let them get away with that once, and then when they do it again, I just keep on talking while they're talking, until I'm through. Then I'll answer. I do that on purpose."

"Wait time," the time an instructor waits for a question to be answered, is an important attribute of effective teaching. Mary Budd Rowe has probably been the greatest proponent of wait-time as a teaching strategy (1986), but research into effective use of wait time continues (Jegede & Olajide, 1995). Gene uses wait-time to some extent (as do the other participants) but not in any systematic way. Gene was asked, "How long do you wait after you ask a question? How long do you wait for an answer?" he replied, "I'm pretty patient. I never really noticed. I just want to make sure even the shy people can feel free to ask a question. I guess almost I encourage them to, and then it's almost, like, give them the optimal amount of time or whatever they need to make sure that if they have a question, I can try to answer it. I don't know." In a follow-up question, Gene was asked, "So you don't count or look at your watch or anything? You do it by intuition or feel?" and he replied "Yes."

Gene commented that as he got older and more experienced, he was gaining more patience. "As I get older, patience is a virtue. I've really come to recognize that, and a lot of times being patient and things just tend to surface naturally." In response to a follow up question about teachers who have minimal or insufficient wait time, Gene said, "I can see this [teacher] being anxious and he's just afraid they're going to ask a question. Like we were talking about, this class where they ask unbelievable questions, things you no way could prepare for."

Another problem arises with student questions. Some of the questions can be difficult to answer, because it is hard to determine what the student is asking. The interviewer commented, "The thing that occurs to me, though, is that we've looked at this now four or five times, and we still can't figure out what the student is asking. Gene replied, "Hey, but we're coming up with different ideas. . . . [I]t just shows us how many infinite number of interpretations [are possible]."

Perceived administrative restraints also limit Gene's questioning style. He said, "I've been reading stuff about having class discussion and stuff, and I think that might be a good idea, just haven't quite figured out exactly how to work it in yet." The interviewer asked a question about flexibility in class content and Gene replied, "That's a whole other issue. See, when I first started, we didn't get our guidelines until a year or two ago, and I was teaching this class like-I want to say theoretical. I was teaching this class as a conceptual class. Now it's more of a physics class." (See Appendix J: Course Guidelines for Centreal Community College Astronomy.)

Teaching Philosophy

Gene's teaching philosophy is included in a document he prepared as part of his evaluation portfolio at Central Community College. This complete document is included in Appendix I. Gene emphasizes problem solving and other thinking skills in his test and homework assignments. "The exams and homework have computational word problems that challenge the students to use inductive and deductive logic. . . . [T]he homework helps the students to understand the material better. . . . Computation problems are assigned to develop logic and show how mathematics is used as a tool to describe the universe. The problems also show how basic physics equations and algebra can be utilized to give approximate solutions to some of the most complex problems."

As an essential part of his teaching philosophy, Gene feels he needs to keep up with all of the most recent information. "I personally receive: *The Physics Teacher*, *Sky and Telescope*, *Astronomy*, *Stardate*, *American Journal of Physics*, *Physics Today*, *Science News*, *Scientific American*, *Discovery*, *National Geographic*, *Notices of the American Mathematical Society*, *Bulletin of the American Mathematical Society*." For Gene, content is of paramount importance. Several times during the interviews, he emphasized the importance of reading journals and other magazines on astronomy and staying current with astronomy research.

Jack

Before joining the faculty at Central Community College, Jack, like most graduate students, had some prior experience teaching university classes as a teaching assistant. Jack's experience also includes secondary level distance learning classes.

Personal Background

Jack is 31 years old and has a Master of Arts in astronomy. He is the only participant in the group that has a degree in astronomy. In addition, Jack has 44 semester hours towards a Ph.D. in Science Education. Jack has taught in various capacities for about nine years. Like most older students, Jack has also done a number of other things. He has been a factory worker in a soft drink bottling plant, groundskeeper for two summers in a metropolitan parks and recreation department in his hometown and worked for several years as a research assistant in the astronomy department of a large, state-supported university.

Jack feels that his experience as a research assistant has given him good insight into the scientific process. He described it as

> . . . a human process, . . . full of twists and turns. Not all of them are going to take you in the right direction but astronomy is done by people, people who have prejudices, biases, who make mistakes. So I think that's one big thing my research background has given me, an insight into what astronomy and astronomers are like. And it's mostly a lot of drudge work for the big discovery. If indeed that ever happens. It's amazing how you realize that even the greatest astronomers fit the piece in the puzzle, no matter how much this person might contribute, it's just such a small part. There's going to come people later on who are going to build on what he or she has done and soon it will become buried underneath a whole bunch of hard work that everybody's done.

However, Jack goes on to say,

> But it was a little frustrating for me. And probably one of the reasons that I got into teaching. In scientific research, you can devote years of your life to a project. And no one will care. Few people will know that you had even passed that way.

> Especially if your work is superseded by some change in technology or some new discovery, and suddenly 10 years of your life are gone. And I didn't like that very much. So I got into teaching where I could make a difference, person by person. I'll make an impact on their lives, for good or for ill. Although most of them will no doubt forget me, there will be a handful of people who will never forget the experience they had in my class, one way or another. The best student review I ever got, the one that almost moved me to tears, was when a young woman wrote on my [student evaluation] . . . 'When I was young, I wanted to be an astronaut. And now I want to be one again.' That made me feel really good. The fact that this young lady had had this dream and she had been somewhat discouraged by it, about it, kind of put it back in her mind, and she took my class and I have no illusions that she's going to . . . become an astronaut. But at least it made her feel that dream again. So that meant a lot to me. I like touching lives. How do you get that in scientific research, touching a computer?

Jack's long term aspirations are to complete his Ph.D. in Science Education and become a teacher educator, training future teachers of science. He said, "I have to get some more experience teaching in different educational situations but that's my ultimate aspiration. To train future teachers of science."

Teaching Style

Jack has expressed a definite preference for a lecture based teaching approach and feels that it may enable students to acquire important skills they will need later in life. Jack said,

> A lot of people knock lecture these days. There's a lot of anti-lecture literature out there, a lot of research proving lecture is ineffective. But I think lecture has its place. I think definitely that lecture helps students develop listening skills, which I think are so important in the real world. [Students] certainly need practice with interaction and discussion and thinking for themselves, but they also need practice in listening and actually getting information from hearing someone talk. . . . To just listen to someone talk and gather information from what people are saying, that's such an important skill in the real world. So I'm trying to help my students develop a knack for understanding the verbal and nonverbal clues that speakers give when they're trying to convey information.

While lecture may be shown to be ineffective by research, many college instructors share Jack's preference for lecture. One of the participants in a study done by

Gess-Newsome (Gess-Newsome, Southerland et al., 2003) understood science to be so inherently complex that beginning students simply could not grasp the concepts. Instead, this person argued that there some scientific conceptions must be *told* to students "if they are to come to a deep understanding" (Gess-Newsome, Southerland et al., 2003, p. 745).

Jack's advocacy of lecture as an effective instructional techniques is distinctly at variance with the recent trends on educational research, especially higher education research (Ely, 1970; Thornton, 1999; Bradley, Ulrich, Jones & Jones, 2002; Halpern, 2002; Lux, 2002; Green, 2003). Furthermore, Jack's expressed preference for lecture style somewhat contradicts statements he made in the initial interview:

> Well, the first situation, handing out the crystals, I think the teacher is employing a good strategy. I guess I could say a bunch of mumbo-jumbo about tactile learning and hands-on, . . . but the fact is that it's more effective to have a crystal in front of you than looking at a crystal in a textbook. Three-dimensional contact. It's easier to grasp when you have the actual item there. And, in addition, she's not telling the students what to look for. She's letting them find out on their own. And that's good teaching.

Many of the things Jack does in the classroom relate to his lecture style and his opinion that lecture can assist students with listening skills. He uses his position in the room and movement to help students focus. "Sometimes when you see me move around the room it's to refocus the students' attention on me." Jack also uses a variety of effective hand gestures. On one occasion, Jack used an economical hand gesture that triggered an appropriate response. "I'll say, "starts with H, four-letter word," trying to prompt them. Trying to communicate to them it's an everyday word. I try to give them this hand gesture to try to get them to think of the word 'heat.'" But the hand gestures do not always work. Later on, Jack was unable, even after much effort, to elicit a desired response.

Jack is the most vocally animated of the three active participants. In addition to hand gestures, he frequently changes his tone of voice from a near whisper to a near shout. He moves around the room from board to stool in front of the class to a position very close to or even among the students. Jack's lectures also reveal a breadth of knowledge including physics, biology and geology as well as history, the arts, and classical literature. He intersperses his lectures with references to sports and classical Greek mythology.

Jack often uses a questioning technique that allows students to comfortably make suggestions that, while incorrect, allow him to direct the discussion to the correct response. He said, "You have to lead them. You hope they offer you a wrong answer, which you can then present a situation that causes them to doubt that wrong answer. If you just say, "No," it's not going to do much for them. But if you can say, "Well, blah, blah, blah," it may sort of turn them around. That's the only way you're going to cause them to change their minds. If you just say no they're just going to close off, just like anybody would, even if you are the voice of authority. You have to get them to realize their answer is wrong, and that's very hard to do in some cases." This questioning approach is the same approach used by many science educators when trying to identify and redirect common student misconceptions. The technique has the student state the misconception, then investigate consequences of it that lead to obvious contradictions (Ridgeway, 1988; Brown & Clement, 1989; Baxter, 1991; Berg & Brouwer, 1991; Dykstra, Boyle & Monarch, 1992; Clement, 1993).

Jack's board technique is consistent with his lecture approach to teaching. He says, "I try, if I can, to prepare the board ahead of time because I just write so slowly that it really does slow the class down. . . . I try to use color as much as I can to show contrast between different points." Jack also uses the board as a sort of active medium. "I think some things like the greenhouse effect really are best explained visually and actively. . . . .This is my big thing with the greenhouse effect, you can illustrate to them it's not just a carbon dioxide molecule grabbing the heat and trapping it. . . . I just show the infrared bouncing around; I'm drawing it in a dynamic fashion. Even when I prepare the board ahead of time, in this case I might pre-draw the clouds and the CO_2 and the surface. But the active things like the sunlight coming in, you've got to do that actively because you have to show the beam of light coming down and striking the surface. Then you have to show the heat rising up off the surface of the planet. Then you have to show the infrared photons bouncing around from molecule to molecule. You have to show that. They don't really get that in the textbook because the picture is static in the textbook. One of the major functions of board work is to show these active processes. . . . Another function is to write words that aren't immediately obvious how they're spelled. I do that."

All of the participants use lecture notes to a certain extent. Jack says he uses notes for two reasons. One reason is to make sure he doesn't miss anything important. "Often I will just barrel along without the lecture notes and then while the students are kind of absorbing some of the things I've said and I think I'm done with a topic, I'll go back to my notes, flip through, and make sure I didn't miss anything. . . . I want my students to get a complete picture and sometimes I get so caught up in the furor or we get talking amongst ourselves that I might leave out an important point."

A second reason for keeping lecture notes, according to Jack, is in case he has to miss a class. "I keep lecture notes in case I miss a class and someone has to substitute for me, so they know exactly what I think is important and what I think the students should know about that particular topic."

Jack then went on to discuss his use of notes in other situations. He does not use notes that cover material with which he is very familiar. “Having said that, there are some parts in my class where I do not have notes. Since stellar evolution was my field of study as a graduate student, I don’t have any notes on stellar evolution, I just wing it.” There are also portions of the material or certain topics where his notes are missing or incomplete. “There are some things that I have not yet got around to creating notes for, a lot of my galactic astronomy. . . .” However, when lecturing on the core material for the class, Jack uses notes extensively. “[E]specially at the beginning of the class when I’m giving the students basic information about the laws of physics and the properties of stars, etc., I keep extensive lecture notes.”

Teaching Philosophy

Jack’s teaching philosophy is included in a document he prepared as part of his evaluation portfolio at Central Community College. This complete document is included in Appendix I. Jack asserts that his background gives him special insight into the needs and aspirations of community college students. He states, “Coming from a very poor socioeconomic background, I was the first member of my family to go to college. But I saw education as a way . . . to a better life. For this reason, I love teaching community college students. Many of them are in the same position as I was, and now I am in a position to help them. . . . The ultimate goal of a teacher is to make students self-sufficient, so that they can become lifelong learners.”

Jack sees potential in all students. He says, “It may seem almost a cliché to make the statement, “I believe that all students can learn,” but I do believe that most sincerely. On the first day of class I urge students to try and set aside any preconceptions they may have about their own abilities to “do” science.”

Jack recognizes that most community college astronomy students do not plan to become professional scientists, but he claims the skills they will acquire in a science class are broadly applicable to other endeavors. "I hope that I can help them develop universally applicable skills in logical thinking, critical reflection, listening, and communication. I believe that college-level education should have a higher goal than mere transmission of content." Jack also sees astronomy as inherently interesting, which enhances its utility. "Astronomy is a fascinating study in its own right, but it is also a fun and interesting venue to train students in basic academic skills which will serve them well regardless of their chosen profession."

On the other hand, Jack feels that students do not need to be entertained and in doing so we may be doing students a disservice. "I like to mix it up a little bit because one thing I try to tell the students is this is not TV. I'm not a TV image. That's why I begin every class by saying to the students, "Good morning," and I expect them to reply. I give them a hard time if they don't. I try to shatter that this-is-not-TV image by moving around the room." In an earlier interview Jack talked about engagement and said "we have done such a good job of engaging students that they expect to be entertained. Jack does not feel like it's our job to entertain. "In fact, most of us are not very good at it. Let the material be engaging."

One of the critical issues in effective teaching and questioning strategies is "wait time." Mary Budd Rowe was probably the greatest proponent of wait-time as a teaching strategy (1986), but research into effective use of wait time continues (Jegede & Olajide, 1995). Wait time is the amount of time the teacher allows for the students to answer a question, either with or without prompts. Jack has somewhat contradictory opinions on wait time. Early in the second interview, Jack says, "I know we're supposed to have silence and wait, that is perhaps the worst part of my development. It's so hard for me to have that silence in the room." But later he says, "Like I said, waiting is a very hard thing for me to do. If I know the students know the answer or if I know it's in their notes or easily at their fingertips, I've taken to just saying, 'I'll wait.' Just sitting at the desk with my arms crossed. 'Oh, well, he needs it,' and they start flipping through their notes." During the extended interval between the first set of classroom observations (in 1996) and the second set (in 2000) the instructor's use of wait time increased significantly. The interviewer pointed this out and Jack responded, "Good. Because I think that is important. I hope I've evolved." Later in the same interview, in one video segment Jack had told the class "I'm not going on with the lecture until I get the answer." He was trying to lead the class to a specific answer, in what is sometimes called "fishing." He said, "And they weren't biting!. I felt the need there to get them to remember what factors determine gravitational pull: mass and distance. I asked the question about two or three different ways and I finally found the right way to ask the question that would get the answer. Maybe if I had asked it that way first, I would have gotten a good response first. But who knows? Maybe it was just the building-up process that finally got students. The reason I said, 'I won't go on with the lecture until I get an answer,' that's my way of saying "I'll wait." Don't let students get away with saying, 'I don't know.' Don't let students get away with waiting you out, make them work. They have to think; they have to be active learners, active listeners. . . . You just have to put your foot down and say, 'Look, I know you know how to come up with this answer and until you come up with it we're done, we're just going to stop. I'm going to sit here and no one is going to move until someone comes up with it.'"

Jack expressed a definite preference for a lecture-style of teaching and justified this by suggesting that student's listening skills would be better trained. Jack stated, "I think lecture has its place. I think definitely that lecture helps students develop listening skills, which I think are so important in the real world. If you're in a board meeting or something like that they're not going to have a facilitated discussion."

Edward

Edward has the most extensive teaching experience of any of the participants. However, the bulk of his teaching experience is in secondary education. He is the only participant that holds a Texas Teaching Certificate.

Personal Background

At the time of the first interview, Edward was 54 years old. He is currently teaching part time at Central Community College and also working as a freelance writer, editor, and curriculum developer. He is a graduate student in science education at a major state university. At the time of the initial interview, Edward had 64 semester hours in graduate level science education courses and other education courses as well as upper division courses in physics and astronomy. Before entering the graduate program, Edward had taught mathematics, physics, physical science, astronomy, biology, chemistry, and other subjects for a total of 24 years in three different high schools in Texas. He has a bachelor's degree in physics from a large state university and a master's degree in physics from a smaller school widely known as a teacher training institution.

While Edward's degree is in physics, not astronomy, his background in astronomy includes extensive formal study as well as an avocational interest going all the way back to high school when he built his first small telescope as a physics class project. His interest in teaching astronomy began when one of the high schools where he taught decided to offer an astronomy class.

Edward has done a number of other things besides teaching. In addition to various summer and part-time jobs, he worked for one year as a field engineer for an oil well service company. Most recently, Edward worked as a multi-media developer, developing science based CD-ROMs and instructional CD-ROMs, and also worked for a publishing development house.

While still an undergraduate, Edward was selected to receive a National Science Foundation grant to work as a research assistant in the physics department. He worked in three different areas of research: biophysics, cryogenics, and cosmic ray physics. The cosmic ray program was the most interesting to Edward because it tied in well with his long term interest in astronomy. In the cosmic ray research program, Edward developed a system for constructing inexpensive, large volume Geiger tubes using burned out fluorescent tubes. The unit cost was very low, so a large number could be built and assembled into as a simple cosmic ray telescope. Edward says, "I learned several important things from this project. I learned that publishing results is important if you want your work to be useful to other people. I also learned that research in fundamental areas is severely limited by funding. When the funding ends, the research stops. I learned that politics at all levels is alive and well in physics research. Politics at the department level determines who gets the most desirable research space. Politics at the college level determines who gets the grants for new equipment."

In graduate school, Edward continued his interest in cosmic ray physics, investigating muon interactions in soils to determine if muon interactions might be responsible for the abundance of certain rare-earth elements. However, by the time Edward received his master's degree, he had lost interest in doing research. He commented, "I won't say physics research disgusted me, but it was close to that feeling. I realized that I did not have the drive and ability to make any significant contributions to the frontiers of knowledge. I worked very hard on my thesis research and it was frankly a very forgettable piece of research. And it's just gone, just buried, lost. And I realize, what I told myself poetically is, that I'm not going to be one of the great architects of physics. The best I could hope for is a job as a hod carrier. Whatever I do is going to disappear. By this time [completion of the master's degree], I had started teaching at a small high school, and I really enjoyed that. It seemed to be the way for me to go."

Edward's long term aspirations are "of course number one, to finish the Ph.D. degree. Then I have a decision to make and my aspirations depend on that decision. The degree I am pursuing is an academic degree which prepares me to teach in a college, teach science education, or a combination of them is one possibility. Or I may continue as a freelance writer and multimedia developer drawing from my science education experience to help me improve my ability to develop instructionally sound interactive multimedia and other materials."

Teaching Style

Unlike the other participants, Edward sees the lecture style of teaching as a sort of "necessary evil" due to administrative restraints. He states that it is a survey class and the list of topics in the college guidelines for astronomy require presenting at least some material from each chapter. (See Appendix J, Course Guidelines for Central Community College Astronomy.)

Edward's journal comments confirm his distrust of lecture methods. In a personal journal entry relating to the first class meeting of stellar astronomy, he said,

> Tonight, for example, I . . . hadn't planned on having any kind of organized lecture or presentation. I was going to go over the syllabus and dismiss them but then I saw sitting on top of the cabinet at the back of the room a lot of celestial globes. It seemed like there were enough to go around and so I guess my thought process was something like, gee, the globes are handy and that fits in the first chapter of material. Let me see if I can start to build a lesson around those celestial globes. So I got everybody to get one down and we put one on the tables, one on each table, and I got one, and we began to talk about various things in

> other parts of the textbook that I could relate to the celestial globe. . . . I think that may have worked out okay.

In another journal entry for the same class, Edward states, “I was teaching astronomy, high school astronomy years ago in [another community]. One of the first times I’d ever taught astronomy and it was final exam week. We were getting ready for the final exams and a student asked me, ‘Which is farther away, the stars or the planets?’ And I suddenly realized I hadn’t taught this child anything. What I had managed was a semester-long vocabulary lesson.”

In a later journal entry relating to the same class, Edward says, “I want to add another comment, . . . which is: I love doing this! This is a lot of fun. I forget how much I enjoy teaching when I don’t teach for a while. When I start it up again, I remember how much I enjoy it. That was a really fun class. I love standing up there and answering questions about something I know something about. That’s kind of dangerous in a way because I love doing that so much, I’ll do it at every opportunity. But it really is probably not very effective teaching. So I need to think about how my fondness for lecturing and didactic teaching can be replaced by a more collaborative teaching style.”

A week or so after the start of this same class, Edward wrote, “Class dynamics seemed to be developing so that I really do best when I respond to students’ questions. What I did this evening which made for a very nice lesson was I let the students’ questions segue me into other sections of the chapter that I was concerned with or that I wanted to talk about. [In effect], I let the students decide what was important to talk about in the chapter by asking . . . leading questions. This may not necessarily have been the same sequence of topics that I would have followed but it made a lot of sense to . . . let the students set the lesson.”

Edward intersperses a few direct questions for the students into his lectures. His use of wait time is extreme, to the point that students appear to become restless. At the point of restlessness, Edward will begin to use a few hints and prompts. Other than active questioning, however, his lectures are not very animated or interactive. At times he appears to be reciting from memory and often drifts off the subject into distracting references to popular culture or classical literature. He does move around the room some, but the movements seem almost random and distracting.

Edward has a deep interest in archaeoastronomy and multicultural astronomy. He will frequently bring in references to Native American, African, Persian, or Indian astronomy. He likes to make calendrical connections, mentioning the solstices, equinoxes, and cross-quarter days and their connections to modern religious holidays and other holidays. He also frequently mentions the Islamic religious calendar and Islamic holidays, although he is not Muslim. For example, he wall say, "I saw the new moon last night as the thinnest sliver of light in the western sky so this must be the first day of Ramadan." While entertaining, these excursions are rarely related to the unit being studied nor are they part of the syllabus. When asked about this, Edward explained "I am trying to make all students feel comfortable and also trying to avoid the sort of Eurocentric, Christian dominated class approach that has been the norm for a century. One way is to bring in the Islamic calendar, the Jewish calendar, and so on. Some of my students are Muslim."

Teaching Philosophy

Edward's teaching philosophy is included in a document he prepared as part of his evaluation portfolio at Central Community College. This complete document is included in Appendix I. Edward sees community college astronomy serving a different role and a different group of students than university classes. Even introductory astronomy classes in taught in universities may be structured differently and are likely to have different teaching styles and different resources. The introductory level university class observed in conjunction with this research was quite different from any of the community college classes. It was an activity oriented, self-paced class. The classroom was used only for astronomy and all the equipment needed was readily available, including specialized solar observation equipment and other laboratory equipment. Much of the class period was spent on the roof of the building, where several small telescopes were made available to the students. Edward states, “A community college astronomy class serves a different purpose than astronomy classes offered at the university level. There is only a small chance that any of the students in the class will become professional astronomers. . . . So how should such a class be set up to best serve community college students?”

Edward lists three reasons for offering astronomy to community college and other undergraduate students. The first is the educational benefit of a rigorous science class: “The cognitive processes trained by a rigorous science class are useful in many different types of problem solving. Students also need to develop a good sense of what distinguishes good science thinking from other forms of thought. Students need to be able to recognize psuedoscience and be able to intelligently reject claims based on faulty logic.”

Edward also likes the way astronomy can be used as a vehicle for presenting the “human” side of science. Astronomy is also an ideal vehicle for presenting science as a human activity. All humans, as far back as history records and beyond, have looked to the night sky for answers to the important questions of life: who are we and why are we here?

Finally, Edward sees astronomy as a more "accessible" science that is still within the reach of ordinary persons with sufficient interest. Edward asserts, "Astronomy remains one of the few sciences where ordinary individuals can and do make significant contributions to the field." Even those who do not pursue astronomy with this degree of rigor can still enjoy it as a hobby: [M]any amateurs receive hours of pleasure from viewing or photographing celestial objects. Not many fields of science are this accessible or have as much appeal. Set up a large Dobsonian reflector in any city park after dark, and soon a group of people will gather and begin to ask questions."

The conviction that lecture and didactic teaching were not adequate or effective led Edward to investigate astronomy misconceptions research and activity-based astronomy. Based on his experience with the student who did not know if the planets or the stars were farther away, Edward tries to include direct and specific instruction related to common astronomy misconceptions. Edward administers a diagnostic test at the beginning of the semester based on findings from the Private Universe Project which grew out of the film, "A Private Universe." (Schneps & Sadler,) The questions for this test are included as Appendix F. Edward also includes hands-on activities from the Private Universe Project and other sources in both solar system and stellar astronomy.

Edward's comments concerning the first situation in the initial interview suggest that even hands-on activities may not be enough without some specific direction.

> In my view is science teaching happening here? Not necessarily, is the conclusion I would come to. Because, without some specific questions or specific information I'm not sure that the students will be extracting the kind of information from examining the crystals that the teacher would want them to extract.. . . . The teacher has asked the question what can you tell me about the crystals that have been passed around. This is a certain amount of direction, but I'm not sure at all that it is sufficient direction to assure that science education or science teaching is happening.

Edward expressed a strong negative opinion of the textbook used by the college for this class. His comments are consistent with his overall teaching philosophy and distrust of lecture. He said:

> I like this textbook much less than the previous book that was used at CCC, *Essentials of the Dynamic Universe*, by Snow. The reason why I like this [textbook] less is because it seems to me to be more encyclopedic. I much prefer a book that takes a few topics, it almost doesn't matter what those topics are, although there are some obvious choices in astronomy. But a book that picks a few topics and really develops those topics in depth. This textbook suffers the same flaw as I believe many textbooks suffer, and that is to try to mention everything the students can possibly imagine as being related to astronomy. Every news story, every tidbit, every trivial pursuit question, is somewhere in the textbook. The textbook becomes very encyclopedic. But nothing is there in depth."

The encyclopedic textbooks commonly used in astronomy and other college science classes are in contradiction to reform efforts such as those of the American Association for the Advancement of Science (American Association for the Advancement of Science, 1990; American Association for the Advancement of Science, 1993). Gess-Newsome states, " . . . the most consistent message has been the call for the distillation of science content coverage to develop deep conceptual knowledge in students." (Gess-Newsome, Southerland et al., 2003, p. 732)

Participants' Self-efficacy

In order to measure the self-efficacy perceptions of the participants, they were asked to complete a self-efficacy questionnaire. Two other groups were also invited to complete questionnaires: Central Community College astronomy teachers who are not active participants and other Central Community College natural science teachers who do not regularly teach astronomy. These three groups provide a baseline for comparison of the participants' self-efficacy scores. The samples are far too small to justify any sort of generalization, but the scores are still interesting.

The instrument chosen to measure self-efficacy scores is called the *Teacher's Sense of Efficacy Scale* (TSES). It was developed by Anita Woolfolk Hoy and Megan Tschannen-Moran (Tschannen-Moran, Woolfolk Hoy et al., 1998). According to Tschannen-Moran and Woolfolk Hoy, the instrument was constructed to be consistent with Albert Bandura's principles for constructing self-efficacy scales (Tschannen-Moran, Woolfolk Hoy et al., 1998; Bandura, 2001). The instrument was developed by Tschannen-Moran and Woolfolk-Hoy to address perceived concerns with existing approaches to measuring self efficacy. The new approach is supported by validity and reliability data from three separate studies.

The *Teacher's Sense of Efficacy Scale* was chosen to avoid the problems of establishing construct validity for a new instrument. This instrument is included as Appendix H. Some of the questions on the instrument were rewritten slightly to make them more appropriate to community college classrooms. However, the sense of the questions was not changed. For example, the question, "How much can you do to motivate students who show low interest in school work?" was changed to "How much can you do to motivate students who show low interest in college work?"

The questions on the instrument are randomly distributed among three different categories, efficacy in student engagement (Engage), efficacy in instructional strategies (Instruction), and efficacy in classroom management (Manage). Table 3 shows the mean non weighted aggregate scores for the three participants in these three categories.

Table 3 Participant Self Efficacy Scores

Name	Engage	Instruction	Manage
Jack	4.7	7.3	8.6
Gene	7.3	8.4	8.0
Edward	7.5	7.9	8.5
Means	6.5	7.9	8.4

For comparison, Table 4 includes the means of the aggregate category means for all groups who completed the questionnaire:

Table 4 College Self Efficacy Scores

Group	Engage	Instruction	Manage
Participants (n = 3)	6.5	7.9	8.4
Other Astronomy Teachers (n = 3)	6.6	7.9	7.7
Other Natural Science Faculty (n = 10)	6.1	7.4	7.2
All non participants (n = 13)	6.3	7.6	7.3
All (n = 16)	6.4	7.7	7.5

Finally, Table 5 shows the sample means as collected by Tschannen-Moran and Woolfolk Hoy (Tschannen-Moran, Woolfolk Hoy et al., 1998) from three different studies.

Table 5 TSES Self-Efficacy scores

Category	Mean	SD	alpha
Engage	7.3	1.1	.94
Instruction	7.3	1.1	.87
Manage	6.7	1.1	.91
All	7.1	.94	.90

The samples collected in this study are far too small to make any robust statistical conclusions. Furthermore, comparisons between community college teachers and in-service secondary teachers (the TSES sample) are questionable at best. However, it may still be instructive to compare some of the means with the TSES sample. In the category of engagement, the community college science faculty scored consistently below the TSES sample, but still within one standard deviation. It is possible that college faculty do not consider student engagement as an important factor. If such a trend were to be supported by a more extensive study, it would seem to be an area needing attention (perhaps through professional development). In contrast, the community college science faculty scored consistently higher in instructional strategies. The difference is less than one standard deviation of the TSES mean as measured by Tschannen-Moran and Woolfolk Hoy, but may be an indication of overall satisfaction with teaching ability. In the category of classroom management, the science faculty scored almost one standard deviation higher than the TSES sample. The participants scored over one standard deviation higher. The participants clearly see themselves as effective classroom managers.

Commonalties

There are distinct differences between the teaching style and teaching philosophies of the participants and there are also definite similarities.

Lecture

All three participants use lecture as the primary instructional style. Gene and Jack view lecture as a preferred teaching technique. Gene's stated goal is to "get their brains to work" and he asserts that lecture can accomplish that. On the other hand, in the initial interview Gene decided that science teaching was taking place as students were watching a television show. He said, "as long as the student's getting information about astronomy through the TV show, I think science teaching is happening there" He goes on to say "I like to include some of these in my own class, The Learning Channel and Discovery Channel, PBS, they all have had good series on astronomy that I show in class."

Jack uses lecture as a sort of mental exercise technique as in this statement, "I think definitely that lecture helps students develop listening skills, which I think are so important in the real world."

Edward sees lecture as a necessary evil, the only practical means to cover the content required by the guideline. He much prefers an activity oriented approach. "I like for the students to do hands on activities, actually observing the night sky, naked eye astronomy type activities as much as possible. . . . It would be better to organize the whole course around this kind of hands on activity as is done in a course I took at the University of Texas. I wish that I were able to do that at Central Community College." In the second interview, there was a segment where Edward said he had been "jumping around" in the chapter, "answering student's questions" which he thought "was great." The interviewer asked why this was great and Edward replied, "It was great because it involved the students. The students were directing the lesson in a sense, they were directing their own knowledge, they were participating in what was going on, they were filling in gaps that they may have had in their own understanding, it was a very active learning situation with the students very much involved. That's the part that I thought was great, the fact that the students were involved."

Religion and Science

By coincidence, all of the participants in this group have deep religious convictions. The participant that had to drop out is a member of an old, large, mainline Protestant denomination. Jack is an active member of a denomination generally regarded as fundamentalist and evangelical. Gene is a member of a small, very conservative Congregationalist Christian denomination that generally teaches a strict form of biblical literacy. Edward is a member of a small, mainline protestant denomination that is generally considered progressive or liberal. All attend services regularly. Edward is probably the most active in religious life as he has served as a minister, choir director, elder, deacon, Sunday school teacher, and in many other roles.

Jack. Identifies himself as a Christian early in the semester with a "disclaimer." He tells the students that while he is an evangelical Christian, in his class they study science, not religion. Edward identifies himself as a Christian when the subject comes up in class in an appropriate context. For example, when discussing the great age of the universe or the big bang theory in stellar astronomy, or when discussing evolution or the great age of Earth in solar system astronomy, Edward will mention that he is a Christian. Gene identifies himself as a Christian only if directly asked. but does not hesitate to do so if asked. "If somebody asks me, then I'll tell them I'm a Christian, but I really don't get asked too often."

It is likely that the strong religious faith expressed by these participants influences their decision-making, but not in any obvious way. For example, on one of the religious "hot-button" issues, evolution, all of the participants follow a strict scientific approach. Edward confronts the issue directly.

> Science, in its desire to be 'scientific,' in opposition to supernatural, always looks for a scientific explanation for things as opposed to a supernatural explanation for things. . . . The so-called conflict between science and religion, or at least the sometimes contradictory and, as perceived by many, incompatible worldviews of science and religion is another one of the fundamental ideas that it's worthwhile communicating to students in a science class. I don't have any objection to whatever a student's religious beliefs may be. I certainly have religious beliefs of my own that I have managed to completely reconcile with my scientific understanding of the universe, and I would certainly be antagonistic to anybody trying to erode student's religious beliefs. But it's important to communicate to students and to others that science must proceed by looking for natural explanations. Anytime science stops . . . looking for natural explanations and invokes a supernatural, it stops being science and the acquisition of knowledge ceases. Certainly the success of science in developing ways of solving problems could not be equaled by a worldview that attributed plagues, for example, to a

> curse from God as opposed to natural event over which we could have control if we have enough knowledge and understanding of what was going on."

Jack uses similar language.

> As I emphasize in class, science is not about a search for the truth; it's about a search for the best possible explanation that we can come up with right now. What we're trying to explain is the solar system. Where did it come from? What happened to create it? It's not something we can ever observe directly; it's something we must piece together from indirect evidence, like a detective trying to recreate a murder. That makes some people uneasy. It runs the risk of offending some people's religious sensibilities because we're dealing with questions of origin, which are never easy. So I feel the need to put up that standard disclaimer. I openly talk about my religious background as a way of assuring students that not all scientists are roaring atheists and not even a majority of scientists are. The majority of scientists have some sort of belief system, a point of which the general public is not aware, because of a few vocal individuals like Steven Weinberg and a few others that make a lot of sound and fury. Most scientists have some sort of belief system, but they are quiet about it and private about it. I chose to go public in that and it comes especially as a shock to people that I'm a fundamentalist Christian because Christian fundamentalists are so greatly associated with anti-intellectuals, which I think is a crying shame.
>
> I'm hoping that will assure some students that I have respect for their religious beliefs. What I'm about to say has nothing to do with their religious beliefs; it doesn't have to have anything to do with their religious beliefs. That it is, instead, a scientific theory, and it should be treated as such, not as a truth, not as gospel, not as a challenge to religion, but rather as the best explanation that science can come up with under the circumstances. It's something I hit at the beginning of the semester and it's something I feel compelled to do at the end of the semester—the difference between science and other ways of thinking. That's why I give that standard disclaimer. It might not be necessary, but if I think it helps to ease the students into the last couple of days of class which are very theoretical and very uncertain.

Gene also makes it clear that his faith and science are separate issues. "Now when we get into—in solar system astronomy, we get into the origin of life, and stellar astronomy we get into the Big Bang, or the creation of the universe. So, in both of them, we had this global theory or theories about physics, astronomy, philosophy, theology. So yes, we're getting some overlap here [between religion and science]. . . . But normally I keep them separate."

Differences

Although the participants share many similar characteristics, they also differ in significant ways. Edward lectures but thinks of it as a necessary evil, while Jack thinks lecture actually improves student's ability to think. Gene sees lecture as an important part of "getting their brains to work." Gene also uses videotapes extensively in the classroom, Edward rarely uses video tapes, and Jack never uses them. Edward gives multiple choice and essay questions on the test, while Jack asserts that he "would resign if the department required multiple choice tests."

While these differences are significant, they represent superficial differences. More significant differences are be revealed by each participant's teaching philosophy and beliefs as presented by classroom behavior and statements made in interviews.

Gene interprets the course guidelines and course description (see Appendix J) as requiring a substantially greater amount of computation than either Edward or Jack include. For example, the guidelines state, "Over 50% of the points on each examination must come from answering questions which test knowledge and skills beyond mere recall of facts. Examples include, but are not limited to, essay questions, computation problems, exercises in making observations of photographs and diagrams, and problems involving the interpretation of charts, graphs, and data tables." Gene is motivated by this statement to include what he calls "physics" problems on homework and tests. He states, "Because they came out with those guidelines, my homework is ten physics problems. . . . So it's a different class now than it was." In response to a question from the interviewer about laboratories and other activities, Gene stated:

> I'm at one end of the spectrum, giving them physics problems as homework. I realize that's probably at the hard end of the spectrum, but I just wasn't comfortable doing some of those other activities. I thought the Internet was just copy and paste. That may be something I can work on myself, where I just give them their homework, just 25 percent, and their four exams are 75 percent. Their homework is physics problems.

In response to another question, Gene responded:

> I'm amazed, I don't know how many come in thinking they're going to memorize the constellations or something. But I'm certain they think astronomy's going to be easy, and it doesn't have a lab, so that's why they take it. Next thing you know we're doing physics problems, we're doing nuclear reaction rates, we're doing relativity, so it's hard, it's physics.

Edward takes a different approach. His written teaching philosophy includes statements about astronomy in community colleges such as this one, "Astronomy is also an ideal vehicle for presenting science as a human activity. All humans, as far back as history records and beyond, have looked to the night sky for answers to the important questions of life: who are we and why are we here? Astronomy allows the presentation of science as a continuing human endeavor instead of 'final-form' science." Statements similar to this suggest Edward sees astronomy as much like a history or humanities subject. This may be due to Edward's secondary school teaching training and experience, especially in courses such as Harvard Project Physics. Edward states, "I always like to try to put things into a historical context. I like to try to present astronomy and all the sciences as a human activity that evolves and develops as part of a process. . . . There is a great discussion going on in science education. This discussion has been going on for many years of whether it is pedagogically better to present the concepts of science in a well-organized, clear, logical manner. . . . Harvard Project Physics . . . took a completely different approach and presented the development of scientific concepts in a historical context. I believe most physics teachers and most physics educators and other educators have adopted the former approach. . . . I am probably a minority in that I prefer to present the concepts of physics and astronomy in a historical context. . . ."

Jack also uses a more conceptual or historical approach to astronomy. He justifies this by saying, "I take an historical approach to teaching astronomy because I want to demonstrate to students that science is a human endeavor. I attack the notion that science is for the privileged few by presenting the stories of men and women who 'broke the mold' and revolutionized science. I hope that this will put a human face on science, and encourage my students to be scientifically aware citizens, even if they do not pursue a technical career."

SUMMARY

The goal of this project is to identify beliefs and other factors that may be influencing classroom decisions. All three active participants have many commonalties of teaching style and background, as well as a few significant differences. All have backgrounds in physics and astronomy, all love what they are doing in teaching, all have expressed an interest in improving their teaching effectiveness, and all share firm religious convictions. Despite their significant differences, in overall teaching style as observed in the classrooms the participants are more similar than different.

The three participants also face similar physical classroom settings and are part of the same "culture" of community college instructors. This suggests that differences in interactive decision making due to differences in culture or physical setting would be subtle at most. In subsequent chapters, the factors that influenced decisions related to each distinct teaching event will be identified.

Table 6: Background, Teaching Philosophy, Content, and Personal Factors

Variables	Jack	Edward	Gene
Personal Background			
Education	MS Astronomy, Ph.D. student science Education	MS Physics, Ph.D. candidate Science education	MS Physics
Experience	9 years as TA or in community college	2 years as TA, 24 years in secondary school, 10 years community college	4 years as TA 3 at CCC
Teaching Philosophy	All students can learn. Education is the way to a better life. Make students self-sufficient. College science part of general education	College science part of general education. Science is good training for thinking, distinguishing good science from bad, human side of science.	Emphasizes problem solving., inductive and deductive logic. Tries to stay current in content knowledge.
Position on lecture	Students do not need to be entertained. This is not television. Lecture improves ability to think.	Lecture is necessary evil. Lecture and didactic teaching are not sufficient to address misconceptions.	Prefers carefully structured class. Lecture important part of getting students brains to work.
Textbook likes and dislikes	Textbook is used only as a resource. Students are expected to get most information from notes.	Dislikes textbook because it is encyclopedic and shallow and it contradicts science reform efforts	Likes the textbook and carefully reads each chapter or unit of material before presenting it to the class.
Content Factors			
Discipline-specific pedagogical knowledge	Extensive	Extensive	Limited
General knowledge of subject	Extensive	Limited	Moderate
Personal Factors			
Religion and Science	Includes explicit statement of religious belief as part of introduction to class	Includes explicit statement of religious belief when appropriate.	Does not include an explicit statement of religious belief but responds to students if asked.

Table 7: Teaching Style

Variables	Jack	Edward	Gene
Teaching Style	Lecture from prepared notes with infrequent direct questioning. Notes are independent of textbook, but include text references.	Lecture with some direct and some interactive questioning. Sees lecture as inadequate, but a necessary evil.	Straightforward lecture, carefully prepared notes, tries to anticipate student questions. Interaction with students limited to responding to student questions. Tries to limit and restrict direct student questions except at designated times.
Use of video	Never or almost never	Infrequent but used when appropriate	Frequent, but use appears to have decreased over study period
Test format	All constructed response. Strong dislike of multiple choice tests.	Uses both constructed response and multiple choice. Thinks multiple choice can be effective.	Mixture of short and long answer constructed response, multiple choice and true/false.
Wait time	Started as relatively short, but increased over the study period. Uses cue words and hand gestures effectively.	Long, to the point of student discomfort. Uses hints and prompts.	Not systematic or consistent. Goes by "feel."

Chapter Five: Internal and External Factors Influencing Teacher's Interactive Decision Making

As stated in the first chapter (see p. 14), the goals for this study are in the form of several questions:

1. What are teachers' stated beliefs about the nature of effective astronomy instruction?
2. What are teachers' perceptions of the purpose of teaching?
3. What teacher beliefs about the nature and purpose of effective astronomy instruction can be extracted from observed teacher behaviors?
4. What specific classroom practices do teachers use?
5. Is it possible to identify a relationship between specific classroom practices and stated or implicit belief systems?
6. Does teaching practice change when teachers begin to reflect on their own beliefs and practice?

The first four questions have been answered, at least partially, in the previous chapters:

- Based on the results from the initial task analysis, the stimulated recall interview, journals, and conversations, community college astronomy instructors do have specific beliefs about the characteristics of effective instruction.
- The purposes of teaching, especially the roles of the community college instructor, are clearly articulated by the participants.
- It is possible to identify specific classroom decisions and behaviors that may be related to beliefs.

- It is possible to identify specific classroom practices that are potentially related to beliefs..

This chapter will extend and amplify answers to the first four questions while attempting to suggest an answer to question five relating to teachers' beliefs and relationships between belief and practice. The answers to question six will be considered in the concluding chapter.

In Chapter 2 of this paper, the interactive decision making models of Clark and Peterson were introduced (Clark & Peterson, 1986). Their most recent model is based on two assumptions: (1) Teachers are not choosing between two or more alternatives, but rather are choosing whether or not to implement a specific action. (2) The decision is preceded by factors other than judgements made about the students or about the classroom situation. These factors include judgements about the teaching environment, the teacher's state of mind, or the appropriateness of a particular strategy. They suggest that failure to consider these other factors would lead to inaccurate portrayals of teacher decision making.

The teaching environment, as suggested by Clark and Peterson, seemed to be an important factor in teacher's decision making. The participants in this study all felt constrained by many different factors both internal and external to the classroom, although they may not have actively expressed a feeling of constraint. There were constraints of administrative requirements, authority issues, systemic constraints (such as preparing future teachers for standardized tests), logistical constraints (such as lack of access to equipment and observing sites), and self-imposed restraints.

The other factors mentioned by Clark and Peterson that influence interactive decision making, the teacher's state of mind and the appropriateness of a particular teaching strategy are also well represented in the data. Another factor that appeared to be of substantial importance in interactive decision making was the tendency for extemporaneous lessons.

ADMINISTRATIVE CONSTRAINTS

One of the odd paradoxes that became obvious early during data acquisition was related to the perception of administrative constraints. The introduction to this paper discussed how Brickhouse had observed that an inexperienced teacher had not reconciled his own conflicting beliefs or the impact of institutional constraints on his teaching (Brickhouse, 1990). Herman (1995) speculated that the reason ESL teachers did not use sound reproduction equipment was due to an administrative constraint. The participants in this research revealed several examples of differences, even contradictions between teachers' statements about constraints and what occurred in the classroom. As the term is used here, administrative constraints include those that arise within the college or department where the participants teach or that are imposed through textbook selection and similar factors. They are local constraints. Broader issues are considered in the separate category of systemic constraints.

The various reactions of the three participants to administrative constraints such as departmental policies and course guidelines can be represented by "catch phrases." Gene sees the various administrative constraints as a *rule book*. That is, they are a set of rules that must be followed precisely. Jack sees the administrative constraints as an *umbrella*. Except in the construction of his syllabus, Jack seems to pay little heed to the course and departmental guidelines, but is perfectly willing to roll them out if the need arises. Edward appears to regard the collection of administrative constraints as an *annoyance*. While he is scrupulous in including required verbiage in his syllabus, he seems to meet the bare minimum of other requirements.

Edward—Lack of Preparation Time

In his journal for the first class night, Edward claimed: "I only learned that I was going to be teaching this class a few days ago. And I really have not had time to prepare or think about what to do in class or how to go about teaching the class. . . . I'm going to need to do a lot more lesson planning than I have in the past, teaching astronomy at CCC. I'm not going to be able to just go in the room and open up the book and wing it." This is apparently a fairly common experience for many part-time community college teachers.

However, describing the first night's lesson, Edward said that he found some celestial globes in the classroom. "So I got everybody to get one down and we put one on the tables, one on each table, and I got one, and we began to talk about various things in other parts of the textbook that I could relate to the celestial globe. I'm not sure that was unsuccessful. I think that may have worked out okay. It did a couple of things. It was really sort of an impulse to do this. They did manipulate, they did look at—at least maybe half the class did look at the globe and fiddle with the knobs and read the names of the constellations and move the sun around and that sort of manipulation at least produced some engagement. Maybe engagement is what I was trying to get. A sense that the class is going to require some engagement on their part, that they can't just sit back and passively listen as I talk." The sense of Edward's comments is clearly that he felt this was a successful lesson in spite of lack of preparation and having to "wing it."

Edward perceived another administrative constraint related to text book choice. He felt he had no influence on the choice of textbook and did not care for the one used: "I, frankly, like this textbook less than the previous book that was used by Central Community College, *Essentials of the Dynamic Universe*, by Snow. The reason why I like [the Chaisson and McMillan book] less is because it seems to me to be more encyclopedic. I much prefer a book that takes a few topics, it almost doesn't matter what those topics are, although there are some obvious choices in astronomy. But a book that picks a few topics and really develops those topics in depth. This textbook suffers the same flaw as, I believe many textbooks suffer, and that is to try it to mention everything the students can possibly imagine as being related to astronomy. Every news story, every tidbit, every trivial pursuit question, is somewhere in the textbook. The textbook becomes very encyclopedic. But nothing is there in depth."

Edward—Lack of Opportunities to Observe the Sky

Many of the astronomy courses taught at Central Community College are held during the day, so there is limited opportunity to do astronomical observation. Solar and lunar observation is possible, but that only fulfills the observation needs for a small part of each course taught. According to Edward, even classes taught at night have limited observation opportunities due to the time constraints imposed by survey nature of the class. Edward's response to this restraint has been to have the students complete projects outside of class that require some observation. Edward feels this has been mostly unsatisfactory, partly because many of the projects have been of very low quality.

Recently, Edward has tried a different approach, requiring students to complete two or three laboratory exercises for a portion of the course grade. These laboratories are much more structured than the projects were, but still lack supervision.

Edward also feels restrained in his ability to require students to attend nighttime observation sessions. Most of the students in community colleges hold full or part time jobs and they depend on the income from these jobs. Many of them use public transportation. So the students are usually not able to attend outside sessions. Recently, the community college has instituted new field trip requirements and there is the possibility of taking students to an observing site. Other classes such as geology and

Environmental Science do this regularly. Even with transportation provided, students will still be restrained by their job schedules. While outside observation can be made a requirement of the course, Edward feels this may be unfair to many students.

Jack—No Constraints

In an informal conversation before class, the teacher said: "I have never felt any constraints on what I do in the classroom. I have always felt that I could do whatever I thought was needed, what was appropriate. Here at [Central Community College] we have complete freedom." This is consistent with my experience in community colleges in astronomy classes. Since these classes are not prerequisites for any other course, there is relatively little restraint on content, sequence, and instructional approach.

But there was an apparent constraint. In class, the teacher was discussing the second major test, a take home test and a student asked, "Will the next test be take home?" The teacher replied, "No, my department head would not approve more than one take home test per semester." Apparently the teacher did not recognize this as a constraint. Or, there was no such restriction and the teacher was using a fictitious restriction as an excuse.

Gene—Being Prepared

During an interview, Gene said. "[I]f you want to be an expert on all of this stuff, it takes a lot of time and preparation and it's a challenge and that's why I like it. It stimulates my brain, you know? It's like going through your oral exams two nights a week. (Laughs) And I like it. I think it's important for them to be able to ask anything that's on their minds and we'll talk about it."

However, Gene appears to be less flexible than he claims. Students do ask questions, perhaps three or four per class period, but the instructor's response is often similar to, “Well, we will be discussing that next week.” The content seems to dictate the pace and sequence of the class.

The Syllabus: An Administrative Constraint

Central Community College requires all instructors to have a syllabus. According to college policy, certain statements must be in the syllabus. These include statements about scholastic dishonesty, academic freedom, student access to college services, and accommodation of students with disabilities. The physical sciences department has discipline specific requirements for grading policies, frequencies of tests, and similar policies. The course descriptions and guidelines impose additional requirements on the syllabus. In spite of these restraints, there is a lot of variation among the participant’s syllabi.

Departmental Guidelines: An Administrative Constraint

The Department of Physical Science at Central Community College had developed a set of course guidelines that were implemented between the first round of classroom observations and the second round (see Appendix J). This was partly due to implementation of the SACS common course numbering system, which assigned Physics rubrics to the astronomy classes. In addition, Central Community College requires all instructors to have a syllabus. The guidelines specify how much weight each category of grades carries. Since implementation of the guidelines, Gene feels he must teach “physics.” This resulted in a substantial change in Gene’s lecture style between the two rounds of observations. He now uses more mathematics and has incorporated derivations and numerical problem solving into his lectures.

In contrast, Edward says he never saw the guidelines. Neither his syllabus nor the content of lectures, tests, and homework assignments has changed. He teaches “conceptual’ astronomy, but does include numerical problems as part of the optional homework assignment..

When asked, Jack stated that he is not sure if he saw the guidelines or not. However, his classes do not seem to have changed as far as content or presentation. The tests are essentially the same, or at least draw from the same master set of test items as before.

ISSUES OF POWER AND CONTROL

All of the participants see themselves as “the one in charge” in the classroom. However, this notion plays out in distinctly different ways between the three participants.

Gene—Being In Charge

Issues of authority are paramount to Gene. During an interview segment when Gene had been asked to delay a test, he went on to say, “. . . the other [reason] was just kind of using my authority to say no.” This issue of authority, just who is in control in the classroom, kept appearing at many different points in both the initial and follow-up interviews with Gene. This would appear to be of paramount importance to him and certainly influences most of his classroom decision making. Here is the complete exchange between the interviewer and Gene regarding the request to delay the test:

> Gene: I guess the student asked if we could have a test on Thursday. It must have been Tuesday, and I pause, acting like I’m thinking about it, and maybe I was thinking about it. Then I said, “No.” The two main reasons were since we had the syllabus that was outlined with specific dates, I didn’t want anyone to be thrown off, like if they weren’t there that night, they might not have anticipated when the right night for the exam was, and so they might have wasted some time preparing if it was delayed, or maybe would have worked it differently. Then the other was just using my authority to say no.
>
> I: We don’t have to apologize for that.

> Gene: Yes, because it's that thing about "give an inch, then they'll want a mile," where the kids were constantly testing. It's true-the more you give, they keep pushing that envelope more and more. You have to impose your control over the class, or authority or something. . . .
>
> I: I think that's . . . legitimate.
>
> Gene: Yes. You have to establish that control, because I've seen some conferences where the audience — they were asking questions and were unruly and just got out of hand. I respect the students and everything, and I encourage them to ask questions, but at the same time it's got to be a nice environment. It's not going to be where they can try to take control of the class and have it their way. Just little things like that.

Edward—Collaboration and Hands-on Activities

Edward approaches the classroom interaction very differently. He apparently prefers a much more interactive and collaborative class. In response to a lesson where students were asking a lot of questions, Edward says, "It was great because it involved the students. The students were directing the lesson in a sense, they were directing their own knowledge, they were participating in what was going on, they were filling in gaps that they may have had in their own understanding, it was a very active learning situation with the students very much involved. That's the part that I thought was great, the fact that the students were involved."

So Edward asserts that he is perfectly comfortable with students "taking control" of the class and claims that he would even prefer a class where that was a possibility, within limits. Nevertheless, Edward still seems to view himself as the one in charge. He said, "I like to have a class that's participatory and collaborative and where we work together, but at the same time we're the ones who assign the grades, and we're the ones who decide when to the give the test, and what's going to be on the test, and that kind of thing. That's what our job is, and we have to set it up that way."

Edward's preference for a collaborative approach also seems consistent with his stated preference for an activity oriented astronomy class. "I like for the students to do hands on activities, actually observing the night sky, naked eye astronomy type activities as much as possible, [but] it's difficult to actually do astronomy activities in class. I have found a few desk-top activities that work pretty well, but they are not completely satisfactory. To make up for this, I have for some years tried to get students to do a project of some sort where they can actually do something, observing the night sky or . . . whatever. . . . It would be better to organize the whole course around this kind of hands on activity. . . . I wish that I were able to do that at [Central Community College]."

Edward also seemed to suggest that students should openly question the textbook. While discussing the relatively strong magnetic fields of Uranus and Neptune, Edward seemed to raise a question about the book's explanation, "[N]either one of them have enough mass to compress the hydrogen enough to reach the liquid metallic phase transition. And so we need another explanation for why Uranus and Neptune have conducting cores that would enable them to have relatively strong magnetic fields.". During the follow-up interview, he mentioned, "I said something a little curious at this point. I told the students that the explanation did not satisfy me, but that I could not exactly explain why." In defense of that position, Edward said, "My thinking, I guess, . . . is that it's OK to challenge the textbook. It's OK to suspend the acceptance of the authority of the textbook. It's OK to be a little rejecting of authoritative statements. Certainly this [is true] in the field of astronomy where there is just simply so much that we don't know. . . . There are so many unanswered questions. So many of our explanations are genuinely tentative explanations. So, I guess, what I'm trying to do this and similar kinds of things that I throw in from time to time is to just encourage students to be a little skeptical. They don't need to throw out everything that's in the textbook of course, but you have to be a little bit skeptical and recognize when the textbook author is proposing an explanation that is somewhat tentative and that, in fact, next week may be completely replaced by different explanation."

Jack—Socratic Dialogue

Jack has a similar teaching philosophy, but uses a different approach. He likes to use a Socratic questioning strategy to lead students along and he encourages participation and active questioning. "You have to lead them. You hope they offer you a wrong answer, which you can then present a situation that causes them to doubt that wrong answer. If you just say, "No," it's not going to do much for them. But if you can say, "Well, blah, blah, blah," it may sort of turn them around. That's the only way you're going to cause them to change their minds. If you just say no they're just going to close off, just like anybody would, even if you are the voice of authority. You have to get them to realize their answer is wrong, and that's very hard to do in some cases."

Jack sees his role as teacher to be larger than just a conveyor of information. "I think, to some degree, my job is to help teach the students how to be students. Teach them how to learn. Part of learning is [recognizing that] not all of your questions are going to be answered immediately. Learning isn't about instant gratification. . . . It's a valid question to ask but we don't yet have the background material to make the answer develop naturally. I don't want to just be the voice of authority telling them things. I want answers to develop naturally. That will be more meaningful, more lasting, to them. I want them to find out the answer for themselves."

SYSTEMIC CONSTRAINTS

Systemic constraints are considered separately from administrative constraints. Administrative constraints are local constraints that arise within the college or department where the participants teach. Systemic constraints are those that apply to colleges in general, including community colleges. Systemic constraints may be state-wide requirements imposed on students or may be constraints imposed by the Southern Association of Colleges and Schools (SACS) or another regional accrediting agency. The Texas Higher Education Coordinating Board has created a common course numbering system to which CCC adheres, and specifies some course content.

Many of the students who enroll in one or more semesters of astronomy are in some program that requires a science credit or two. In those cases, astronomy may be the only science course these students ever take. If that is the case, the need to provide students with a firm grounding in the nature of science becomes a systemic constraint.

Astronomy may also be a specific requirement of professional certificate programs, such as teacher preparation programs. Teachers, especially elementary school teachers, need a good understanding of what science is about if they are going to provide science content in their classes.

LOGISTICAL CONSTRAINTS

Logistical constraints are external constraints created by the institution or the nature of a college class. These are separate from systemic constraints, which may be caused by restraints external to the institution, and self-imposed restraints, such as the syllabus as a type of contract.

Following the Book

All three participants follow the sequence in the textbook very closely. In part, this is due to the course guidelines provided by the Physical Sciences Department (see Appendix J).

Edward—Textbook as Unreliable Encyclopedia

In response to a question by a student concerning the thickness of Earth's crust, Edward replied, "Instead of answering the students question directly, how do we know all this stuff, I gave him the information from the textbook, I directed all the students to the information from the textbook about seismic information. . . ." This seems to indicate that Edward sees the textbook as a source of accurate information that is readily accessible to the students. During a response to another interview question, Edward said, "While information is certainly useful, I'm really not a big fan of testing and requiring students to memorize things they can be looked up in a few minutes, for example, looked up in the textbook."

At times, Edward seems to feel the need to press on with the course sequence even when confronted with novel questions. In one segment, a student asks the question, "A planet made all out of neon, what would it look like?" In the follow-up interview over this segment, Edward said "I thought it was a very interesting question. I probably should have tried to pursue where the student was coming from. I told the student that I don't know what the planet would look like. . . . Another student said that it would knock Saturn out of the favorite viewing object category. The first student said, 'it would be like glowing,' so that reinforces my understanding now that the students were thinking of [what we incorrectly call] neon colors. . . [T]hat is a misconception that obviously I should have corrected, if I had recognized that that was where they were going. . . . Instead I was, I guess, convinced that I needed to proceed with the textbook."

It is interesting to contrast this apparent dependency on the textbook with Edward's disapproval of the book's encyclopedic characteristics, "The . . . information that Jupiter must have a liquid metallic hydrogen core . . . is, of course, contained in the textbook, but what I was trying to do is pull the information out of just the encyclopedia kind of presentation and put it instead in terms of knowledge that we have about Jupiter and how it relates." There are also several occurrences of Edward openly encouraging the students to be skeptical of the textbook. In response to a question by a student about the cause of the extinction of the dinosaurs, Edward said, "I make a point of emphasizing that this is one of those places where we have to speculate. We don't know with certainty, so any explanation is somewhat speculative. I try to caution the students to accept what the textbook says but with a little bit of a skeptical or at least open attitude."

The textbook contains the following question, "From Venus, how would Earth appear?" Edward routinely assigns this question for homework. The interviewer asked, "If this is a faulty or trick question, why assign it?" Edward responded, "Exactly because it is a poorly stated question. I want students to think through situations like this and recognize that sometimes textbook authors and community college instructors ask dumb questions. In this case, a bright student could easily have pointed out that from the surface of Venus, you can't see Earth, or any sky at all. The cloud cover is complete and impenetrable. I imagine the author intended the question to be about retrograde motion, inferior and superior planets, or albedo. But it is a poorly worded question, unless the author meant it to be a trick question. If that is what the authors meant, then I like it."

In one video segment, a student is apparently having difficulty grasping a point. Edward finally abandons the struggle and proceeds with the lesson. The interviewer asked "Why didn't you pursue the matter farther?" Edward responded, "I don't know. There are several reasons for terminating a sequence such as I was having with that student. One is when it no longer seems to be getting anywhere. If the student is disengaged, or seems to be losing interest in the exchange, or seems to have all the information the student is interested in getting. Another reason for terminating an exchange like this one is when it is beginning to embarrass the student. That is, the student realizes that they don't understand what's going on and they are embarrassed about asking so many questions and would rather terminate the exchange until they have an opportunity to review the material perhaps in the textbook or some other source. A third reason would be if the amount of time is limited, and no more time can be invested in a single student at the expense of the other students in class. After all, she always has the opportunity of visiting me during office hours."

Edward does alter the textbook sequence when necessary, but seems to still feel bound to include all of the content. In one video segment, Edward stated that he was reversing the sequence in the chapter, putting historical development first rather than, as the textbook did, discussing the concepts first and putting historical development later. As a justification for this action, he said, "I always like to try to put things into a historical context. I like to try to present astronomy and all the sciences as a human activity that evolves and develops as part of a process. I believe science textbooks make a mistake in presenting to students what is sometimes known as 'final-form science.' Astronomy books and biology books and all other science textbooks present science as if it were revealed, intact, in final form, to the original researcher and all that researcher did was write it down and do a few experiments to test it, verification type experiments, and then publish the results. And of course that's not at all the way science is done. Science is done by fits and starts, personalities are involved, historical context is involved, paradigm shifts are involved, lots of things are involved and it's a gradually evolving process."

Edward is also willing to depart from the content of the textbook, "We're astronomy teachers, but we're astronomy *teachers*. I am certainly not rigidly attached to the content in the textbook as what we're going to cover. That and no other and we're going to get through every . . . word in it. I certainly don't have that compulsion. . . ."

Gene—Accurate Information

During the initial interview, Gene said. "I think it's important for them to be able to ask anything that's on their minds and we'll talk about it. We don't want to get too far off the subject, or you know, we can't get too far off for too long because there's some stuff we need to achieve, but I think it's important that they be able to ask anything they want to and that I'll hopefully have a good answer for them. I'm real careful to give them the most accurate information."

Unlike Edward, Gene seems to want more information in the textbook. In response to a student question about virtual particle pair production near the event horizon of a black hole, he states, "I think they're asking about the virtual pair particles and one making it into the black hole and the other one being radiated away with Hawking radiation. [The] picture's not even in the new textbook, and they don't even have Hawking radiation mentioned at all in the book. [T]here were several things in the old edition that they don't have in this one."

However, Gene also finds the textbook somewhat unreliable. He said, "There were several errors in [the] old textbook. I'm trying to remember if I detected any in the fourth edition. I think I have, but I don't remember what they were."

Jack — Teach the Way You Understand

Jack uses the textbook as a resource, but feels there are many things he can do in class that the textbook cannot do well. He uses board work to model dynamic processes, something the static images in the textbook cannot do. "I just show the infrared bouncing around; I'm drawing it in a dynamic fashion. Even when I prepare the board ahead of time, in this case I might pre-draw the clouds and the CO_2 and the surface. But the active things like the sunlight coming in, you've got to do that actively because you have to show the beam of light coming down and striking the surface. Then you have to show the heat rising up off the surface of the planet. Then you have to show the infrared protons bouncing around from molecule to molecule. You have to show that. They don't really get that in the textbook because the picture is static in the textbook. One of the major functions of board work is to show these active processes. . . . Static pictures, I generally just leave those up to the textbook because they can do a much better job than I can."

Jack also views the textbook as a resource for students. "I really would like to get more discussion going in my science class. I would if I could rely on my students to read the textbook before class; we could have some lovely discussions. But the sad fact of it is that most of them don't read beforehand. So we often are criticized for treating the students like the tabula rasa but in many cases they come into the class as a tabula rasa because they don't have any prior experiences. I think that's the function a textbook can serve."

Like the other two participants, Jack also finds the textbook somewhat unreliable. "I would nominate differential rotation as the most poorly understood concept in planetary astronomy because most textbooks don't get it right."

Jack also departs from the textbook sequence whenever necessary. "Sometimes I think material is presented in the wrong order. Normally I try to follow the order of the book just so students won't be terribly confused. . . . I jump around a bit, but I try to avoid it if I can. . . . You shouldn't be a slave to the schedule or the textbook. Teach what you want to teach in the order in which you want to teach it. . . . [T]he way I understand it and the way I want to teach it are totally different [from the book]. You've got to teach the way you understand it. Otherwise you wind up looking stilted and awkward. You have to teach it the way you understand it."

SELF-IMPOSED RESTRAINTS

Going beyond the external constraints, all three participants impose additional restrains on themselves. These are closely related to the beliefs the participants hold about effective teaching and the instructor's role.

The Syllabus: An Internal Constraint

Gene was asked in class whether a test could be delayed a day or two and he declined to do so. In the follow up interview, he gave as his rationale, "The two main reasons were since we had the syllabus outlined with specific dates I didn't want anyone to be thrown off, like if they weren't there that night, they might not have anticipated when the right night for the exam was and so they might have wasted some time preparing. . . ."

All of the participants consider the syllabus to be a contract with the students, but to Gene it would seem that the issues of authority and control dominate, while the other participants are more collaborative in their approach. For example, Edward wrote in his journal, "Today a student asked if we could postpone the test scheduled for Wednesday. I replied no and explained that I felt the syllabus was a contract. She replied, 'you are the only instructor that sticks to it!' I explained that many students had to rearrange their work and child care schedules to make time for studying and to make sure they would be in class." So Edward does not hesitate to exercise his authority when necessary, but the reason seems to spring from his conviction that the syllabus is a contract, not from a desire to exercise control.

Jack also considers the syllabus as a contract and says so specifically. In response to the question, "Why do you feel constrained by the syllabus?" Jack replied, "I consider . . . this to be a legal document between me and the students. It's a promise I make at the beginning of the semester. I take it very seriously. It's a promise I have to keep. A student might get sick. I don't want to spring a test on them all of a sudden with no warning. I think it also is a point of encouraging student responsibility. Because the syllabus is iron clad, there is value in getting it done. It's not just another meaningless piece of paper. It's there. We're going to stick to it. So get to know it. But mostly I feel bound to that document because it's promise I make of how the class will go. I only change my grading scheme under extreme circumstances. I only change the date of the test in situations of extreme disaster. Otherwise if it's a schedule, I stick to it."

Paradoxically, all three participants admit to having difficulty staying with the syllabus. Edward expressed considerable difficulty in keeping up with his own schedule. In his journal after one class, Edward remarked "It's only the second day of astronomy class and I'm already behind according to my syllabus!" Edward expanded on this by saying, "I lay it all out for them. They know what we are going to be talking about every day, pretty close. You can't do it exactly. I try to stay with a schedule, but if I do get behind there's some places in the syllabus where the schedule is kind of light." Edward also used his own syllabus to fend off questions. In response to a student's question in the solar system astronomy class about nucleosynthesis, he said "It's not part of our syllabus to get into that this semester."

Although Jack has indicated that the syllabus in a contract and that he felt like having made that contract, he was required to adhere to it. Yet in a conversation after class, he said "well, I always get behind on the syllabus."

Gene says, "Actually I do pretty good, and usually there's some chapters . . . where we can catch up. . . . This semester it's kind of weird, but we'll have one class per week already, so one class we did Chapter 1, one class Chapter 2. Next week we're going to cover Chapters 3 and 4, and then we're going to have Chapter 5 and a review, and then their exam. It's more up front and then as the semester goes on, then it's like one chapter per week. So at the end I'm ahead, and we're actually slowing down because I figure their other professors are avalanching, snow falling."

Sticking to the Book

While the attitude toward the book varies widely among the participants, one aspect of textbook use is striking — all the participants follow the book closely. Edward's and Jack's syllabi follow the chapters in order with very few exceptions. Edward's and Jack's syllabi are also very similar. Gene's syllabus is much less detailed than those of the other participants, but still follows the textbook chapters in order.

EXTEMPORANEOUS LESSONS

No matter how careful the planning and preparation, there will be inevitable moments when astronomy teachers must "make it up as they go along." This moment may be due to unexpected circumstances, such as equipment malfunctions, bad weather, or schedule changes. More often the moments occur when in the course of an interaction between teacher and student, something unexpected happens. For example, when a question leads the lesson in a completely different direction. These are the moments when all of the teacher's decision making skills and techniques come into play. These are the moments when planning and preparation fail and intuition takes over.

At these moments, teachers can call on several different kinds of knowledge. Lederman and others (Lederman, Gess-Newsom & Latz, 1993) found that teachers in training used both subject matter knowledge and knowledge of teaching in this kind of decision making but found pedagogical knowledge to be the more important of the two. Two of the participants, Edward and Jack, have formal training in pedagogy so they might be expected to draw from both of these sources as well as other kinds of knowledge.

Edward described an example of an extemporaneous lesson in his journal. (The problem with late notification of class assignments has been mostly eliminated at Central Community College by a better organized administrative process and by college-wide hiring procedures rather than campus based hiring.)

> If I'm supposed to be a reflective teacher, reflective learner, I'm not sure I did a real good job tonight because I mostly, I think I would characterize this as saying that I mostly made it up as I went along. I only learned that I was going to be teaching this class a few days ago. And I really have not had time to prepare or think about what to do in class or how to go about teaching the class. I'm hoping that I can spend a lot of time with it this weekend because I have a long weekend and then do a much better job thinking about these things next week. I did try to use the celestial sphere a lot, the hands-on, concrete examples. I probably was more effective at asking students to participate than I usually am, the number of questions. I got some reasonable participation.

This is not a typical extemporaneous lesson, but there are still interesting aspects. Edward feels that this lesson produced more class participation than usual and that he was “more effective at asking students to participate.” To Edward, extemporaneous lessons imply more class involvement.

Jack frequently uses extemporaneous elements within a lesson structure. In discussing the repertory of gestures and non verbal signals he uses, he said :”I can't profess any one strategy; you have to be able to improvise in the classroom.” Jack’s lessons frequently show this sort of extemporaneous character. He will try several different strategies to provoke a student answer, rather than simply answering the question himself. In response to this prompt by the interviewer, “You were trying to get the student to respond ‘closer,’” Jack replied

> And they weren't biting!. I felt the need . . . to get them to remember what factors determine gravitational pull: mass and distance. I asked the question about two or

> three different ways and I finally found the right way to ask the question that would get the answer. Maybe if I had asked it that way first, I would have gotten a good response first. But who knows? Maybe it was just the building-up process that finally got students. . . . I eventually managed to ask the question in the right way. Sometimes you have to ask a question two or three different ways before you hit the proper buttons.

The term "biting" ties into another questioning strategy that the participants characterized as "fishing for an answer." Often, it seems, the participants were looking for a precise answer to a specific question, and were willing to go to great lengths to provoke that answer. This often involved spontaneous analogies. For example, when discussing density Jack said, "here I was fishing for a precise answer. 'Lighter' was not quite the right term because the mass had not changed. 'More spread out' was actually a pretty good answer from that student."

Planned Spontaneity

Jack also introduced the phrase "planned spontaneity." While at first glance this seems like an oxymoron, it makes sense in context. The somewhat unpredictable nature of the classroom environment means that all of the participants had to be flexible in lesson approach. An example of planned spontaneity is taking advantage of equipment when it is available but being able to work around it when it is not. The term arose in explanation of the use of a bowling ball as a prop.

> Interviewer: You went to a lot of effort to roll the bowling ball in the middle of the room. Did this work?
>
> Jack: I like using that analogy, I think it does illustrate to people why stuff is striped on the surface of Jupiter. I could just say, and sometimes in semesters when I can't get my hands on that prop. I just say, "Well, the rapid rotations stretches the stuff out." I think it makes it much more real to have these physical objects involved. That was another example of something that was kind of spontaneous, sort of planned spontaneity. I could do that if the prop were available. Since it was there, I seized on it.

Planned spontaneity is also a useful construct in describing what Edward went through when faced with the last minute class assignment described above. As he said in his journal:

> I think . . . I mostly made it up as I went along. I only learned that I was going to be teaching this class a few days ago. And I really have not had time to prepare or think about what to do in class or how to go about teaching the class. . . . I did try to use the celestial sphere a lot, the hands-on, concrete examples.

Gene was presenting a lesson early in the semester on electromagnetic radiation. A certain student began to ask a series of questions. One student noticed that the regions of the spectrum assigned to different categories overlapped to some extent. Gene explained what happened next.

> [T]his is a great question; it was about the electromagnetic scale. . . . [A]s you look at it and it has microwaves, radios and x rays and gamma rays, there's an overlap where it's not a-and so I was like, well I don't know why. [But] as time went on her questions didn't make a lot of sense. I had to ask her, "What do you want to know?" . . . We talked about how one of the fun things about it and one thing to really keep your mind sharp is these dudes just come up with unbelievable questions. As I read through the chapters, I'm constantly trying to think of what they can ask, and then no way you can tell. Even simple questions like: "Are there other universes beside our own?" That's a simple question, and it's just something I never thought they would ask. Every semester, all the time, they'll ask good questions.

Extemporaneous lessons are important when unexpected events prevent the implementation of the scheduled lesson. Equipment failures are the most common. Videotapes or video equipment might be unavailable. Among all of the participants, Gene seemed to have the strongest urge to stick close to his planned lesson. At the beginning of one class, Gene had to go and find the video player and monitor, which took a significant amount of time. Edward uses overhead transparencies more than the other participants. On one occasion, he found the overhead projector to be missing. The next day, the overhead projector was back in its place, but the following day, it was missing again. This time he went looking for it and found that the instructor next door had simply taken the overhead projector from Edward's room and was using two overhead projectors at the same time. Edward had to demand it be returned. This took a significant amount of time away from class. In these cases, both Edward and Gene exhibited a strong reluctance to change the lesson or make up a new lesson.

Spontaneous and Planned Analogies

Analogies are widely used by all teachers and analogies are considered an effective way to address the problem of misconceptions (Clement & Brown, 1984). However, the analogies that are effective in dealing with misconceptions are carefully constructed, planned analogies. The participants used a variety of different analogies during the period of observation. Some of these were planned, but many were spontaneous. All analogies depend for success on common experience (such as basketball) and on students perceiving the analogy in the same way as the teacher using the analogy. As Jack said, "That's the problem with analogies because you don't know students' past experiences, what they bring to the table. That's going to shape how they react to your analogy. It's especially a problem with students from foreign countries."

The use of analogies is also risky, because analogies may inadvertently lead to new misconceptions (Duit, 1991). Students are actively constructing new concepts as old concepts are modified or displaced (Dreyfus, Jungwirth & Eliovitch, 1990). Even planned analogies are not immune from error. In physics, some well known planned analogies are known to lead to misconceptions. For example, the common analogy of water flow for electrical current is well known to lead to several misconceptions (Heller & Finley, 1992). One misconception results when electric potential is compared to water pressure. Using the analogy, some students may erroneously conclude that potential can be measured absolutely. Absolute pressure is a useful concept, absolute potential is not. Perhaps this is why some students attempt to connect a light bulb with only one wire or think that electricity can leak out of a socket.(a bucket only needs one hole in order to leak).

Spontaneous analogies (Clement, 1987) are even more likely to be misleading, especially analogies that are constructed by teachers in an attempt to make the unfamiliar familiar. Tierney found that social studies teachers used frequent “small scale” analogies as reinforcement. The teachers seemed to assume that students were familiar with the analogies and would use them correctly without guidance (Tierney, 1988). This is a risky assumption. For example, Lola Hill observed, “In my experience as a visiting educator to perhaps a hundred primary classrooms over more than a decade, I have witnessed innumerable interactions between teachers and children in which the teacher appears not to have grasped the meaning or consequence of a child’s intellectual offering.” (Hill, 1999, Introduction ¶ 1)

Even correctly used analogies may lead to unexpected connections in the student’s mind. Many of these connections may lead to new insights, but many others may be erroneous (Duit, 1991). Analogies are, by definition, imperfect copies of the intended concept. Therefore, there is always some point at which the analogy will fail.

Jack used analogies extensively during instruction, both planned and unplanned. For example, he feels that many text books cause students to misunderstand differential rotation. In the follow-up interview, he said:

> I tell the students “I want you to put a big X through that box and write in your notes, ‘This is wrong.’” I wait for them to do it. So many people get it wrong; so many textbooks get it wrong. I use the analogy of a vinyl record, which isn’t as mysterious as you might imagine. I had one student pipe up and say, “We know what vinyl records are, they’re used in clubs.” But in answer to your question here, that is my planned analogy. I do feel the need to illustrate what differential

> rotation is not. I'm trying to communicate to them that every spinning object has different parts moving at different speeds. A lot of beginning physics students come out of beginning physics not knowing the difference. I feel the need to make this analogy and perhaps spend an inordinate amount of time on it. It's a question that's worth about five points on my test. But it's so misunderstood so I do feel the need to spend what is probably an excessive amount of time talking about it, because it is so poorly misunderstood.

This is a good example of a carefully planned analogy used, in this case, to correct a common misconception. However, other analogies have the potential to distract students. Both Jack and Edward use an analogy for the inverse square law of light intensity that involves peanut butter and bread. In response to a question by the interviewer if this analogy might be distracting, Jack said, "Food. That's the problem when you make a sports analogy, when you make a food analogy, when you make a sex analogy. Any kind of analogy you make you run the risk of creating a Homer Simpson reaction, 'Peanut butter mmmmm.....' You run that risk with any analogy you make."

For a term project in a class, Edward interviewed his own students after the end of the semester concerning the planned and spontaneous analogies he had used. On the basis of these interviews, he concluded "It was clear that some students had understood the analogies perfectly, but in a way clearly different than that intended. It was also clear that even when the analogies were understood, deep misconceptions had developed." Since then, Edward has restricted the use of analogies. In his journal for this research project, he wrote, "I find that I am in general being much more cautious in my use of analogies after my experience of a few years ago when I examined my use of spontaneous analogies in the classroom and found that they were not nearly as successful as I thought, that in fact they as often led to worse misconceptions as they led to better understanding."

Not surprisingly, Edward did not abandon analogies completely. In addition to the peanut butter and bread analogy, he used an analogy to illustrate stable and unstable equilibrium. "In the midst of this I gave an analogy to a marble in the bottom of a bowl and then the marble with a bowl turned upside down. Looking at the tape I think it may have been possible that the students misunderstood that analogy. I thought at the time that maybe I should draw picture on the board. I turned around to start to draw a picture, but for some reason I didn't draw it. I don't know why I didn't, but obviously looking back in the tape I should have gone ahead and drawn a picture to make sure the students understood the analogy I was making."

Gene also admits to the difficulty with analogies. Most astronomy textbooks include a balloon analogy to try to explain the expanding universe. The interviewer mentioned difficulty a student was having with that concept. "The balloon analogy is very common. This student's questions are almost making me think like he's being misled by that analogy. It seems to me that what he's thinking about is the center of that balloon, which is beyond our comprehension. But he's thinking that it's something we could point to, to find." Gene responded, "I'm guessing he's, like that picture in the book, point A and point B forming, and the center would be in the middle of them. I have a struggle with it myself. I think why can't you just go to the center of the balloon? The balloon analogy, yes you've got a balloon, so we got a center of the balloon. Why can't you go there?"

CHAPTER SUMMARY

The purpose of this chapter was to develop an answer to the fifth research question: Is it possible to identify a relationship between specific classroom practices and stated or implicit belief systems? All of the participants cited administrative constraints as restricting or directing their classroom decision making to some extent. Edward spoke of lack of preparation time and lack of opportunities to observe. Jack claimed he did not perceive any constraints, but then used "department policy" as a reason for his test policies. Gene listed the need to be prepared as a constraint. All of the participants saw the syllabus as an administrative constraint to the extent its content was specified by the college or by department guidelines. The department has specific guidelines for the astronomy classes, which all of the participants are supposed to follow. Nevertheless, Edward and Jack seem to be much less concerned with these than Gene was.

The nature of authority and the power structure in the classroom are very different for the three participants. Gene feels like he "must be in charge." Neither Edward nor Jack seem to have given that issue much thought. Edward uses collaborative activities and has a clearly stated preference for highly interactive classes with many student questions. Jack does not appear to overtly "exercise authority" but still manages to maintain control in the classroom through questioning strategies.

Perceived systemic constraints also restrict the range of decisions of the participants to a slight degree. The course content is partly specified by the Texas Higher Education Coordinating Board through the common course numbering system. More critical are the perceived needs of students outside of the class for transfer credit or certification.

Logistical constraints are critical. The textbooks are selected by department, so all instructors must use the same textbook. However, Edward sees the textbook as an unreliable encyclopedia, Gene reads it scrupulously, while Jack only occasionally refers to it and freely alters the sequence to suit his teaching style.

There is also a range of self-imposed restraints. All of the participants saw the syllabus as an implied contract between the teacher and the students. However, Edward and Jack did perceive some flexibility in this contract, while Gene seemed more rigid.

Paradoxically, all three participants admit to having difficulty keeping up with the schedule in the syllabus, even though they set the schedule.

Extemporaneous lessons frequently happen in all of the classes taught by the participants. No matter how careful the planning and preparation, there will be inevitable moments when astronomy teachers must "make it up as they go along." These are often the result of unexpected or weird questions from students. Extemporaneous lessons are often necessary when students fail to grasp the concept using the planned lesson. All of the participants used both planned and spontaneous analogies, even though spontaneous analogies are suspect and are known to lead to misconceptions. The best description of the extemporaneous lessons is "planned spontaneity," a phrase introduced by Jack.

These extemporaneous lessons offer the best opportunity to look for relationships between the beliefs the participants hold and the progress of the lesson. No connections could be identified between the participant's religious beliefs and their interactive decision making. The teacher's state of mind and the teacher's perception of the appropriateness of a strategy are clearly evident in their decision making. However, the strongest determining factor leading to the decision about the progress of a lesson seemed to be the teacher's perceived state of the learner. This concept is discussed more extensively in the next chapter and possibly could be included in the construct of personal practical theories.

Chapter Six: Tying It All Together

Tentative answers to the first several questions listed in Chapter One (see p. 14) were summarized in Chapter Five. Community college astronomy instructors do have specific beliefs about the characteristics of effective instruction. The purposes of teaching, especially the roles of the community college instructor, are clearly articulated by the participants. It is possible to identify specific classroom decisions and behaviors that may be related to beliefs. Specific classroom practices have been identified. Chapter 5 also explored the relationship between specific classroom practices and stated or implicit belief systems and identified several factors that influenced teachers' interactive decision making. This chapter will first suggest ways the different ideas proposed so far can be tied together into a unifying structure or model of how community college instructors decide how to proceed when faced with novel situations. The chapter will close with possible answers to the remaining research question concerning changes in teacher practice based on knowledge of beliefs and current research.

Chapter 5 also proposed that many aspects of teacher decision making can be explained in the interplay between spontaneous decision making and planned lessons. While teachers often "make it up as they go along," they do so within an overall structure and a set of specific goals related to the syllabus as an implied contract.

TEACHER'S PERCEIVED STATE OF THE LEARNER

The teacher's perceived state of the learner (Englert & Semmel, 1983) appears to be an important factor in teacher's interactive decision making. Extensive conversations with the participants in this study have revealed that the participants hold detailed and complex perceptions of the state of the learners in their classrooms. These perceptions are based partly on short pre-tests and questionnaires given at the beginning of the semester, but are primarily based on interactions between the teacher and student in the classroom.

For example, in the follow up interview Edward asserted that "[s]tudents frequently have conceptions and ideas about the way to do things, especially the activities in class, that they pick up from unreliable sources." When asked, he explained that he had no emperical basis for this assertion, but that it was based on experience with students in the classroom. Later on in the same interview, Edward described his reasoning for including archaeoastronomy activities this way, "I think that astronomy has a lot of possibilities as a multicultural type of course. . . . Every culture has had astronomy as part of its society in some form or another. It may not be exactly the same thing is what we would call astronomy but it is astronomy nevertheless. So I think archaeoastronomy . . . gives all students something they can relate to that at least if it's not in their own personal background it's perhaps in their parents or grandparents or great-grandparents background or is somewhere back in their ancestral tradition." Edward is also developing a multicultural astronomy curriculum based on this notion, again without any statistical basis for the assertion. The curriculum features (among other things) megalithic sites in northeastern Africa and the epic Indian poem, *Mahabaratta*. However, it is not clear that the African-American or Asian-American students he seems to be thinking of feel any sort of cultural connection to their ancestral traditions. In a follow-up question about a segment where he presented the curriculum ideas to students as a basis for class projects, Edward admitted that "I don't think any of them gained any useful information from that segment."

In a different sequence of questions relating to modeling and other aspects of teaching scientific thinking, Edward said, "The answer I gave is consistent with my understanding of how students should understand the scientific process." This is a clear indication that Edward does have specific notions about student perceptions of the scientific process. After discussing models of Earth's interior for some time, a student asked "What's in the core?" Edward explained that his response to her question " was that we had gone through a lot of interaction, a lot of discussion, back and forth, discussing the conditions, and modeling, and she just wanted confirmation, I think, of what was in the center. So it was more effective pedagogically to simply confirm her understanding, which I believe is what she was looking for."

While reviewing a later segment, the instructor said that he was jumping around the chapter answering people's questions which he thought was great. Asked to explain, he said, "It was great because it involved the students. The students were directing the lesson in a sense, they were directing their own knowledge, they were participating in what was going on, they were filling in gaps that they may have had in their own understanding, it was a very active learning situation with the students very much involved. That's the part that I thought was great, the fact that the students were involved." This perception is certainly consistent with current thinking about student engagement and "minds on" learning, but it is not clear from anything the instructor said that this is a good application of the idea.

After several lessons related to Earth's internal structure, a student asked "What does this have to do with astronomy?" Edward stated that he had given a satisfactory rationale, but the question represented a fundamental oversight. Students may have perceptions about what astronomy is and what it is not. No attempt was ever observed in this series of lessons to determine what those perceptions are. However, in a third interview conducted recently, Edward shared that he had made many changes in the class structure and that students now took a misconceptions survey and that students receive direct instruction in the nature of astronomy and science.

Gene has several times clearly stated beliefs about the state of the learner's. At times he seems almost confrontational, "Yes, because it's that thing about 'give an inch, then they'll want a mile,' where the kids were constantly testing. It's true-the more you give, they keep pushing that envelope more and more. You have to impose your control over the class, or authority or something." This perception permeates much of Gene's thinking. However, nowhere in any lesson or during interviews did Gene justify this perception with statistically supported or other empirical evidence.

The interviewer and Gene were discussing the surprising questions student's ask and he said, "We talked about how one of the fun things about it and one thing to really keep your mind sharp is these dudes just come up with unbelievable questions. As I read through the chapters, I'm constantly trying to think of what they can ask, and then no way you can tell. Even simple questions like: 'Are there other universes beside our own?' That's a simple question, and it's just something I never thought they would ask. Every semester, all the time, they'll ask good questions."

Jack has several well formed perceptions about learners. He clearly believes they need to improve their listening skills. "I think definitely that lecture helps students develop listening skills, which I think are so important in the real world." Jack develops this idea even further, "I think students are losing the ability to listen. To just listen to someone to talk and gather information from what people are saying. That's such an important skill in the real world. So I'm trying to help my students develop a knack for understanding the verbal and nonverbal clues that speakers give when they're trying to convey information." This is a common notion and most people blame the short attention span of students on television. Jack seems to make a similar connection when he says, "I try to shatter that this-is-TV image by moving around the room."

It is also possible that the participants formed tentative hypotheses about the learner's ability based on miscues or incorrect answers (Englert & Semmel, 1983). In contrast, Jack seems to value wrong or incomplete answers, but this leads him to a questionable attitude toward student prior knowledge:

> "But it gets them stimulated and receptive asking them a question like that. Especially if you ask a question that some of them might be able to give a partial answer to, that's even better. It's hard to do in a science class. I really would like to get more discussion going in my science class. I would if I could rely on my students to read the textbook before class; we could have some lovely discussions. But the sad fact of it is that most of them don't read beforehand. So we often are criticized for treating the students like the tabula rasa but in many cases they come into the class as a tabula rasa because they don't have any prior experiences."

Later, however, Jack almost seems to contradict himself when discussing analogies when he says, "That's the problem with analogies because you don't know students' past experiences, what they bring on the table. That's going to shape how they react to your analogy."

In the initial interview, Jack said "A lot of the students are getting the right answer, but they're just not speaking up. There are some students who speak out boldly so they may seem to be dominating." This sounds like an example of a teacher perception of student thinking and a behavior based on that perception. However, the perception seems questionable. Jack does not explain how he knows the students are getting the right answer.

Clearly, all of the participants have strongly formed opinions about the nature of community college students. In discussing the use of analogies, Jack said, "It's especially a problem with students from foreign countries. The physics questions that I ask, I have to be careful. You can write a question about a horse pulling a sled, but what if these people have never seen a sled? Or a horse? So everything just sort of falls flat. So it's one thing for us to say we should speak to students' experiences, but you don't know what those experiences are. Or if you have such a diverse group of students, you have a diverse group of experiences. I think it's a little bit easier teaching at the 'Big U' because you can rest assured that the large portion of your students have had a similar group of experiences. But at the community college you've got people coming in with a huge diversity of ages and backgrounds. It's so hard to make analogies they can understand."

Discussing the same subject, Edward said, "Actually, that's what I like about community college is that it is such a diverse population. Diverse and under-served population."

Perceptions Not Based on Ethnicity or Religion

It is also possible that some perceptions are based on ethnic or racial stereotypes. While no concerted effort was made to identify any such perceptions, no detectable evidence of racial or ethnic stereotyping was revealed in the conversations or during field observations. There is actually little opportunity to observe possible racial or ethnic stereotyping, since minority enrollment is generally small in astronomy classes at CCC. One in every five students is a minority at CCC, but minority enrollment in astronomy is much lower. A typical astronomy class of 25 to 30 students might have four or five minority students and these are most likely to be Asian and Hispanic. African American students are almost completely absent from astronomy classes. (This is an area of concern for the college that probably needs to be addressed through some sort of community-based action.)

Participant's Perceived State of the Learner — Summary

Whatever the source, the participants respond differently to different students and this is likely to be a result of different perceptions of learner characteristics. However, it is unlikely that the participants could correctly match the learner characteristic with the appropriate response. The participants probably do not have the skill to do this and certainly do not have the time to effectively analyze the pertinent learner characteristic before responding. Even if the participants had the skill and time, matching the response to the situation based on learner characteristics is not likely to be productive because the participants have no means of working through all possible outcomes of different responses to find the most effective one. Further, any attempt to match appropriate response to an accurate analysis of learner characteristics depends on understanding what the learner is asking or how the learner is responding to a particular situation. This analysis is always going to be incomplete. Teachers are rarely if ever going to be able to precisely and effectively respond to a learner question, because teachers are never completely certain what the student is asking.

PARTICIPANTS' PERCEPTIONS OF SELF-EFFICACY

Both the participants and Central Community College natural science faculty perceive of themselves as effective classroom managers. Both groups scored approximately one standard deviation higher than the TSES sample as collected by Tschannen-Moran and Woolfolk Hoy (Tschannen-Moran, Woolfolk Hoy et al., 1998). One other curiosity appears in Table 5 on page 88. Jack's score on Efficacy in Student Engagement is much lower than his other scores and lower than the other participants or any other faculty member's score. Rather than a perceived failing, this may simply be a reflection of Jack's stated teaching philosophy. He is a strong proponent of lecture, believing it to be beneficial to students to learn to take good notes and to pay careful attention in class. In response to a question about lecture, Jack vigorously defended it. "A lot of people knock lecture these days. There's a lot of anti-lecture literature out there, a lot of research proving lecture is ineffective. But I think lecture has its place. I think definitely that lecture helps students develop listening skills, which I think are so important in the real world. If you're in a board meeting or something like that they're not going to have a facilitated discussion. They certainly need practice with interaction and discussion and thinking for themselves, but they also need practice in listening and actually getting information from hearing someone talk." In addition, it is likely that Jack shares with other community college faculty the perception that the students are adults and are responsible for their own learning.

PERSONAL PRACTICAL THEORIES

Gess-Newsome and others (2003) were interested in the structure of change in college science teaching. They concluded that "to create and sustain fundamental change, there must be specific and concentrated attention to the personal practical theories of the faculty involved. Change in practice requires dissatisfaction with the teaching and learning goals established for students, beliefs about students and how they learn, and beliefs about the effectiveness of instructional practices used to meet newly established goals." (Gess-Newsome, Southerland et al., 2003, p. 762)

Although change in practice was not the primary goal of this research project, one of the research questions addressed the possibility of " change when teachers begin to reflect on their own beliefs and practice." In addition, personal practical theories can serve as a structure that helps to understand the decision making process of the participants.

TEACHER SELF-IDENTITIES

The notion of teacher self-identity is closely related to the personal practical theories held by that teacher. Drake and others investigated the effect of teachers' self-identities (as teachers and as learners) on their teaching and learning practices (Drake, Spillane et al., 2001). The best way of determining the individual self-identities is through the stories teachers tell (Bruner, 1990; McAdams, 1993). These stories help others understand how individuals know themselves and their social situation. Thinking about self-constructed identities has become a popular approach to research on teachers (Connelly & Clandinin, 1999a; Connelly & Clandinin, 1999b). Teacher's stories encompass many different beliefs and sets of beliefs and can possibly form a metaphorical lens through which a researcher can examine teacher decision making. In the next section, the self-identities and personal practical theories of each of the participants is represented in a grid. The following section describes the self-identities and personal practical theories of each participant.

PARTICIPANT GRID

Each of the three active participants presents a distinctly different teacher identity. The self-identities and personal practical theories are summarized in Table 8, along with the identifying characteristics and typical quotes from each participant.

Table 8: Teacher Self Identities

	Self Identity	Personal Practical Theory	Characteristic quotes	Observed Teaching practices
Jack	Making a difference	Training for the future "Listening/ Thinking Skills"	That made me feel really good As a science researcher, no one would care	Entertaining lecture Few demonstrations Stays close to syllabus
Gene	Content is paramount	Issues of Control "Being in charge."	Using my authority to say no Get all the information Give an inch, they'll want a mile	Straight lecture, little student interaction, discourages questions and off-topic rambles. Uses videos but stays close to syllabus
Edward	Teaching for Understanding	Spontaneous decision making: "It seemed like a good idea at the time"	Get brains to work Experimentation Observational skills Passive learning can't occur Misconceptions	Primarily lecture. A few paper and pencil activities. Rare videos.

Jack

Jack sees himself as someone who can make a difference. He was originally training as a research scientist, but realized he really wanted to teach instead. He said, "Probably one of the reasons I got into teaching [was] in scientific research you can devote years of your life to a project, and no one will care. . . . I got into teaching where I could make a difference, person by person." This kind of person to person experience is described by Jack this way, "Although most of them will no doubt forget me, there will be a handful of people who will never forget the experience they had in my class, one way or another. The best student review I ever got, the one that almost moved me to tears, was when a young woman wrote on my [student evaluation] . . . 'When I was young, I wanted to be an astronaut. And now I want to be one again.' That made me feel really good."

Gene

In answer to a request to delay the test, after a pause Gene said "no." His explanation was that the syllabus was a sort of contract and he did not want anyone "thrown off." But then he added, "the other was just using my authority to say no." This sense of needing to be in charge permeates Gene's responses to interview questions and is readily apparent on the videotapes. Later, he said, "You have to establish that control. I've seen some conferences where the audience were asking questions and they just got out of hand."

Sometimes, Gene does seem to encourage questions or does seem to respond positively to them. "This was a great question. It was about the electromagnetic radiation scale. . . . One thing to keep your mind sharp is these [students] just come up with unbelievable questions." Even in those situations, he does try to maintain control. "As I read through the chapters, I'm constantly trying to think of what they can ask." However, the control is only partial. "Even simple questions like 'Are there other universes besides our own?' That's a simple question and it's something I never thought they would ask. Every semester, all the time, they'll ask good questions."

Edward

Edward self identifies as trying to keep the students engaged. "The students need to be engaged. [Some teachers] use the term 'hands-on, minds-on.' Hands-on is not enough. Unless the brain is engaged, students are not going to be learning anything." Edward also emphasizes science process skills, such as observation. "Careful observation is essential. . . . [S]tudents need to develop their observational skills." To Edward, the opposite of engaged is passive. He says, "Passive learning can't occur. It's an oxymoron. There is no such thing as passive learning. Unless a student is actively engaged with the material, they're not going to learn anything." However, Edward does think it is possible for a student to appear passive and still be actively engaged. "The idea that all activities are going to be hands on, . . . I don't accept that."

Edward spends the most time of any of the participants talking about misconceptions and misconceptions research. He administers a survey in class the first week to reveal misconceptions students may have about the seasons, phases of the moon, and other ideas. (See Appendix F). He says, "Misconceptions are really important in astronomy instruction, because there are lots of misconceptions." To address misconceptions, Edward likes to try to create cognitive dissonance. "Unless cognitive dissonance is achieved, and you can achieve it several ways, misconceptions won't be dislodged."

Edward used the phrase "teacher as performer or teacher in the wings." He says "I think all beginning teachers see themselves as performers. They see themselves putting on a show for the students. . . . This was certainly true of me when I began teaching." But he has changed his instructional approach. "It's not the teacher's performance that counts, it's the student's performance."

HYPOTHESES

There are several possible ideas that could explain the decision making of the participants. Since the participants have a variety of different backgrounds, one possibility is that each participant draws from a completely different set of ideas.

Teachers Teach as They Have Been Taught

The notion that teachers model their behaviors and classroom decision making on their own classroom experience has been around for many years. In 1896, James Johonnot said, "Teachers have been content to follow the methods in which they themselves have been taught. . . ." (Johonnot & Johonnot, 1896, p. 40). The empirical research demonstrating the validity of this assertion is rather sparse, but there have been a few recent publications supporting or discussing the idea (Johnson, 1990; Elmore, 1996; Elmore, Peterson & McCarthey, 1996). Since community college instructors in general have little formal education in pedagogy (or androgogy) (Brawer, 1996; Powers, 1999) (ERIC Clearing House for Community Colleges, 1995), it is tempting to assume that they are probably just following a pattern established by their own teachers over the years.

Training and Professional Preparation

The degree of training and professional preparation varies significantly among the three active participants. So the notion that this has a substantial influence on classroom decision making is both plausible and possible.

Religious Beliefs

All of the participants are self-identified as committed Christians. This fact immediately suggests a hypothesis that participant's religious beliefs may somehow influence their decision making in some way. It is certainly possible that this is true. However, the participants never identified religious beliefs in relation to any of the observed classroom decisions they made. On the contrary, all of the participants are careful to state that their religious beliefs are kept separate from and do not inform their classroom practice. So this hypothesis cannot be supported by any of the statements made by the participants in interviews, journals, or in class. Furthermore, there were no instances in the hours of classroom observations for each participant where it was apparent that religious beliefs were influencing decision making in any way, except by being systematically excluded from consideration by all of the participants. So this hypothesis cannot be supported by this set of data.

It Seemed Like a Good Idea at the Time

This could also be called "spontaneous decision making" (Englert & Semmel, 1983). It is possible and plausible that community college instructors (along with other teachers) are unaware of what factors controlled their decision making process. While the teachers in the study group were almost always able to explain why they did what they did, there were a few instances when they could not explain their actions. So this suggestion remains a possibility in a few instances.

Personal Practical Theories

Gess-Newsome et al. (2003) following a model first proposed by Feldman (2000) have suggested that "personal practical theories" are a strong factor in classroom decision making. Personal practical theories are formed through experience and reflection. They are formed from the images of teaching and learning, the perceived roles of teachers and students, and the understood purposes and methods of instruction. Gess-Newsom et al. found that personal practical theories both shaped and constrained teachers interaction with reform. It seems reasonable that the same set of ideas might shape and constrain teacher's classroom decision making.

Gene shows the highest degree of consistency between the proposed personal practical theory, "being in charge." His extensive preparation to anticipate student questions, reluctance to change the test schedule, sometimes almost confrontational classroom presence, and almost compulsive reading of journals and popular works in astronomy all suggest that Gene will decide how to proceed with a lesson based on "being in charge."

Jack is also consistent in his belief that he is training the students for the future. However, there is one curious factor that must be included for consideration. The interviews with Jack are the most extensive of all the participants, running to well over seven hours. In addition, there are 12 hours of video tape and extensive field notes. In all of this material, there are very few direct references to students as a class of learners. There are many references to individual students, but fewer statements about the nature of student learning or student needs. This may simply be an artifact of the interview process. But if real, it seems to indicate a lack of well-formed opinions of community college students as a class of learners. That could be an important factor in Jack's preference for lecture methods and general distrust of activities that support student engagement.

Edward is the hardest to pin down. It seems harsh to characterize Edward's decision making as "it seemed like a good idea at the time," but this hypothesis is the most consistent with his classroom decision making process. This hypothesis is further supported by the frequent introduction of unrelated anecdotes (fishing, sports, music) that he admits are a distraction and that have been commented on by students in evaluations. His lectures lack a real sense of structure and he is chronically behind schedule. On the other hand, Edward is very knowledgeable of science pedagogy (he calls it androgogy) and is the most direct in his approach to exposing misconceptions and in using engaging and hands on activities in the classroom.

SUMMARY AND CONCLUSIONS

The goal of this project was to establish, through empirical, qualitative research, a causal link between teacher beliefs and practice. This was to be part of a larger investigation of the process by which all persons make decisions in complex situations when insufficient information is available to make rational decisions. The fundamental idea was, that when faced with those sorts of situations, the participants would fall back on belief systems that did not necessarily have a rational basis.

No strong causal link between beliefs in the conventional sense and participant decision making has been revealed by this empirical research. For example, religious beliefs are beliefs in the conventional sense as defined in this paper. No direct link between religious beliefs and participant decision could be established. Links between conventional beliefs and decision making may exist and further investigation might reveal them. On the other hand, definite links between the similar constructs of self-identities and personal practical theories appears to exist. Since self-identity and personal practical theories incorporate beliefs, this indicates there may be indirect links that should be further investigated.

In addition, a powerful unifying theme for teachers' interactive decision making has been developed based on the notion of extemporaneous lessons within a structural context of an implied contract between the students and the teachers. The terms of this implied contract are found in the administrative constraints, the systemic constraints, the personal restraints of the participant teachers, and the personal restraints of the students.

Some of the terms of this contract are explicitly stated in the syllabus or are implied by the order of topics in the textbook.

Many aspects of teacher decision making can be explained in the interplay between spontaneous decision making and planned lessons. While the participants often "made it up as they went along," they did so within an overall structure and a set of specific goals related to the syllabus as an implied contract and the perceived state of the learner as guided by personal practical theories. The name assigned to this unifying theme is "planned spontaneity." While sounding like an oxymoron, it concisely suggests the kind of flexibility required of all teachers who are faced with an ever shifting classroom environment and a specific requirement for schedule and topics covered.

WHAT NEXT?

Research question six, "Does teaching practice change when teachers begin to reflect on their own beliefs?" has been at least partially answered by this research project. During informal conversations following the stimulated recall interview, all of the participants indicated a change in their teaching practice as a result of viewing themselves on videotape and thinking about their classes in journals. This is a potential area of study that would require cooperation over a longer period of time with a cohort who would agree to view themselves on videotape and keep journals to see if teaching practice did change. It may be possible to return to the existing videotapes and identify some measurable quantities, such as wait time, that could be compared between the early tapes and the later tapes.

No matter how careful the planning and preparation, unexpected events occur that challenge the teacher to respond in new and creative ways. Some use the occasion as a launch point for a different lesson, some revert to the original lesson. There has been no attempt in this paper to identify a "best" way to respond. However, the process itself has provided an opportunity for reflection and introspection that may, ultimately, produce a significant and useful change in the teaching practices of the participants and perhaps others with whom they have contact.

One barrier to change is "instructional complacency," as discussed by Gess-Newsome (Gess-Newsome, Southerland et al., 2003, p 760). Improvement will not occur until instructional complacency encounters pedagogical dissatisfaction (Gess-Newsome, Southerland et al., 2003)

The teacher's perceived state of the learner (Englert & Semmel, 1983) appeared to be a significant factor in teacher decision making. The participants in this study do hold detailed and complex perceptions of the state of the learners in their classrooms and according to their own words, do make decisions based on these perceptions. However, matching the response to the situation based on learner characteristics is not likely to be productive because the participants do not have a clear understanding of the state of the learner and have neither the time nor the skill to work through all possible outcomes of different responses to find the most effective one. This is a possible area for future research.

If personal practical theories are indeed a strong factor guiding classroom decision making, then investigating these is a logical next step. The participants in this study have all admitted that their teaching could be improved and they have all expressed an interest in ways their teaching could be improved. This would suggest, as Gess-Newsome and others have indicated, removal of contextual barriers, specific and concentrated attention to the personal practical theories of community college instructors, and a deep commitment to personal reflection leading to some degree of pedagogical dissatisfaction.

Finally, it should be possible to blend the three closely related notions of "personal practical theories," "teacher's self-identity," and "teacher's perceived state of the learner" into a single construct that shows great promise and broad applicability as a predictor of teacher's interactive decision making. The evolving idea of collective efficacy beliefs shows promise as an effective means of instructional improvement.

Appendices

Appendix **A: WHY DO QUALITATIVE RESEARCH?**

> For many parts of Nature can neither be invented with sufficient subtilty nor demonstrated with sufficient perspicuity nor accomodated unto use with sufficient dexterity, without the aid and intervening of the Mathematics: of which sort are Perspective, Music, Astronomy, Cosmology, Architecture, Enginery, and divers others.
>
> Francis Bacon (1605)

> I often say that when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind
>
> William Thompson, Lord Kelvin (1891)

It may seem strange to adopt a qualitative or naturalistic approach to understanding any area of science, even science teaching, especially given the forthright opposition of such great exponents of Western thought as Francis Bacon and Lord Kelvin. If we seek an explanation for the domination of the world by Western thought for the last 500 years or so, it is not enough to cite science and technology. Alfred Crosby persuasively argues that it was the epochal shift from qualitative to quantitative perception in Western Europe during the late Middle Ages and renaissance that made science, technology, and business practice possible (Crosby, 1997) Why then use a qualitative approach? It seems like a giant step backwards. But another famous thinker, Albert Einstein, is widely reported to have had a sign on the wall of his Princeton office that read, "Not everything that can be counted counts, and not everything that counts can be counted."

Most thoughtful qualitative researchers seek to understand the logical foundations of qualitative research. The superficial position has been to suggest that quantitative research is deductive while qualitative research is inductive. However, this is both incorrect and misleading. Quantitative research is at heart inductive. In his 1965 classic *Aspects of Scientific Explanation*, Hempel argues forcefully that science operates on the basis of, among other things, statements or propositions that have explanatory power (Hempel, 1965). But as he notes on p 338, these statements are not laws in the sense that Aristotle would have used the concept, When Aristotle said that a law was true, he meant "true" in such a way that the conclusions were not just quasi-necessary, but truly necessary. He did not admit to any functional role for inductive reasoning, save the weight of evidence that ought to set one looking in a certain direction for laws in the first place. Hempel argued that scientific conclusions are nomological instead of self-evident. By nomological, he means that they are more or less supported or confirmed by evidence, but their truth status is probabilistic rather than being necessary. This probabilistic truth value spreads through the entire deductive structure, so that any claim is to some extent tentative, rather than being a necessary consequence as would be true with a deductive claim. Therefore, every quantitative study is grounded on the inductively determined probability of the law-like statement being indeed true. If Aristotle granted any weight to induction, it would be as only a precursor for the real empirical task at hand — to uncover and use these self-evident laws from the world of experience.

Traditional or positivistic research (which is usually but not essentially quantitative) seeks to add to the body of knowledge in a particular field primarily by examining existing theories, drawing hypotheses from those theories, then testing those hypotheses to determine if they are true or not. True hypotheses are added to the body of knowledge and false hypotheses are rejected. (Popper, 1959; Campbell & Stanley, 1963). Theory testing not only leads researchers to determine the truth or falsity of various propositions, but also leads researchers to asking the proper questions. Theories chart out the domains of meaningful claims before research begins. Using this approach, issues of meaning need not be addressed. One of the important developments in this particular research approach was the notion of operational definitions. (Brown, 1977). The concept of operational definitions allowed the focus of research to be on verification of theoretical claims.

The development of operational definitions and the avoidance of issues of meaning was part of the larger philosophical movement known as logical positivism. Logical positivists asserted that all issues of meaning reside in making proper definitions and that the purpose of inquiry is not to seek meaning, but verification.

Qualitative research takes the radical position that hypotheses derived from theories are not always needed beforehand. It is a legitimate empirical position to ask what a phenomenon could mean in general without worrying about whether there is a theory in place to account for that meaning. Issues of meaning can and should be pursued and resolved independently of issues of viability or truth of hypotheses. Qualitative research holds that we can conduct empirical inquiry into meaning and not necessarily use that inquiry to ground further empirical inquiry dealing with verification. In fact, the aim of most qualitative research efforts is to discover something in the world of experience, and then examine how these discoveries modify the way we understand the phenomena in question (von Uexkull, 1982), while the aim of most quantitative research is to establish whether or not some hypothetical claim about phenomena is actually true. These are neither competing nor necessarily complementary modes of research; they are research models that address different purposes.

These qualitatively oriented ideas evolved from a philosophical tradition that developed contemporaneously with logical positivism. The tradition is generally called pragmatism. (James, 1948; Peirce, 1955; Murphy, 1990). Pragmatism was extensively developed by the philosopher and semiotician C. S. Peirce. He studied the relationship of truth to meaning and the importance of that relationship to scientific inquiry.

Appendix B: POSITIVISTIC AND NATURALISTIC INQUIRY

Some qualitative researchers reject outright many of the traditional characteristics of quantitative research (Kelle, Prein & Bird, 1995, p. 20). They assert that such concepts as validity, generalizability, and reproducibility arise from a positivist epistemology that is not applicable to qualitative research. J. K. Smith states in effect "We don't do validity and reliability." (Smith, 1984) These researchers describe what they are doing as naturalistic research, as opposed to positivistic research (Erlandson, Harris, Skipper & Allen, 1993). The difficulty arises because naturalistic research has its roots in a paradigm that is distinct from more traditional and positivistic scientific research and the knowledge claims made by naturalistic research are distinct and have a different basis. Some would even call it a constructivist epistemology. So the difference is not between qualitative and quantitative research but rather between a naturalistic and a positivist paradigm. It is clearly possible to conduct qualitative research that has a positivist epistemology, or to include qualitative components in an otherwise positivist study.

Validity

The concept of validity as generally applied to quantitative research is not particularly useful in a naturalistic approach because reality can be interpreted in different ways by different individuals and the conclusions, while arguably valid on their own terms, cannot be compared to the conclusions of others. In naturalistic research, validity means telling the truth.

For example (adapted from Strauss & Corbin, 1990, p. 75) suppose you observed (as I have done) two shabbily dressed men of indeterminate age sitting on a park bench at 9:30 in the morning, drinking from a shared bottle wrapped in a brown paper bag. I might dismiss them as a couple of winos and think no more of them. This is certainly one interpretation of reality. But my friend and walking companion might see the same scene and decide it was about friendship, sharing, hardship, or coping with adversity. This is also a valid interpretation. Neither is wrong, neither is *the* correct interpretation. The fact that we do not agree on our interpretation is not related to the validity of either interpretation.

Consider, for another example, a road cut exposing stratified layers of limestone containing fossils of ancient sea life. To a geologist, this tells a story of the ancient history of life on Earth. It also tells us a story of how that piece of land has changed over the years as rock was built up then cut away. Of course "telling" is a conceit. There is no intent to communicate. "Signify" is a better term than "tell." Whether the road cut is telling or signifying, it is pointless to argue which is the correct interpretation. Both are important and valid interpretations.

The danger in the naturalistic or constructivist approach to data is that the logic can become circular and self-refuting. If every thing is just a construction anyway, then why bother to take data? Just write the report! A more moderate position might be to hold that every observation represents, in some sense and to some limited extent, a representation of reality. As McGettigan puts it, "The material, obdurate nature of experience means that people do not simply invent meanings and interpretations." (McGettigan, 1997, p. 376) Many interesting phenomena would never have been uncovered if naturalistic methods were not used. As in this study, the interactions are so complex that they cannot be removed from their context and studied in the laboratory. Like most social phenomena, including teaching, they must be studied in their natural surroundings. Since the variables cannot be controlled in any normal sense of the term, the notion of validity as it is normally meant simply doesn't fit very well. In fact, attempts to validate the results of a qualitative research study in the same way a quantitative result would be replicated is inconsistent with the qualitative research methodology. Validity then must depend on an analysis of the scientific process itself.

Generalizability

Generalizability is another area where the naturalistic and positivistic traditions diverge. Most naturalistic, qualitative studies have very small sample sizes; some extended and in-depth case studies have involved only one subject (Wolcott, 1973). There is no attempt to generalize from these types of case studies. The life or event studied is significant in itself (Weiss, 1994, p. 32). Even with somewhat larger sample sizes, generalization is risky. Naturalistic researchers tend to use convenience samples, selected individuals, and exceptional cases. Even when a respondent makes a statement like "I'm probably similar to everybody else in this regard" generalization is not appropriate. Self perceptions may be inaccurate.

Instead of generalizability, naturalistic, qualitative research is characterized by transferability. The readers or consumers of the research must decide if the similarities in the case presented are sufficient to justify taking action in their own case.

Reliability

Reliability arises from the notion that there is isomorphism between reality and results. This is a useful construct in positivist inquiry. However, in naturalistic research validity and reliability are replaced by other constructs such as credibility, plausibility, dependability, transferability, trustworthiness, plausibility, and confirmability. These are achieved by a careful and thoughtful explication of the process used to obtain and analyze data. The work is trustworthy and credible. The process of demonstrating confirmability can be assisted through the use of computer aided qualitative data analysis (Northey, 1997). For example, instead of using techniques common in quantitative work, such as interrater reliability, a report ca easily be generated showing the text units and the codes associated with each. Another researcher can then check these matched codes and text units to see how well the codes are supported by the text (Northey, 1997).

Reproducibility

Reproducibility suggests that when an experiment is done again, the same result will be obtained. However, in naturalistic research, reproducibility is rarely attainable, because a new situation will have many different conditions that don't match the original. The social settings studied in naturalistic, qualitative research are so complex, with so many uncontrollable or even unrecognized variables, that there is little chance of being able to reproduce any given situation. Instead, the researcher carefully documents the process of data acquisition and analysis.

This chart (adapted from Ross, 1996) summarizes how the traditional characteristics of quantitative research are replaced by equally rigorous and demanding, but different characteristics.

Positivist Research seeks:	Naturalistic Research seeks:
Internal Validity	*Credibility*
Extent of a causal relationship Relation between independent and dependent variables	Prolonged engagement Triangulation* Referential adequacy Thick descriptions Member checks Peer review Reflexive journals and documentation
External Validity	*Applicability*
Generalization	Purposeful sampling Reader is responsible for determining transferability Thick descriptions Reflexive journals and documentation
Reliability	*Dependability*
Replication of results Interrater reliability	Credibility and confirmability Audit trail Reflexive journal
Objectivity	*Confirmability*
Intersubject agreement Interrater reliability Etic viewpoint	Member checks Emic viewpoint Audit trail Reflexive journal

* The meaning of the term "triangulation" is changing in modern ethnographic research. The term, as it was borrowed from an older tradition, meant checking data against many different sources (the term originates in surveying). These sources are supposed to agree, or at least not contradict each other. Modern ethnographers generally take the term to mean being very explicit about sources of data and documenting how that data is reconciled.

Appendix **C: MAPPING THE PROCESS**

The title for this appendix is borrowed from an article by Beth Harry and others (Harry, Sturges & Klingner, 2005). They assert that many researchers have called for more openness in qualitative research (Harry, Sturges et al., 2005). This is especially important for educational researchers faced with calls by the No Child Left Behind Act of 2001 and the National Research Council (National Research Council, 2002; National Research Council, 2004) for more "scientific" research. Other writers have suggested that education research needs to be more "scientifically" based (Eisenhart & DeHaan, 2005). Quotes are used around "scientific" and "scientifically" in the previous sentences because it is not completely clear what these references mean by scientific research. However, the assumption made here is that "scientific" means "empirical." This appendix is a response to these two suggestions, to demonstrate how the research described in this paper is empirical and to open up the process of coding, analysis, and identification of unifying themes.

Open Codes

After the initial and follow-up interviews were completed and the classroom observations made, all audio materials were transcribed. Audio portions of selected video segments were also transcribed. The transcripts were read and a set of "open" codes was developed. ("Open codes" is a term first applied in grounded theory (Glaser & Strauss, 1967), but is now widely used to describe the initial coding process.) After several review passes were completed, around 130 initial codes were selected.. This number seems rather large, but it includes around 30 base data codes, such as participant information and question numbers. The 100 or so codes that are directly related to instruction were then sorted into 33 different conceptual categories. For example, the codes Abstract Concept, Physics Content, Goals and Objectives, Encouraging Class Interaction, Wait Time, and Misconceptions along with several others were grouped together into the conceptual category of Pedagogy. Pedagogy was further grouped together with Test Design Issues, Knowledge Categories, Cultural connections, Use of Analogies, and Questioning Strategies, to form the larger category of Teaching Strategies. These categories were grouped, revised, and regrouped many times as understanding developed.

Developing the Themes

The 33 categories developed during the process of open coding were then examined to reveal themes that could relate the categories to each other and to the broader concept of teaching. The guiding principle for theme selection was to look for a deeper connection, not just common vocabulary or similarity of situation. To do this, the original documents were first re-examined for additional statements of interest that were not coded and also for connections between the various categories. One means of revealing connections between categories is using the search tools built into the computer software that was being used to assist in coding. (See Appendix D.) For example, it was a matter of a few key strokes to locate text units that were coded at each of two different "nodes." (The term "nodes" is used by the software of choice and is more or less synonymous with "codes." Then it was a simple matter to examine the text units to discern why they were coded at those two nodes and how the text units and the nodes were related at a deeper level. Using this and other Boolean search techniques as well as close reading of the texts, the several levels of categories related to teaching were collected into a few broad themes. Another group of top level nodes was used to code "base data." These two top levels of nodes are outlined below. (A complete list of nodes is included in Table 9)

Thematic Outline

1. Teaching
   a. Extemporaneous lessons
   b. Constraints (administrative, personal, textbook, resources, syllabus, classroom)
   c. Strategies (pedagogy, knowledge categories, cultural connections, activities)
   d. Rationale (open ended questions, purpose of lesson design)
   e. Style (notes, board use, overhead use, rambling and bird walking, humor)
   f. Resources (web, magazines, course guidelines, amateur astronomy)
   g. Teacher as learner (professional development, summer classes)
2. Base Data
   a. Participant Information
   b. Research Description (in journals and in conversations)
   c. Identification Codes (used to distinguish speakers)
   d. Question codes (used to identify questions in the initial interview

The node "Extemporaneous Lessons" is noteworthy. This code referred to a relatively few text units (198 text units in 6 documents), but proved to be the most difficult to explain in terms of conventional notions about teacher training, belief systems, and other factors. Because of this, it is listed as a top level node. It was this node and the text that was coded to it, more than any other, that led to the development of the notion of using personal practical theories and self identity as an explanatory framework for teacher's interactive decision making.

Table 9: Codes

Q.S.R. NUD*IST Power version, revision 4.0.
Licensee: Elliot Richmond.

PROJECT: astronomy, User Elliot Richmond, 9:36 am, Jul 11, 2005.

Node Identifier	Node title
(1)	Teaching
(1 1)	Teaching/Extemporaneous lessons
(1 2)	Teaching/Constraints
(1 2 1)	Teaching/Constraints/Administrative
(1 2 1 1)	Teaching/Constraints/Administrative/classroom arrangement
(1 2 1 3)	Teaching/Constraints/Administrative/book dislikes and likes
(1 2 1 8)	Teaching/Constraints/Administrative/syllabus
(1 2 1 8 1)	Teaching/Constraints/Administrative/syllabus/grading philosophy
(1 2 2)	Teaching/Constraints/Systemic
(1 2 3)	Teaching/Constraints/Student personal
(1 2 4)	Teaching/Constraints/Teacher personal
(1 2 5)	Teaching/Constraints/lack of resources
(1 2 6)	Teaching/Constraints/low attendance
(1 2 7)	Teaching/Constraints/getting behind
(1 3)	Teaching/strategies
(1 3 1)	Teaching/strategies/Pedagogy
(1 3 1 1)	Teaching/strategies/Pedagogy/activity based
(1 3 1 1 1)	Teaching/strategies/Pedagogy/activity based/archaeoastronomy
(1 3 1 1 2)	Teaching/strategies/Pedagogy/activity based/post modern activity
(1 3 1 1 3)	Teaching/strategies/Pedagogy/activity based/extracurricular activities
(1 3 1 1 4)	Teaching/strategies/Pedagogy/activity based/demonstrations
(1 3 1 2)	Teaching/strategies/Pedagogy/abstract concept
(1 3 1 3)	Teaching/strategies/Pedagogy/physics content
(1 3 1 4)	Teaching/strategies/Pedagogy/callback
(1 3 1 5)	Teaching/strategies/Pedagogy/textbook design
(1 3 1 6)	Teaching/strategies/Pedagogy/Goals and objectives
(1 3 1 7)	Teaching/strategies/Pedagogy/getting information
(1 3 1 8)	Teaching/strategies/Pedagogy/tabula rasa
(1 3 1 9)	Teaching/strategies/Pedagogy/real world skills
(1 3 1 10)	Teaching/strategies/Pedagogy/embarassing students
(1 3 1 11)	Teaching/strategies/Pedagogy/Student educational level
(1 3 1 12)	Teaching/strategies/Pedagogy/encouraging class interaction
(1 3 1 13)	Teaching/strategies/Pedagogy/Perceptions about learners
(1 3 1 14)	Teaching/strategies/Pedagogy/student led class
(1 3 1 15)	Teaching/strategies/Pedagogy/misconceptions
(1 3 1 16)	Teaching/strategies/Pedagogy/wait time
(1 3 2)	Teaching/strategies/Test design issues
(1 3 3)	Teaching/strategies/Knowledge Categories
(1 3 3 1)	Teaching/strategies/Knowledge Categories/syntactical knowledge
(1 3 3 2)	Teaching/strategies/Knowledge Categories/basic information
(1 3 3 3)	Teaching/strategies/Knowledge Categories/abstract concepts
(1 3 3 5)	Teaching/strategies/Knowledge Categories/Previous knowledge
(1 3 3 6)	Teaching/strategies/Knowledge Categories/unifying theme
(1 3 3 7)	Teaching/strategies/Knowledge Categories/Nature of Science
(1 3 4)	Teaching/strategies/referring to book
(1 3 5)	Teaching/strategies/cultural connection

(1 3 5 1)	Teaching/strategies/cultural connection/international students
(1 3 5 2)	Teaching/strategies/cultural connection/Religion student
(1 3 5 3)	Teaching/strategies/cultural connection/Religion teacher
(1 3 5 4)	Teaching/strategies/cultural connection/Multicultural
(1 3 5 5)	Teaching/strategies/cultural connection/special-needs students
(1 3 6)	Teaching/strategies/use of analogies
(1 3 6 1)	Teaching/strategies/use of analogies/spontaneous analogies
(1 3 6 2)	Teaching/strategies/use of analogies/Planned analogies
(1 3 6 3)	Teaching/strategies/use of analogies/counter examples
(1 3 7)	Teaching/strategies/questioning
(1 3 7 1)	Teaching/strategies/questioning/challenging assumptions
(1 3 7 2)	Teaching/strategies/questioning/opportunity
(1 3 7 3)	Teaching/strategies/questioning/discovery
(1 3 7 4)	Teaching/strategies/questioning/delayed answers
(1 3 7 5)	Teaching/strategies/questioning/Listening to questions from students
(1 3 7 6)	Teaching/strategies/questioning/restate question
(1 3 7 7)	Teaching/strategies/questioning/interdiction
(1 3 7 8)	Teaching/strategies/questioning/student dominating
(1 3 7 9)	Teaching/strategies/questioning/eliciting response
(1 3 7 10)	Teaching/strategies/questioning/weird questions
(1 3 7 11)	Teaching/strategies/questioning/Encouraging reasoning
(1 3 9)	Teaching/strategies/Lesson Design
(1 3 10)	Teaching/strategies/Decision points
(1 3 11)	Teaching/strategies/defining terms
(1 3 12)	Teaching/strategies/Teachable moment
(1 3 13)	Teaching/strategies/understanding
(1 3 15)	Teaching/strategies/Formula and data manipulation
(1 3 16)	Teaching/strategies/concept maps
(1 3 17)	Teaching/strategies/reaching difficult students
(1 3 18)	Teaching/strategies/Historical approach
(1 3 20)	Teaching/strategies/use of cues
(1 3 21)	Teaching/strategies/change student focus
(1 3 22)	Teaching/strategies/lesson transitions
(1 3 23)	Teaching/strategies/process skills
(1 3 30)	Teaching/strategies/healthy skepticism
(1 4)	Teaching/rationale
(1 4 1)	Teaching/rationale/Tricky questions
(1 5)	Teaching/Teaching style
(1 5 1)	Teaching/Teaching style/lecture notes
(1 5 2)	Teaching/Teaching style/use of board and overhead
(1 5 3)	Teaching/Teaching style/Teacher as performer
(1 5 4)	Teaching/Teaching style/rambling and birdwalking
(1 5 7)	Teaching/Teaching style/Behaviors
(1 5 9)	Teaching/Teaching style/humor and stories
(1 5 10)	Teaching/Teaching style/personalizing
(1 5 12)	Teaching/Teaching style/teacher boredom
(1 5 14)	Teaching/Teaching style/appearance
(1 5 16)	Teaching/Teaching style/authority
(1 7)	Teaching/Resources
(1 7 1)	Teaching/Resources/web astronomy
(1 7 2)	Teaching/Resources/magazines

(1 7 3)	Teaching/Resources/alternative astronomy
(1 7 4)	Teaching/Resources/Astronomy course guidelines
(1 7 5)	Teaching/Resources/amateur astronomy
(1 8)	Teaching/Teacher as learner

(2)	Base Data
(2 1)	Base Data/Participant information
(2 1 1)	Base Data/Participant information/education level
(2 1 2)	Base Data/Participant information/teaching experience
(2 1 5)	Base Data/Participant information/preparation
(2 1 6)	Base Data/Participant information/shmoozing
(2 1 7)	Base Data/Participant information/Religion
(2 1 8)	Base Data/Participant information/Attitude toward teaching
(2 2)	Base Data/Research description
(2 2 1)	Base Data/Research description/astronomy teachers
(2 2 2)	Base Data/Research description/change research focus
(2 2 3)	Base Data/Research description/types of beliefs
(2 2 4)	Base Data/Research description/ethics
(2 2 5)	Base Data/Research description/Technical
(2 3)	Base Data/Identification
(2 3 1)	Base Data/Identification/Jack
(2 3 2)	Base Data/Identification/Gene
(2 3 3)	Base Data/Identification/Edward
(2 3 4)	Base Data/Identification/Interviewer
(2 4)	Base Data/1st question codes
(2 4 1)	Base Data/1st question codes/Q 1 answer
(2 4 2)	Base Data/1st question codes/Q 2 answer
(2 4 3)	Base Data/1st question codes/Q 3 answer
(2 4 4)	Base Data/1st question codes/Q 4 answer
(2 4 5)	Base Data/1st question codes/Q 5 answer
(2 4 6)	Base Data/1st question codes/Q 6 answer
(2 4 7)	Base Data/1st question codes/Q 7 answer
(2 4 8)	Base Data/1st question codes/Q 8 answer
(2 4 9)	Base Data/1st question codes/Q 9 answer
(2 4 10)	Base Data/1st question codes/Q 10 answer

Appendix D: QUALITATIVE DATA ANALYSIS SOFTWARE SELECTION

The standard source of information about qualitative data analysis software is a recent book by Weitzman and Miles (Weitzman & Miles, 1995). However, this is a rapidly changing field and any information in a ten-year old book is most likely out of date out of date. More up to date information can be obtained by those with Internet access at any of several web sites maintained by universities and publishers. One of the best is the CAQDAS site, maintained by the CAQDAS Networking Project, Dept of Sociology, University of Surrey, GUILDFORD GU2 5XH. The URL for this site is http://www.soc.surrey.ac.uk/caqdas/. (CAQDAS is an acronym for Computer-Aided Qualitative Data Analysis Software.)

I used several of these resources to attempt to narrow down the possibilities. Each of the available programs has strong points and weak points. By searching the various resources I was able to locate and download demonstration versions of several of the top programs. The three that I looked at most closely were *The Ethnograph*, *Atlas/ti*, and *NUD•IST*, because these three programs are either used widely in the field or have been recommended to me by other researchers. I also downloaded and examined demonstration versions of *WinMax*, *Kwalitan, Hypersoft, HyperResearch,* and *Code-A-Text*. There were significant differences in quality and ease of use among the various tutorials and demonstration programs. This is bound to affect purchasing decisions. (Perhaps the publishers need to give some more thought to this as a marketing tool.)

In evaluating the various programs, I looked for ease of use; ability to handle off-line documents such as video and audio files; ability to handle large documents; ability to accept coding for small units of text; ability to handle interviews, field notes, journals, and other text sources; code and retrieve capabilities; memoing, and note taking capabilities. I also tried to judge how difficult the program would be to learn. Since none of the programs were satisfactory in all respects, I created a numerical score to help me decide. Using my criteria, slightly weighted for factors I considered most important, the three top scoring programs were *The Ethnograph*, *Atlas/ti*, and *NUD•IST*. *The Ethnograph* seemed the best program for ethnographic-type research, including such things as conversation analysis. *Atlas/ti* seemed to be the best for a hermeneutical approach, attempting to derive meaning from texts. In fact, *Atlas/ti* refers to documents as hermeneutic units. *NUD•IST* seemed to be best suited for theory building. As I came to understand the task before me, the hermeneutic approach seemed most appropriate, so *Atlas/ti* was my initial choice. However, *Atlas/ti* is only available for the Windows operating systems. *NUD•IST* was the only one of my top three that was available in the Macintosh operating system. For a variety of reasons, I chose to work in a Macintosh environment, so *NUD*IST* became my final choice.

Since the capabilities of all of the programs overlap to a significant extent, the choice of a particular software package does not restrict the researcher to a single interpretive framework. However, each of the authors has designed a program that incorporates their own unique style and approach to data analysis, so each is somewhat idiosyncratic. The user of these programs must be aware of these idiosyncrasies and use caution to make sure that the program is forced to accommodate the data, not the other way around. Likewise, the consumer of this research must be aware of my choice of *NUD•IST* and the possibility that the program choice influenced my analytical approach and results.

Appendix E: Judging Qualitative Research

Like all research, qualitative research can be good or bad. The general requirements for good qualitative research are not different from the requirements for good research in general. The same requirements of scientific rigor, good design, and careful reporting are still there. Research should uncover new ideas, reveal new information. Gary Shank has proposed a model for judging the quality of qualitative research (Shank, 1996).

Test One: Is It Qualitative?

1) Does it seek to discover or uncover previously unknown meanings?

This is a basic criteria of research. Qualitative research is not excused from breaking new ground. While the type of information, searching for meanings, may be somewhat different in qualitative research the expectation is still there. In fact, qualitative research often proceeds into areas unavailable to more traditional research.

2) Does it focus on the unique, the surprising, or the unexplained?

While much quantitative research focuses on what is the same in different situations in order to uncover patterns and general principles, qualitative research frequently focuses on what is different, unique, or interesting in one situation.

3) Does it alter, rather than simply augment, our understanding of the phenomenon in question?

The goal of quantitative research is often testing a hypothesis. In fact, the whole structure of a well designed quantitative research question revolves around the statement of a null hypothesis. Qualitative research may delve into areas where there are no hypotheses to test. Instead, hypotheses are discovered as part of the process of analysis.

4) Does it provide a reflective base for understanding our own concerns?

One of the main goals is generating theories which make sense to the participants and can provide a basis for action or an altered way of thinking about a phenomena.

5) Can it readily be translated into a quantitative design?

A qualitative research study that could better be done as a quantitative study is not well designed. Good qualitative research *requires* that the approach be qualitative. On the other hand, qualitative research may precede quantitative research as new ideas are revealed, interesting variables are discovered, or hypotheses are proposed. The danger here is in thinking that this is the only role for qualitative research. Good qualitative research stands on its own. It is not simply a way of discovering hypotheses to be tested quantitatively, although it may admirably serve that purpose if the research design calls for it.

Test Two: Is It A Good Qualitative Study?

1) Are its findings obvious?

It is possible to properly conduct a qualitative research program yet produce results that are trivial or insignificant. Good research reveals new ways of looking and seeing.

2) Could its findings have been reasonably anticipated in advance?

While it is sometimes useful to point out the obvious, good research points out the not-so-obvious. Or it points out what is unique and overlooked in situations thought to be obvious.

3) Is it merely a descriptive piece?

Good ethnographic studies carefully describe a situation or culture. But it is not sufficient to stop with the description. Good research sometimes goes beyond description to discover meaning.

4) Is it simply a theory-driven precursor to a quantitative study?

It may be that a researcher has an interview component included in a survey or other quantitative study, with the idea that the responses will be used to illustrate points brought out in the statistical analysis. There is nothing wrong with this approach, but it is not a qualitative study.

5) Is the primary expenditure of effort in delineating methodology aimed to convince the reader of the scientific legitimacy of the study?

If a researcher or report spends much or most of the time trying to justify the methodology, rather than presenting the data and analysis and allowing the reader to decide, then the quality of the research is called into question. Qualitative research is a well established, rigorous methodology and should require only minimal explanation with references for more information.

Appendix **F: ED'S PRIVATE UNIVERSE SURVEY TEST**

1. Which of the following four diagrams most accurately depicts the shape of Earth's orbit around the Sun?

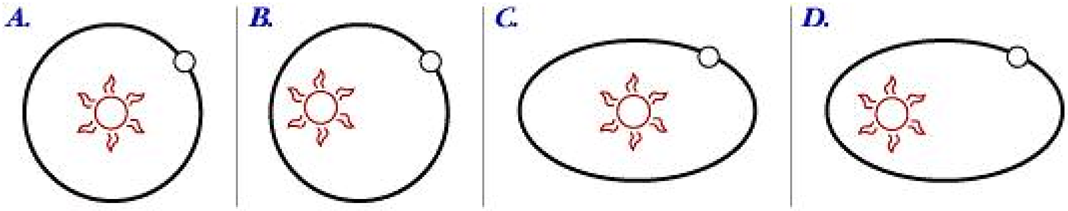


    Diagram A
    Diagram B
    Diagram C
    Diagram D

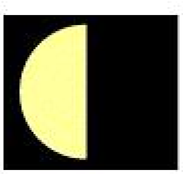
2. Which of the following responses most closely explains why it is hotter in New York in June than it is in December?

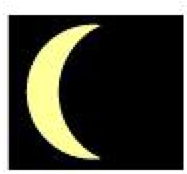
    A. The Sun gives off more heat energy in June.
    B. Earth is closer to the Sun in June.
    C. The Northern Hemisphere is closer to the Sun in June.
    D. The Sun is higher in the sky and provides more hours of daylight in June.

3. Put the following objects in the correct order, starting with the object that is closest to Earth.

    A. Moon, Sun, clouds, Pluto, stars
    B. Clouds, stars, Moon, Sun, Pluto
    C. Clouds, Moon, Sun, Pluto, stars
    D. Clouds, Moon, Sun, stars, Pluto

4. Sometimes the Moon looks like this, and sometimes the Moon looks like this





    What causes the Moon to change its appearance in this way?

    A. As the Moon orbits Earth, Earth's shadow covers the Moon.

B. Clouds block part of the Moon from our view.
C. As the Moon orbits Earth, we see different views of the Moon's sunlit side.

5. Which of the following diagrams most closely depicts the distance between Earth and the Moon?

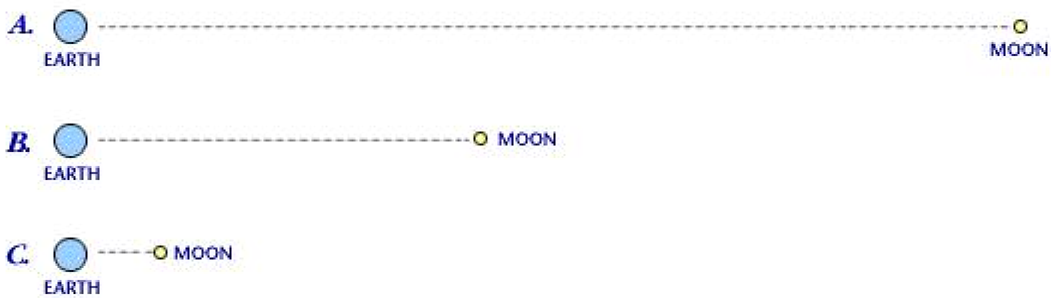


Diagram A
Diagram B
Diagram C

Appendix G: JOURNAL QUESTIONS

Participating teachers were asked to respond to the following questions:

1. What was the goal of the lesson for the day?
2. What teaching strategy did you use to accomplish the goal?
3. Why did you select that particular strategy?
4. Was the goal accomplished?
5. Did anything occur which you found interesting or out of the ordinary?

All participants kept journals to some extent. One participant journal covered the entire period of observations. The other two participants used occasional notes or personal communications. Much of the information that would have been included in a journal was developed during the follow-up interviews as participants discussed what their intent was for a particular lesson. The teaching philosophies included as Appendix I also contain much material that might have been in a journal. Finally, the participants often engaged in casual conversation before or after a class. These conversations served much the same purpose as a journal would have served.

Appendix **H: THE TEACHER BELIEFS SURVEY**

Teacher Beliefs	**How much can you do?**
Directions: This questionnaire is designed to help us gain a better understanding of the kinds of things that create difficulties for teachers in their college classrooms. Please indicate your opinion about each of the statements below. Your answers are confidential.	Nothing / Very Little / Some Influenc e / Quite a Bit / A Great Deal
1. How much can you do to get through to the most difficultstudents?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
2. How much can you do to help your students think critically?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
3. How much can you do to control disruptive behavior in the classroom?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
4. How much can you do to motivate students who show low interest in college work?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
5. To what extent can you make your expectations clear about student behavior?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
6. How much can you do to get students to believe they can do well in college?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
7. How well can you respond to difficult questions from your students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
8. How well can you establish routines to keep classes running smoothly?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
9. How much can you do to help your students value learning?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
10. How much can you gauge student comprehension of what you have taught?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
11. To what extent can you craft good questions for your students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
12. How much can you do to foster student creativity?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
13. How much can you do to get students to follow classroom rules?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
14. How much can you do to improve the understanding of a student who is failing?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
15. How much can you do to calm a student who is disruptive or noisy?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
16. How well can you establish a classroom management system with each group of students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
17. How much can you do to adjust your lessons to the proper level for individual students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
18. How much can you use a variety of assessment strategies?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
19. How well can you keep a few problem students form ruining an entire lesson?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
20. To what extent can you provide an alternative explanation or example when students are confused?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
21. How well can you respond to belligerent students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
22. How much can you assist students with families to do well in school?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
23. How well can you implement alternative strategies in your classroom?	(1) (2) (3) (4) (5) (6) (7) (8) (9)
24. How well can you provide appropriate challenges for very capable students?	(1) (2) (3) (4) (5) (6) (7) (8) (9)

Appendix I: NARRATIVES ON TEACHING AND TEACHING PHILOSOPHY

Edward

A community college astronomy class serves a different purpose than astronomy classes offered at the university level. There is only a small chance that any of the students in the class will become professional astronomers (although the possibility exists). So how should such a class be set up to best serve community college students? I believe that there are three overlapping and complimentary purposes.

While the students may not be on the way to an academic degree in astronomy, they can still benefit from a rigorous science class. The cognitive processes trained by a rigorous science class are useful in many different types of problem solving. Students also need to develop a good sense of what distinguishes good science thinking from other forms of thought. Students need to be able recognize psuedoscience and be able to intelligently reject claims based on faulty logic.

Astronomy is also an ideal vehicle for presenting science as a human activity. All humans, as far back as history records and beyond, have looked to the night sky for answers to the important questions of life: who are we and why are we here? Astronomy allows the presentation of science as a continuing human endeavor instead of "final-form" science. Further, all cultures share this common heritage. Many students, especially minority students, feel somewhat distanced from typical class work, seeing it as western oriented or Eurocentric. Astronomy allows students to relate back to their own cultural heritage.

Astronomy remains one of the few sciences where ordinary individuals can and do make significant contributions to the field. While not all amateur astronomers pursue the hobby with that degree of commitment, many amateurs receive hours of pleasure form viewing or photographing celestial objects. Not many fields of science are this accessible or have as much appeal. Set up a large Dobsonian reflector in any city park after dark, and soon a group of people will gather and begin to ask questions. While many of these people are unable to distinguish astronomy from astrology, the attraction indicates that we still seek an understanding of the night sky.

The tests and other assignments reflect this philosophy. Memorization and the acquisition of facts are minimized. Students are encouraged to think through processes. Test questions are intended to provoke extensive and thoughtful answers, not to just repeat information from the book or lecture. The semester project gives students an opportunity to connect "school knowledge" back to their own lives in a meaningful way.

Jack

Coming from a very poor socioeconomic background, I was the first member of my family to go to college. But I saw education as a way out of poverty, a way to a better life. For this reason, I love teaching community college students. Many of them are in the same position as I was, and now I am in a position to help them. CCC students are very goal-oriented, and I know my job as a teacher is to challenge them and assist them in helping themselves. The ultimate goal of a teacher is to make students self-sufficient, so that they can become lifelong learners.

It may seem almost a cliché to make the statement, "I believe that all students can learn," but I do believe that most sincerely. On the first day of class I urge students to try and set aside any preconceptions they may have about their own abilities to "do" science. I tell them that I would not give them assignments if I did not believe that they all could do it, and that I am there to give them whatever help they need to succeed. At ACC, it has been my experience that students only need an instructor to have confidence in them and be willing to help them, and they will achieve. They rarely disappoint me. I truly enjoy working with students; the look of dawning realization and confidence in a student's eyes is very affirming.

I take an historical approach to teaching astronomy because I want to demonstrate to students that science is a human endeavor. I attack the notion that science is for the privileged few by presenting the stories of men and women who "broke the mold" and revolutionized science. I hope that this will put a human face on science, and encourage my students to be scientifically aware citizens, even if they do not pursue a technical career.

I know that most of my students will not even consider a career in professional science, but I hope that I can help them develop universally applicable skills in logical thinking, critical reflection, listening, and communication. I believe that college-level education should have a higher goal than mere transmission of content. Students deserve more. Astronomy is a fascinating study in its own right, but it is also a fun and interesting venue to train students in basic academic skills which will serve them well regardless of their chosen profession. I work hard as a teacher to give students value for their hard work and dedication.

Gene

My exams are thorough and complete. The four exams account for 75% of the grade. The number four for the number of exams is a good balance between having too many or too few exams. The exams are given in class and I supply all of the paper for the students. The exams have questions and computational word problems that account for over 50% of points coming from questions that test knowledge and skills beyond just recalling facts. This fulfills one of the requirements in the astronomy guidelines. The guideline states that over 50% of the examination must come from answering questions which test knowledge and skills beyond mere recall of facts. The remainder of the exam has definitions, fill in the blank, multiple choice, and a few true/false questions. The approach to the exams is good, because the exams thoroughly test their understanding of the material. The final exam is not comprehensive even though some of the material builds on previous discussions. The guidelines state that a comprehensive final exam is not required for astronomy classes. The exams and homework have computational word problems that challenge the students to use inductive and deductive logic, because they have to figure out what equations to use and how to solve for the required unknown.

The four homework assignments account for 25% of the course grade fulfilling one of the requirements of the guidelines. The guideline states that at least 20% of the course grade should come from non-examination assessment instruments. The number four for the number of homework assignments is a good balance between having too many or too few assignments. The assignments cover the material that will be on the corresponding exam and are due on the day of the exam. The approach to the homework is good, because the homework helps the students to understand the material better. I assign the homework as soon as we begin covering the material for the exam. Computation problems are assigned to develop logic and show how mathematics is used as a tool to describe the universe. The problems also show how basic physics equations and algebra can be utilized to give approximate solutions to some of the most complex problems. Sometimes I curve the exams and homework to get a better distribution of grades.

The textbook is very good, because of the content and pictures. I have a lot of very good transparencies that I use with an overhead projector. I use the board to write down definitions, laws, principles, etc. I use basic physics equations and algebra to solve problems (e.g. we calculate the density of the universe!). Sometimes, I will show the class a video on the material we covered. The videos are good, because it is able to show the motions of various systems (e.g. a prominence, a flare, sunspot activity and the differential rotation of the sun). I also use the Internet to provide the students with updated and accurate information about the different topics we cover. I give them the addresses of the web sites and show them how to use the Internet and software to get the information they need. The approaches I use to teach astronomy are the best ones I know right now. I research and read about how to be a better educator, so I am constantly trying to improve on teaching techniques.

The students tell me they really enjoy my class. I received a "good" rating in the evaluation by the students. Astronomy is an extremely exciting course to teach because of all of the recent discoveries and all of the discoveries to look forward to. I have been teaching at ACC since the summer of 1993 and teach one astronomy class every semester. I am fortunate to have a lot of time to be a better educator and teacher. I personally receive: "The Physics Teacher", "Sky and Telescope", "Astronomy", "Stardate", "The American Journal of Physics", "Physics Today", "Science News", "Scientific American", "Discovery", "National Geographic", Notices of the American Mathematical Society", "Bulletin of the American Mathematical Society", etc. Plus, almost everyday in the newspaper there is an exciting article about some topic in astronomy. I share all of the new discoveries and theories with the students. I am constantly increasing my knowledge of astronomy, physics, mathematics and all of science and engineering.

I have a burning desire to know and understand how everything in the universe works. The students recognize this passion and realize how having knowledge and logic can work together to understand the universe that we live in.

Appendix **J: COURSE GUIDELINES FOR CENTRAL COMMUNITY COLLEGE ASTRONOMY**

Course Descriptions

PHYS 1311 STELLAR ASTRONOMY (3-3-0). A study of stars, galaxies, and the universe. Discussion of atomic spectra, nuclear energy, and astronomical tools (such as optical, radio, and other telescopes and image enhancers) as they provide knowledge about distant objects. Emphasis on recent discoveries about quasars, black holes, and cosmology. Skills: B Prerequisites: One year of high school algebra or equivalent. One year of high school science recommended, but not required.

PHYS 1312 SOLAR SYSTEM ASTRONOMY (3-3-0). A study of the Sun and its solar system: planets, satellites, meteors, comets, and asteroids. Theories about the structure and origin of the solar system, with emphasis on recent discoveries. Includes a scientific investigation of other solar systems and the possibilities for extraterrestrial life. Skills: B Prerequisites: One year of high school algebra or equivalent. One year of high school science recommended, but not required.

Course Guidelines

Lecture

1. Each instructor shall cover the entire list of required topics for the course. Not all material must be covered densely, nor with equal emphasis, but all of it must be covered. Additional material may be included at the instructor's discretion.
2. Instructors shall meet all scheduled classes during the semester. Absences shall be handled according to ACC policy.

Determination of Grades

1. Examinations
   a. At least 3 full-standard-class-period exams must be administered during scheduled class time for each course. From 3-5 are recommended.
   b. These exams together must count at least 60% of the total course grade.
   c. Over 50% of the points on each examination must come from answering questions which test knowledge and skills beyond mere recall of facts. Examples include, but are not limited to, essay questions, computation problems, and exercises in making observations of photographs and diagrams, and problems involving the interpretation of charts, graphs, and data tables.
2. Extra credit (defined as credit for work not required of every student) combined with passive measures of student work such as class participation and attendance

may raise a student's grade by only one letter grade, whatever that may mean in the individual instructor's grading plan.

3. At least 20% of the total course grade should come from non-examination assessment instruments. These methods include, but are not limited to, homework assignments, in-class laboratory and exploration assignments, research papers, evaluation and opinion papers, and out-of-class observing projects.
4. A comprehensive final exam is not required for astronomy classes. However, a final exam of some sort must be given during the last week of class, preferably on the last class day. Instructors must be present for all classes.

List of Required Topics

PHYS 1311

I. Fundamentals
- a. Celestial coordinate system
- b. Newton's Laws of Motion and Gravity
- c. Light and Matter
  - i. Wave-particle duality of light
  - ii. Electromagnetic spectrum
  - iii. Kirchoff's Laws
  - iv. The Bohr Model of the atom
  - v. Astronomical Spectroscopy
  - vi. Luminosity and Brightness
- d. Telescopes *

II. Properties of Stars
- a. The Sun *
- b. Nuclear Fusion
- c. Magnitude system
- d. Spectral types
- e. The Hertzsprung-Russell Diagram
- f. Binary stars
- g. Star clusters

III. Process of stellar evolution
- a. High-mass vs. low-mass stars
- b. Stellar remnants

IV. Galaxies
- a. Structure of the Milky Way
- b. Types of galaxies
- c. Theories of galaxy formation
- d. Quasars and active galaxies

V. Cosmology
- a. The expansion of the universe

b. The Big Bang Theory

*May also be covered in Physics 1312

PHYS 1312

I. Fundamentals
   a. Angle measure
   b. The origin of the seasons
   c. Apparent retrograde motion
   d. Solar System Models
      i. Geocentric models
      ii. Heliocentric models
   e. The Renaissance
      i. Discoveries of Galileo **
      ii. Kepler's Laws of Planetary Motion **
      iii. Newton's Laws of Motion and Gravity
      f. Solar System Exploration
II. The Inner Planets (emphasis on comparison and contrast)
   a. Earth
   b. the Moon
   c. Mercury
   d. Venus
   e. Mars
III. The Outer Planets (with emphasis on comparison and contrast)
   a. Jupiter
   b. Saturn
   c. Uranus
   d. Neptune
   e. The satellites of the outer planets
   f. Ring systems
IV. Minor bodies
   a. Pluto
   b. Asteroids
   c. Comets
   d. Meteors
V. Summative topics
   a. The origin of the solar system, including Earth and the Moon
   b. The search for extrasolar planets
   c. Possibilities for extraterrestrial life

**May also be covered in Physics 1311

Appendix K: Central Community College Now

At the time of this writing, all of the active participants in this study are still on the faculty of Central Community College. Since the end of formal data acquisition, I have also remained on the faculty of CCC and I have observed a number of changes in the organization and professional relationships in the Department of Physical Science (which includes Astronomy). Central Community College is a very different place today than it was when the study began.

Adjunct faculty are now included in the college decision making process and can serve as members of all committees except faculty search committees. There have been two complementary changes in college organization. Faculty (both full time and adjunct) are now hired at the college level instead of the campus level. This means that adjuncts may teach at several different campuses, especially in programs like Astronomy that have a relatively small number of sections. However, since adjuncts have access to all the campuses, there are more opportunities for teaching classes. A significant consequence of this change is that most adjuncts are now hired on a longer term basis and generally know weeks or months in advance which classes they will be teaching. Edward and the other participants will now rarely have to deal with insufficient preparation time or last minute telephone calls the evening before class starts.

At the same time, many decision making procedures have been moved to the department level, so both full time and adjunct faculty have a much greater role in decision making than under the old system, at least in the physical sciences. Adjunct faculty have an equal voice in the selection of textbooks, thus answering one of Edward's concerns. While Edward and the other participants may not get the textbook they want, at least they do get to participate in the process.

Professional development requirements have also changed quite a bit. Adjunct faculty are now required to attend four hours of professional development training each academic year. Full time faculty must attend eight hours. Much of the college wide training that is available has been perceived by the Physical Sciences faculty as not particularly useful. Consequently, in 2003, the Physical Sciences Department requested permission to hold its own professional development program. This has proved very successful and will continue in future academic years. A professional development session might consist of presentations of current research in a particular discipline, current research in science pedagogy, workshops in utilization of laboratory equipment, or workshops in writing effective test items. This has helped significantly to relieve the sense of isolation expressed by Edward and Jack. Unfortunately, Gene is unable to participate in the faculty workshops, due to his full time job.

The individual participants have also substantially changed their teaching practices, although it is not clear that participation in this project was a determining factor. Jack has incorporated more interactive group lessons into his class structure, especially the lessons developed by Adams and others (Adams, Prather & Slater, 2005). Edward continues to emphasize misconceptions research, but has also introduced interactive group activities. Gene has substantially modified his lecture style and now uses a much more open approach to student questions. So, all of the participants have changed. I hope that their participation in this research project was at least partly responsible for the changes that have occurred.

Finally, one of the significant shortcomings expressed by all of the participants, the lack of a true laboratory component, has been addressed. In addition to the one semester hour credit laboratory in astronomy Central Community College now offers Stellar Astronomy as a four semester hour credit laboratory course.

L: PERSONAL BIOGRAPHY

In any qualitative research study, the researcher becomes much more involved with the acquisition of data. In a sense, the researcher becomes the measuring instrument. Thus I must be acutely aware of and sensitive to partiality. In this study, I have gone a step further than many other qualitative studies by including myself as a study subject. It is appropriate, therefore, that I describe myself; my biases about education, my understanding of science education, and the nature of education research; and my intellectual background. However, even this autobiography is suspect, because it is my perception of myself so it is potentially as full of distortions as any other writings I may produce.

For the first 50 or so years of my life, it never occurred to me that I should be taking field notes. I wish I had kept a journal, or a diary, or even just a few notes at important times. I did not do that. So what I have now are not so much memories as they are memories of memories. The original memory is overlaid with many later instances of recalling and thinking about the event. These later thoughts get incorporated into my recollection of the event and it is no longer possible to recover the original memory. With that caveat, the consumer or reader of this research can judge how credible and dependable my conclusions are.

Personal Information

I was born in San Antonio, Texas in 1942 into a more or less typical American family, two parents, two children, both boys, father as the sole wage earner. My parents were hard-working, lower middle class, white Protestants. (Of course, in 1942 we didn't know we had a socioeconomic class and probably would have rejected the notion anyway.) After being discharged from the Civilian Conservation Corps, my father worked as a surveyor, chemist, and accountant. This included a stint trying to re-develop a worked out gold mine in Dos Cabezas, Arizona, and working in and around the mercury mines near Lajitas, Texas. After moving to San Antonio, he worked for various road contractors, worked in public accounting for several years, and at his retirement was treasurer and chief financial officer of a small steel foundry. He was very active in church work and Freemasonry.

My father liked to work things out. He was fond of mechanical puzzles, liked drafting, liked to work on cars and other machinery, and was a fair chess player. He liked to read westerns, blood-and-guts murder mysteries, historical fiction, history of the American West, history of World War II, and travel literature related to the American West. Although moderately conservative in his political views, he was very tolerant of a variety of opinions and was a compassionate and charitable person.

My mother never worked outside the home and to my knowledge never expressed a desire to do so. Perhaps she considered the care of my brother and me a full-time occupation. However, she was also very active in church work and was for many years a member of the Order of the Eastern Star, a Masonic affiliated organization for men and women. My mother also liked to read, although she preferred magazine articles and short fiction. My mother was a kind and loving person, but she was much less tolerant of differences in people than my father and was even fearful of people who were different from her in skin color, dress, or lifestyle choice.

Neither of my parents watched much television except for musical variety shows such as Ed Sullivan. However, both enjoyed table games such as canasta, forty-two, and dominoes.

We lived in the same house from the time I was about four years old until I moved away. I attended an elementary school a few blocks away, and I attended a junior high school and high school both within walking distance of my house. Until I entered high school, most of my friends lived within a few blocks of my house. When we first moved to the neighborhood, it was a relatively undeveloped suburb. Nearly the entire block across from my house was vacant when I was in elementary school and it would grow up in the summer in sunflowers and prickly pear. The sunflowers grew taller than me. My friends and I would make tunnels and pathways through the weeds. It was hot, sticky, dirty, forbidden, and wonderful.

My parents continued to live in this house until their death. While it is true that the neighborhood changed some while my parents and I lived there, becoming less suburban and white and more urban and Hispanic, it remained a safe and stable middle class neighborhood where children could play baseball in the streets. This is the environment of my youth and, while I am probably not fully aware of how or to what extent, it must have had a deep influence on me.

I attended Thomas Jefferson High School, graduating in 1960. After graduation, I attended what was then called the Agricultural & Mechanical College of Texas. At the time it was a relatively small, all-male, military, land-grant institution. (It is now known as Texas A&M University.) I graduated from Texas A&M with a B.S. in Physics in 1965. I then attended Sam Houston State University in Huntsville, Texas for a while, majoring in physics. During this period, I also taught high school in a small community south of Huntsville. While teaching at that small high school, I was the only math teacher and taught every math course the school offered as well as physics.

In 1967 I married Kathy McDaniel, and thirty-eight years later we are still married. The next year, 1968, I left Sam Houston State University and the small high school and went to work for an oil well logging company as a field engineer. After a year of that interesting and demanding work, I returned to Sam Houston and completed my master's degree in Physics in 1970.

Although it was never my intention to make a career of teaching high school, jobs were scarce for physics majors in 1970. After a lengthy search involving hundreds of letters, applications, and resumés, I finally managed to obtain a job teaching high school physics, astronomy, and physical science in a small community in southeast Texas. I lived and taught there for fifteen years. Shortly after moving to southeast Texas my wife and I had our first child, Jennifer. Seven years later we had our second child, Elanor, and we decided that two children were enough. It seemed by this time that I had permanently settled into the community. I became active in church work, joined the local Masonic Lodge, and helped to start a chapter of the Order of Demolay for Boys, another Masonic affiliated organization. The small church we belonged to had difficulty keeping a full time minister, so I occasionally served as interim minister as well as choir director, deacon, and elder. During this period I also coached cross-country and track, started and sponsored the fencing club, and started and sponsored a science club and a chess club.

I might well have remained in Southeast Texas for many more years, but in 1985, it became necessary for me to move to be nearer my elderly and ailing parents. My parents still lived in San Antonio and my wife's family had all moved to Central Texas, so I began looking for a job in this area. We eventually moved to Austin, Texas where I accepted a job teaching high school physics and astronomy at a suburban high school near Austin. The following summer, I also began working part-time as a materials developer and test designer for a multimedia company, Texas Learning Technology Group (TLTG). TLTG designed and produced interactive multi-media instructional materials, primarily for science instruction. I began with TLTG as they were developing a physical science course and continued to work with them during the development of a chemistry course and an environmental science series. My duties with TLTG continued to expand and change as well as I moved from materials developer to subject matter expert to instructional designer and finally to project manager. .

My mother died in September of 1991 and my father a died a few months later in April of 1992. By this time, I was working nearly full-time for TLTG, teaching full-time in high school, and also teaching a few courses in astronomy at a local community college. It was obvious to me that this could not continue, and I was becoming ever more interested in trying to understand the teaching process through formal study. After the death of my parents, I was relieved of some financial responsibility and time restrictions and I began to think about returning to school. In order to do that, I had to make a decision whether to quit teaching and stay with TLTG or remain a high school teacher. Since TLTG was able to offer me flexible hours that would allow me to attend school, I left high school teaching and began a Ph.D. program at The University of Texas in January of 1993.

In 1997, I faced a personal tragedy. My youngest daughter, Elanor, was killed in an automobile crash near Kingman, Arizona on July 13. For a period after this, I was barely able to function in my job and could not manage anything beyond the simple tasks of getting up and going to work. All progress on my dissertation came to a halt and remained on hold for nearly four years.

In 1999, I had an additional setback. TLTG ceased development of new products due to lack of continued funding by their parent company. So it became necessary for me to make other arrangements. I worked for one year as Senior Project Manager for a development house that served several major textbook publishers. The work was challenging and satisfying, but very time-consuming. This, combined with continued personal difficulties dealing with my daughter's death caused me to change jobs again. In

August, 1999, I became primarily self-employed. I am currently working as a freelance writer and curriculum developer and teaching astronomy at Austin Community College.

So I bring twenty-four years of experience as a classroom teacher, over eight year's experience as a multi-media developer, and several year's experience as a freelance writer to my nascent research program. My research interest continues to be in that peculiar human activity known as teaching and especially in the richly complex details of the interaction between teacher and students. I am especially interested in how humans are able to make effective decisions based on insufficient information.

Intellectual Journey

While teaching in Bridge City, I began to think of myself as a high school teacher and also began to think about the teaching process and how it might be possible to become a better teacher. As my interest in teaching as a career and worthwhile occupation increased, I took advantage of college-credit courses in content and pedagogy. One of the most worthwhile of these was a week long workshop in environmental studies offered by Texas A&I University at the Welder Wildlife Refuge near Sinton, Texas. I also took courses at Lamar University in Beaumont in teaching special student populations and in science teaching.

After moving to Austin, I sought opportunities for workshops, seminars, and college credit courses. It was during this period that I attended a course at Texas A&M University in teaching advanced placement physics, attended a workshop in teaching PSSC Physics at the Colorado School of Mines in Golden, Colorado, and took advantage of a National Science Foundation funded workshop and college credit course in teaching activity-based astronomy. The best part of that course was spending a week at McDonald

Observatory near Fort Davis, Texas, and the best part of *that* was the opportunity to work with a research grade 36" reflector.

Although I have always been interested in how to teach the concepts of physics and astronomy, I really became intrigued with the problems of teaching these subjects at a meeting of the Texas Section of the American Association of Physics Teachers in 1992. At that meeting, Alan Van Heuvelen described some informal research he and his colleagues had done in trying to identify which students were Aristotelian in physics concepts and which had progressed to a Newtonian understanding (Heuvelen, 1992). The conclusion he came to was that a semester of physics instruction had achieved a three percent success rate! He then said this was a very liberating result because it meant physics teachers were free to try anything. We couldn't possibly be doing any worse!

Much earlier, I had been attracted to the physics program then known as Harvard Project Physics. I started teaching this program without formal training, using materials I was able to beg, borrow, scrounge, and photocopy. The course emphasized a "humanistic" approach to teaching physics. In Harvard Project Physics, later published by Holt as *Project Physics,* students learned the concepts of physics in a historical context and following a more-or-less historical sequence. The course used much more reading of literature, made many references to technology and society, had a nice set of ancillaries, encouraged a contract approach to grading, and was generally regarded as less mathematically demanding than other courses.

Somewhat paradoxically, I have also been attracted to *PSSC Physics*, which mostly ignores the historical sequence of concept development and uses a sequence based on the presumed internal logic of the concepts themselves. I am attracted to the notion of following a sequence that makes the concepts themselves as clear as possible, so that one flows into the next in a logical and cognitively sound way. The student is bridged from one concept to the next. I have used PSSC materials off and on for most of my teaching career, usually in conjunction with *Project Physics*. After attending a workshop one summer in Golden, Colorado, I was invited to participate in the pilot program for the seventh edition of *PSSC Physics*.

Arnold Arons (1965) has, for many years, attempted to develop a synthesis of these two ideas, combining the relevance and natural appeal of a historical approach and the clear logic and natural progression of a conceptual approach. Relevance is the essential problem in teaching the concepts of physics. An approach like *PSSC Physics* may do the best job of presenting the concepts in a clear and unambiguous way, but tends to concentrate on final-form science. Many students fail to see physics as a fallible human activity. On the other hand, a purely historical approach muddies the conceptual waters and may leave out important steps in conceptual development. The two approaches are not completely compatible.

Relevance is one of the overriding issues in teaching all science, as in any other subject. At Bridge City High School, the physics enrollment went up while I was using Harvard Project Physics, but began to drop again after those materials were no longer available. (The publisher ceased publication of the materials after one state adoption cycle.) At the high school in Austin, enrollment was always high but the motivation of the students was, I suspect, more from transcript enhancement than from the innate appeal and intellectual delights of physics. I don't think students were primarily motivated by how relevant physics was to their lives.

However, while I was teaching at the high school in Austin, another teacher introduced me to the works of Paulo Freire (1970) and Ira Shor (see for example Shor, 1986; Shor, 1987; Shor, 1987; Shor & Freire, 1987; Shor, 1992). Paulo Freire led me by indirect routes to the writings of bel hooks (she prefers that her name be spelled with lower case as a statement about class and patriarchy) who gives a more feminist perspective to liberatory education (hooks, 1994). The notion of a liberatory education grounded in the lives of the students has continued to appeal to me and has always seemed perfectly consistent with my other notions about how science teaching should be done. While Freire's work and the work of Ira Shor, bell hooks, and other disciples of a liberatory education has been generally in teaching English, writing, and language arts, I believe the concepts can be applied with success to the "exact" sciences. The value and relevance of Freire's work has become preoccupation with me, to the extent that every time I find a book or paper I like, I look to see if Freire is listed in the bibliography

Around the same time, I was introduced to a book of essays by Peter Elbow, *Embracing Contraries* (Elbow, 1986). He gives a nice balance and context for Freire, especially in his essay "Pedagogy of the Bamboozled," and helps me to keep perspective. Elbow makes the point well that while it is relatively easy to claim a Freireian approach to teaching, it is much harder to actually do it. Elbow also does a good job of extracting the essential steps in liberatory teaching:

- The teacher must become a collaborator and ally of the students, not a supervisor.
- The subject (whatever the name of the course) must be the lives of the students, reflected back to the student as a problem or source of contradiction.
- The goal must be not just to change the student but to work with the student to change the world.
- The process must be rational and cognitive, rather than affective, involving critical thinking, problem-posing, looking for contradictions, and using metacognition.

Most recently, I have tried to incorporate constructivist ideas into my conceptual framework. Although I did not have a name for this idea until I was in graduate school, I like to tell myself that I was thinking along these lines early on. I first used the term "constructivism" in a paper I wrote in one of my first classes at UT. "Constructivism (von Glasersfeld, 1983; von Glasersfeld, 1989) . . . takes the view that knowledge does not exist outside the mind of a cognizant being. Reality exists . . . , but knowledge and experience are constructs. All knowledge is constructed within the context of cultural bias and prior knowledge. Objectivism demands that knowledge match reality perfectly. Constructivism recognizes that, at best, the match will only be an approximation. Therefore the goal of science (and of science education) is to 'construct viable models to fit with current understandings and experience." (Tobin, 1991, p. 4) Constructivism recognizes that students are not "human video cameras" (Glynn, Yeaney & Britton, 1991, p. 5). Constructivist teachers now view students as active learners participating in their own education."

Finally, I am convinced that all of these ideas integrate into a framework for teaching science that will ultimately be more effective and productive than any thing science educators have been able to devise. For me the two ideas of liberatory pedagogy and constructivism match and mesh perfectly. Constructivism is, as used by science educators, primarily a theory of learning. While it can be argued, and I have argued, that there is no such thing as constructivist teaching, only constructivist learning, science teachers still use constructivism as a framework for selection of activities, lesson design, writing objectives, and evaluation. I am interested in how this can be done in a way that *liberates* students while at the same time does a better job of teaching than the three percent success rate we currently have.

Liberatory teaching can provide the motivation to learn. It is an internal motivation, built up in collaboration with the students, as they ground their education in their own lives. As a collaborator, the teacher must continue to learn as the students learn. For example, art teachers regularly model the behaviors for students by participating in the same activities as the students. Many English teachers recognize the value of writing along with their students, even allowing their students to criticize the teacher's efforts. While it may be more difficult for science teachers to collaborate on projects that are meaningful to the students and the teacher, they can still model a love of learning. They can still get off the stage and stop pronouncing "final-form science" for the students to memorize. Science teachers can begin to think about the lives of the students and how science can be grounded in those lives.

In the last decade or so, I have transferred my interest in science education to higher education, especially community college science education. Community colleges have been and remain a neglected area of science education research. This is unfortunate, because the majority of students that attend post secondary institutions enroll in community colleges. Since I teach at a community college, focusing my research on community college science education has been both convenient and practical.

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Vita

Marvin Elliot Richmond was born in San Antonio, Texas on September 6, 1942, the son of Sam Doss Richmond and Koreski May Richmond. He received the degree of Bachelor of Science in Physics from Texas A&M University in 1965. After graduation, he taught high school science and mathematics and worked as a field engineer for an oil well service company. He returned to graduate school and received the degree of Master of Science in Physics from Sam Houston State University in 1970. He taught physics and astronomy at Bridge City High School in Bridge City, Texas for 15 years, coaching cross country and track for the last five years. In 1985, he moved to Austin, Texas and taught physics and astronomy at Westlake High School for seven years. He also worked part-time for Texas Learning Technology Group (TLTG). In 1992, he left teaching and worked full time as a project manager for TLTG. In 1995, he joined the adjunct faculty of Austin Community College as an astronomy instructor. In August, 1999, he became a freelance writer and curriculum developer. He continues to teach astronomy at Austin Community College. He entered the Graduate School of the University of Texas at Austin in the spring of 1993.

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