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A CALL FOR SELF-REFLECTION AS PROFESSORS ENGAGE
THE ISSUES OF SCIENCE EDUCATION REFORM:
AN ETHNOGRAPHIC STUDY

BY

MIGUEL M. LICONA, B.A., M.S.

A Dissertation submitted to the Graduate School
in partial fulfillment of the requirements
for the Degree
Doctor of Philosophy

Major Subject: Curriculum and Instruction

New Mexico State University
Las Cruces, New Mexico
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I owe much to the participants for allowing me to share in their worlds. This version of their realities has potentially been distorted and limited. These are not whole stories but instead reflections on a moment in time. My journey to the present has been paved with experiences unique to myself. Forty years of schooling and twenty-five years of teaching have had an indoctrinating effect. That has produced one particular epistemological perspective that was responsible for this research outcome. I am only beginning to make sense of my educational experience within the larger context of schooling.
ABSTRACT

A CALL FOR SELF-REFLECTION AS PROFESSORS ENGAGE
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Science becomes distorted and undemocratic when it is categorized into
disciplines that, in turn, perpetuate borders creating conditions of inequality for the
general population. Science education reform represents a starting point from which
to approach notions of exclusion and inaccessibility. Students not intending to major
in science often encounter environments as well as professors that serve to limit their
potential and thereby exclude them from greater exposure and participation in the
sciences. This qualitative study considers professional practices of professors who
hold key positions for the success of science teaching and learning. Through
classroom observation, in-depth interviewing and a survey questionnaire, this study
sheds light on the process of science education reform. Participants included six university professors who taught a reformed science course developed under the guidance of a National Science Foundation initiative known as the Collaborative for Excellence in Teacher Preparation. The purpose of this study is to understand the nature of faculty beliefs concerning teaching and learning science for students not intending to major in science, most of whom are elementary education majors. In this study, professors' espoused belief systems were elicited while their mental models that drive behavior were observed in the classroom setting. Incongruencies between theories in practice and theories in use were uncovered and explored. Major implications for who can and cannot learn science within the context of a system that currently serves to pre-select who will succeed are uncovered as a result of this study. The constant comparative method developed by Glaser and Strauss was used to analyze the words of each individual participant as she/he worked to consider the incongruencies in her/his theory and practice (as cited in Bogdan & Biklin, 1992; Lincoln & Guba, 1985; Maykut & Morehouse, 1994). Self-reflection is identified as key in the process of praxis that will aid professors in their efforts to close the gap between theory and practice.
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CHAPTER 1

INTRODUCTION: REFLECTIONS ON SCIENCE EDUCATION REFORM

Background

There are many nationally recognized undergraduate science education reform initiatives currently under way (National Science Foundation [NSF], 1996a, 1996b, 1996c, 1996d, 1996e). The Directorate for Education and Human Resources in the Division of Undergraduate Education oversees most of these. This study investigated an NSF Collaborative for Excellence in Teacher Preparation (CETP). The Education Reform Initiatives Report prepared by the Education Development Center (1995) for the National Science Foundation Statewide Systemic Initiatives describes twenty programs that are in some respect attempting to pinpoint and address problems in curriculum and instruction in Science, Math, Engineering, and Technology (SMET). Each initiative provides a forum of support in order to develop and implement ways to strengthen and improve the educational context so that student participation and learning increases. Reform proposals have emerged to try to address the causes of science illiteracy in student populations as well as in elementary teachers. As information dealing with these issues is gathered, professors can enhance their view of the larger picture. This research deals with a vital area that requires attention if university science professors interested in reform are to move towards a transformation of curriculum and instruction in science. This study highlights a reform initiative from the perspective of the professors that teach the required general science for undergraduate education majors.
Bethel (1984) and Seymour and Hewitt (1997) suggest that many of the shortcomings in science preparation for elementary teachers can be attributed to the experience of pre-service students in their college and university science courses. Many students also have negative and disconnected K-12 experiences. Where do we as reform-oriented university science professors attempt to “fix” these problems? These initiatives advocate intervention and change at various levels of science instruction. While I agree that every level requires attention, I propose that one of the most significant areas in which to address reform is at the university where science professors have a high impact on the students studying to become teachers. These university students will ultimately teach our children in the elementary and secondary schools. For this reason, I chose to explore and try to make meaning out of the post-secondary science experience of pre-service elementary teachers from the perspective of the professors who develop and implement the teaching of science courses.

Beaton, Martin, Mullis, Gonzalez, Smith, and Kelly (1996) and Harmon, Smith, Martin, Kelly, Beaton, Mullis, Gonzalez, and Orpwood (1997) report disappointing progress of American students in science within the international student community. An emerging body of research on undergraduate science education shows that even students who are apparently successful in collegiate science courses have disturbing gaps and misconceptions in their understanding of those subjects (NSF, 1996d). These shortcomings have led to many conferences and policy advisory reports that outline the direction for reform (American Association for Advancement of Science [AAAS], 1990, 1993; National Research Council [NRC], 1996a, 1996b; NSF, 1996d). Many initiatives have emerged to explore new
approaches to traditional science courses. A large number of these courses have an
interdisciplinary configuration. The 1990s has been designated the “Decade of the
Brain” and the development of “reformed” courses can be greatly informed by
research on human learning and the brain (Caine & Caine, 1994, 1997a, 1997b;

Students enrolled in elementary teacher preparation courses at the university
level are mirroring the deficiencies delineated above. They are coming to science
methods courses with a serious lack of conceptual understanding of science and
corresponding fears. One of the major criticisms of science education is that
elementary teachers lack content preparation (Bethel, 1984; Heikkinen, 1988).
According to Keating and Ihara (1998), this is due in part to inadequate and
sometimes inappropriate science instruction. Anderson and Mitchener (1994) agree
and suggest widening the breadth of subject exposure by requiring course work in all
the major disciplines. The Collaborative for Excellence in Teacher Preparation
course is doing this by teaching and attempting to integrate the disciplines within the
course context.

Many elementary teachers report that science courses taught in college often
over-utilize the lecture/text format which results in student memorization of facts and
regurgitating them on tests (Mayer, 1996; Barba, 1994). This view was born out in
my qualitative study. An over reliance on the lecture/text format exemplifies what
Caine and Caine (1997a, 1997b) have termed Perceptual Orientation 1 (PO1).
Instructional Approach 1 (IA1) evolves from this perceptual orientation. Keating and
Ihara (1998) indicate that most science methods courses teach strategies and science
content applications with the assumption that students have already acquired competency in science content prior to the courses. The lack of cohesiveness between education and science courses may play an important role in perpetuating low self-confidence, weak concept development, and a general lack of enthusiasm for teaching science by future elementary teachers. Others studies report on the disjuncture between teacher education programs and the sciences (see Gilbert, 1993). Many pre-service elementary science methods instructors express this as a major problem and support a greater level of coordination between scientists, science teacher educators, classroom teachers, and education faculty during the undergraduate education of prospective elementary teachers (Johnson, Tamppati & Tanner, 1994). This is the articulated intent of the CETP initiative at this university.

The NSF initiated a program in 1993 to support CETP with the intent of significantly changing teacher preparation programs (1996e). These programs aim to help prospective teachers develop a more profound understanding of the fundamental concepts, principles, and reasoning processes at the heart of science and mathematics. The programs also aim to create learning environments in which students can actively investigate problems that help them construct personal understanding of key concepts.

**Purpose**

The purpose of this study is to consider science education reform from the perspective of those professors who had developed and were attempting to implement a reformed science course. I have attempted to gain insight and a deeper understanding of the interplay of their individual and collective belief systems with
theory and practice. The gap that exists between theory and practice must be addressed. By becoming aware of their actions and recognizing how these are or are not congruent with their explanations, practitioners may begin to create the possibility for genuine transformation (Caine & Caine, 1997a, 1997b).

The term “change” is used extensively in the literature. I feel that it is a process, not an either/or phenomenon, and I will therefore use the term “transformation” when addressing the process that professors are going through in their efforts towards becoming critical science educators that will serve the needs of all students (Freire, 1993; Giroux, 1988; McLaren, 1994). The transformation process can be considered as a continuum of change. Inherent within this process is an acknowledgment that there is no one location at which to arrive. Instead, transformation can be understood as a journey of reflection and de/reconstruction. Transformation is at the heart of educational reform. I believe reform is not possible to achieve without the transformation of university professors’ mental models that represent the deep-seated beliefs that affect their behavior (Caine & Caine, 1997a; Crowell, Caine & Caine, 1998). These beliefs and perceptions have been forming through a lifetime of experiences and my intention is not to look for professors to “change their minds,” but for them to become critically aware and mindful in order to enhance the transformational process (see Brooks & Brooks, 1993; Hart, 1998).

**Rationale for This Study**

This narrative interpretation revolves around a reformed general science course intended for pre-service elementary education teachers. It is my intent to shed light on the professional practices of the participating professors who potentially hold
key positions for the success of science teaching and learning. Readers should be able to take this experience into account when imitating reform movements. This study should also provide readers with a greater understanding of reform efforts in general. It will be presented from the perspective of six science and engineering professors who developed and taught a uniquely integrated and theme-based course.

Studies presented by the Educational Development Center (1995) have provided information on programs, theories, pedagogies, curriculums, and student perspectives of the schooling process. Some recent initiatives are beginning to uncover the perspectives of key players; the university professors (see Fedock, Zambo & Cobern, 1996; Gardner, 1998; Hinton, 1997; Jennings, 1997; Mattson, 1997; Pape & Tittle, 1998, Thoresen, 1994, 1998). The context within which reform efforts play themselves out should be coupled with the results of research conducted over the last decade on the human brain and learning. This will allow for a broader understanding of science education reform.

Both constraints and possibilities must be explored, uncovered, and shared. My intention is to allow the readers to interpret an understanding so that existing "answers" can be questioned and further research can ultimately improve teaching and learning for all students, particularly in science.

My focus will be on description and documentation rather than on judgment or success and failure. The purpose is to contribute to an ongoing effort through continuous reporting of observations and experience, to illustrate the issue within case analysis (Merriam, 1988). Participants as well as others interested and committed to
reform can enhance their construction of meaning through lessons learned from this experience (Lincoln & Guba, 1985).

The needs of the institutes of higher learning do not seem to have been taken into account and consequently change has been less than effective. Thomas Kuhn (1996) presents how paradigms have changed due to change in contextual settings. Paradoxically, science educators at the university level seem to be embracing a new paradigm while not letting go of the old. "To be accepted as a paradigm, a theory must seem better than its competitors ..." (p. 17). "The decision to reject one paradigm is always simultaneously the decision to accept another ..." (p. 79).

Science education is currently filled with anomalies. Traditional pedagogy can no longer be used with a non-traditional student population (see Hurd, 1997). Too much has changed. We are in the midst of a scientific revolution. "Scientific revolutions are taken here to be those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one" (Kuhn, 1996, p. 92). There is a parallelism here between scientific and political revolutions. There is a sense of malfunction in science education today. Kuhn delineates that this sense, whether in scientific or political development, can lead to crisis, which is a precursor to revolution. "Political revolutions aim to change political institutions in ways that these institutions themselves prohibit" (p. 93). What I am trying to establish here is there is this sense of urgency where a paradigm shift is occurring in science due to social changes in our country as well as globally. The malfunction has transformed to crisis levels now that our world and all of its diversity has been exposed to us by a technological revolution.
Society and education have evolved unequally. Society has moved from an agricultural to an industrial base and recently to one based on information (Caine & Caine, 1997a, 1997b; Hurd, 1997). The educational system has moved, but lagged behind the changes in society. The artifacts in our schooling system from the apprenticeships of the agricultural era and from the factory model of the industrial revolution can still be seen. Educators are having a difficult time with information and meaning-making as a way to deal with schools and students. Biology has advanced our knowledge and understanding of how we learn (Caine & Caine, 1994; Diamond & Hopson, 1998; Jensen, 1998; Sylwester, 1995). The focus on how the brain works is dissociated from learning. Educators seem to shy away from information that is steeped in the biological sciences rather than education. Caine and Caine (1997b) feel that the following questions represent a gateway to significant learning:

Human learning involves questions such as; Do I want to learn this? Have I ever wondered about that? Is this related to what I already know? How does this make sense? What do I get when I learn this? Do the people I love and respect do this? (p. 7)

By acknowledging student purpose, educators can teach to expand dynamical knowledge rather than requiring students to memorize facts.

Research Questions

These questions surfaced during a review of recent studies done by Caine and Caine and others in the 1990s, which was a prolific decade on research dealing with the brain and learning. They also emerged from over twenty years of teaching
experience as well as my recent participation with the NMCTEP initiative that gave rise to this reformed course.

(a) What is the nature of faculty beliefs concerning science and the interdisciplinary learning and teaching of science to students not intending to major in science?

(b) What are the contextual limitations that constrain implementation and success of this reform initiative?

(c) How do professors perceive their participation in science education reform?

(d) Is there congruence between professors’ espoused theories and their mental models regarding teaching, learning, and students?

(e) How do these professors from astronomy, biology, engineering, and chemistry perceive their practice?

History of Science Education Reform

Science reform might be rooted to the early part of this century with the Progressive Movement. Critics in the 1940s caused reform efforts to lose steam by attacking them as “watered-down content” and focusing “on children’s psychological adjustment at the expense of learning” (Elmore, 1996, p. 8).

Following Sputnik in 1957, new instructional materials for the high school were developed. The NSF supported development of PSSC Physics (developed by MIT professors and no teachers), BSCS Biology (co-developed with teachers), CHEM Study, and Man, A Course of Study (MACOS), (Sneider, Barber, & Bergman, 1997). These projects were followed by the development of elementary
programs like Science A Process Approach (SAPA), the Science Curriculum Improvement Study (SCIS), and Elementary Science Study (ESS). The Intermediate Science Curriculum Study (ISCS) and Introductory Physical Science (IPS) were developed for the intermediate level (Sneider et al., 1997). The science education vision at this time was similar to that of early reformers. Today’s vision has not changed much.

NSF funding was dramatically cut in the 1970s. This diminished the opportunities to train teachers in new methods and most schools adjusted by returning to text-based instruction along with memorization of terms, recipe-type labs, and multiple-choice tests (Elmore, 1996; NRC, 1996). Elmore refers to the lack of incentives to change as a major reason that these past efforts of science education reform never “caught on” to a majority of schools. He further states that good instructional materials and teacher training is insufficient to maintain reform. Sustained support and incentives need to be provided by universities, professional organizations, administrators, community members, and credentialing boards.

Reform Efforts of the 1990s

In the decade of the 1990s, a widespread agreement emerged among educators that effective science education should be inquiry-based, experiential, and constructivist in nature (Gardner, 1998; Mattson, 1997; NRC, 1996a, 1996b; NSF, 1996d; Pearsall, 1992; Sneider et al., 1997; Thoreson, 1994; Tobias, 1992a, 1992b). Three initial reform documents ensued and produced a common vision: Project 2061; The Scope, Sequence, and Coordination Project (SS&C); and The National Science Education Standards (NSSE).
Project 2061 produced Science for All Americans and Benchmarks for Science Literacy. The former provided an operating definition of scientific literacy while the latter provided a comprehensive listing of what every student should know and be able to do by the end of the 3rd, 5th, 8th, and 12th grade levels. The SS&C established guidelines for restructuring the school science experiences for students in grades 6 through 12 while the NSSE provided a comprehensive vision for science education and the systems that are needed to support it. These reform projects were responsible in helping establish this common vision.

Emergence of CETP

The vision produced in the 90s is being advanced towards becoming a reality by the CETP initiatives with support from NSF. The CETP program was initiated in 1993 with the NSF’s Division of Undergraduate Education.

The teacher preparation enterprise is elaborate and complex, yet this initiative has developed to include many diverse institutions within a given area. These include two-year colleges, comprehensive and research universities, school districts, and other community resources. The CETP leadership teams include faculty and administrators from a variety of SMET disciplines. They intend to create models for improving the quality of science and mathematics teacher preparation. One significant factor is that the science and mathematics faculty have joined with education faculty and K-12 teachers in these CETP initiatives.

Brain-based Learning

Geoffrey and Renate Caine using Leslie Hart’s Proster Theory as a foundation coined the term brain-based learning. Hart’s book *Human Brain and Human*
Learning (1998) is a seminal source for the development of a coherent theory of learning. Caine and Caine (1997a, 1997b) have developed a continuum with three perceptual orientations identifying "benchmark" locations. Perceptual orientations are characterized by four qualities or dimensions: (1) From Power over Others to Self-Efficacy Grounded in Authenticity; (2) Expanded Cognitive Horizons; (3) Self-Reference and Process; (4) From Control to Building Relationships That Facilitate Self-Organization. Each perceptual orientation has a corresponding pedagogical behavior that will be associated with Instructional Approaches One, Two, and Three.

Perceptual orientations represent worldviews of education that are quite different. This makes communication between individuals and institutions of differing views extremely difficult. Individual transformation is a tenuous process, but it is further constrained when the system itself is not set up to accept new ways of thinking. When teachers, especially pre-service ones, are given the opportunity to reflect on their philosophy of education in light of the current reform movement, they tend to begin the transition from Perceptual Orientation One (PO1) toward Perceptual Orientation Three (PO3). The system they are working within has a particular culture that seems to rob them of their desire to be "innovative." A reflective practice that allows for the identification of convictions on issues that define one's philosophy of education must be a starting point for transformation. How can we know where we are going if we do not know where we are? My experience supports that most pre-service teachers as well as many veteran teachers have not done this and when asked to do so find it a formidable task. Teachers have mental models that govern their
actions and I feel it is important to make the theories-in-use explicit for individuals through the reflective process.

Caine and Caine (1997a, 1997b) developed three perceptual orientations that give rise to corresponding instructional approaches. They posit that when teachers do not understand why they do what they do at a significant enough depth, any changes tend to be superficial and temporary. Understanding the purpose of teacher actions is crucial to understanding these perceptual orientations. The first orientation lies within the traditional/transactional worldview that is prevalent in the factory model of schooling. The second is a transitional orientation while the third coincides with reform-oriented transformational educational philosophies.

Participants included six professors involved in a reformed course initiative. I interviewed them, administered a questionnaire, and observed them during instruction. The following indicators can be used to place the participants on a continuum of instructional approaches based on their perceptual orientations. This may be used as a method of creating a base line from which these professors, and others, may view the way they perceive their roles in the context of science education reform. Caine and Caine (1997a, 1997b) provided all but the last of these indicators. I added the last one.

- The objectives of instruction
- The teacher’s use of time
- Sources for curriculum and instruction
- How teachers define and deal with discipline
- How teachers approach assessment
• How teachers approach diversity

These came to be changed as the analysis of the data took place. Teacher's use of time and how they define and deal with discipline did not provide viable data while other issues emerged instead. The combined issues came to be identified as components of the professors’ belief systems.

**Instructional approach 1.** This is primarily a command-and-control mode of instruction described as a stand-and-deliver mode. This approach is compatible with a mechanistic and bureaucratic worldview and has become synonymous with a behavioral approach to education (Caine & Caine, 1997b).

• The objectives of instruction: The teacher focuses on students acquiring pre-specified information, facts, and skills through memorization, practice, rehearsal, and repetition. From a brain based learning perspective, the goal is the acquisition of *surface knowledge* with emphasis on programming the *taxon memory system* such as teaching to the test.

• The teacher's use of time: The teacher imposes an artificial time schedule on students. Deadlines are based on how long something “should” take without regard for student-articulated needs for time.

• Sources of curriculum and instruction: The teacher spells out what students should learn using a designated curriculum guide or other authoritative device. Texts, manuals, lectures, and demonstration videos are choice instruments for delivery of information. Subjects are taught as a series of fragments and topics.
- How teachers define and deal with discipline: Discipline is referred to as procedures needed to control behavior that disrupts instruction and teacher control. Rules are made explicit and posted throughout the school setting in an authoritative manner. Punishment and consequences are similarly specified. Discipline is approached from a behavioral perspective.

- How teachers approach assessment: The students are assessed according to their ability to replicate precisely what the instructional source presented. Instruments for assessment include tests and quizzes with true-false, multiple choice, or right-wrong answers.

- How teachers approach diversity: Students are viewed as equal with little regard for their experiences and knowledge they bring to the classroom. Differences are seen as deficiencies rather than strengths.

Instructional approach 2. This approach shares many of the same beliefs and practices expressed within IA1. However, some critical differences do exist. There is a fundamental change in classroom management in order to allow students to experiment and move about more freely. The teacher uses more complex materials, incorporates engaging experiences, and focuses on creating meaning as opposed to memorizing information. This approach is seen as a necessary step for educators who are willing to make the move towards IA3.

- The objectives of instruction: Teachers use a highly focused set of outcomes. They tend to combine prescribed curriculum with instructional activities and prepared materials such as those provided by SEPUP and
FOSS for example. Student purposes remain secondary. The goal of students is to acquire *scholastic or technical knowledge*. The teacher is concerned with students' understanding of the concepts, but lacks the ability to translate the concepts to real-life experiences and to connect concepts to each other.

- The teacher's use of time: Time frames begin to expand and become more flexible, but this seems to frustrate the teacher since the students are engaged in teacher-orchestrated activities.

- Sources for curriculum and instruction: Limited thematic instruction and integrated curriculum are utilized, but tend to be highly structured. Instructional sources now include groups, discovery, and technology. Students are allowed to interact more through exploration and exchange.

- How teachers define and deal with discipline: The approach to discipline has not changed much. Teachers design activities using a coherent plan of instruction and students must know how to cooperate with those objectives. Non-cooperation is seen as disruptive to the maintenance of discipline.

- How teachers approach assessment: Teacher-controlled performance assessments and evaluations are now added to paper and pencil tests. Rubrics may collaboratively be developed with students in order to begin using some types of authentic assessment of student projects and performance, yet the teacher still selects and controls the meaning and purpose for the experience.
• How teachers approach diversity: Teachers acknowledge diversity within the student population and act in assimilating ways. Multicultural education is not yet practiced.

Instructional approach 3. This approach is the most student-centered with genuine student interest at its core. Instruction is based on the view that students learn naturally if placed in an enriched and meaningful context. Others often consider the language and methods of these teachers suspect. This approach can generate too much uncertainty or garner negative community or system reactions because of the non-traditional approaches not used in the aforementioned “safer” instructional approaches.

• The objectives of instruction: The teacher allows learning to occur naturally and encourages the development of connections between ideas and concept to real-life experiences. This approach creates a context for meaningfulness by engaging students in a search for purpose and meaning that prepares them to transform the curriculum into knowledge they can use naturally in their everyday lives. Individual purposes and goals interact with changing contexts to drive the organization of information and the construction of meaning. This type of learning results in dynamical or perceptual knowledge and uses the locale memory system.

• The teacher’s use of time: Time becomes flexible and is directly tied to the needs of the learner, driven by complex individual and group projects.
• Sources of curriculum and instruction: Instructors and students develop partnerships using multiple sources. The prescribed curriculum is embedded in student-centered processes capitalizing on student interests.

• How teachers define and deal with discipline: The traditional approach has been discarded and replaced by a sense of order based on learning and instruction tied to common meanings and purposes.

• How teachers approach assessment: Authentic assessment is employed. Students are involved in evaluating their own process and progress. Assessment primarily focuses on two issues: 1. What does the student understand and how can it be demonstrated? 2. What can the student do with this understanding and how can this knowledge be applied?

• How teachers approach diversity: Difference is embodied in a spirit of community (Kohn, 1996). Personal identities are embraced and valued rather than marginalized (Nieto, 1996).

A Call for Research

Recent research presents a multi-faceted perspective of the issues related to reform (see Bruckerhoff & Bruckerhoff, 1996; Fedock et al., 1996; McGinnis & Watanabe, 1996; Seymour & Hewitt, 1997; Thoresen, 1998; Watanabe, McGinnis, & Roth-McDuffie, 1997). Elementary children are being “turned off” by science even though they are naturally curious. Elementary teachers are not responding in a positive way to science taught in traditional formats. They either leave out science in the curriculum or they address it in a way that is not meaningful to them or their students (see Bethel, 1984). University science professors have taught the courses
that pre-service teachers must take during their first two years of college in a traditional lecture format and often in large classes that can reach into the hundreds of students. Education departments provide the science methods course usually in the junior or senior year after they have taken the survey science class that researchers have identified as memorization-oriented, where grades are based mostly on tests, quizzes and exams. The laboratory sections are usually disjoined by who teaches them as well disconnected from the lecture in time. Sometimes the lecture and labs are taught in different semesters. The pre-service teacher is then placed in a student-teaching situation with teachers who are part of the very system in question; a system that produces teachers who do not teach science and if they do, it is done poorly. When teachers get a teaching position, they often enter a culture that is resistant to any innovations they may bring with them and the cycle continues (McClurg, 1991).

At the university, professors must contend with a culture that values research over teaching. Science teaching is based on a system of self-selection where they perceive that they move away from lecture-based teaching when the number of students in their classes get smaller, which is usually when students are enrolled in upper-division science. By this time, the non-science majors have been eliminated and those who can learn by the more traditional method have been selected. Science has enjoyed a superior and more prestigious position in the hierarchy of knowledges (or disciplines). Rewards at the university, those dealing with tenure and promotion of professors, are based on research and publication and not on teaching (Hinton, 1997; Jennings, 1997; Pape & Tittle, 1998; Seymour & Hewitt, 1996; Tobias, 1992a, 1992b). These two aspects of higher education, coupled with the fact that most
professors never receive pedagogical or learning theory during their formal training, make for an interesting mix of circumstances that can spell out an outcome of science illiteracy for most Americans.

The current NSF-sponsored collaboratives are adding to the body of knowledge that will further understanding of teacher candidates and faculty. Seymour and Hewitt (1997) reviewed much research up until the initiation of the CETP collaboratives. They found that research had not focused on professors. Their study was also particularly interesting since it was a qualitative study that looked at the schooling process from the students’ perspective. My study adds to this by looking at the process from the perspectives of the professors.

Fedock et al. (1996) conducted a literature review that revealed no research about what happens to science professors as they interact with teachers. They feel that “knowledge of this process is crucial if those interested in improving science education expect to effectively involve science professors in teacher education on a consistent, long-term basis” (p. 8).

McGinnis and Watanabe (1996) studied math and science faculty in order to paint a picture of the discourse landscape that higher education teachers inhabit in reference to their thinking. They did this in order to understand the teaching faculty’s beliefs and actions in designing and implementing undergraduate teacher preparation science classes. These researchers examined the dialogue between science content specialists and science methods specialists. They found that faculty transformations are affected by differing beliefs, which ultimately impact the collaboration between the disciplines. I found evidence of this in my research. Science professors do not
hold other disciplines in the same hierarchical regard as their own. This seems to be one of the components of their belief system that needs to be better understood in order to remove this obvious constraint from the reform process.

Studies of professors' belief systems seem to be rare while studies of students, pre-service teachers, teaching assistants, and in-service teachers are more abundant. Watanabe et al. (1997) conducted research on teachers and instructors participating in the Maryland Collaborative for Teacher Preparation (MCTP). They found that teachers who teach other teachers have a profound indoctrinating effect (see also Brooks & Brooks, 1993; McGinnis & Watanabe, 1996). How can university content specialists model good instruction in light of this? They found that the instructors accepted the idea of modeling good instruction and this experience actually impacted their teaching in general. My research captures the belief systems of reform-oriented professors as they enter these new teaching experiences. It is important to understand their belief systems because they must transform their pedagogical stance that has long been in place while they are trying new practices. What are these belief systems based on? In the Watanabe et al. (1997) study, some professors taught the science class with intentions of teaching college students while others taught the college students as if they were teaching students in the middle grades. This was also observed in this study.

McClurg (1991) reported on an NSF funded initiative that identified an important perspective that must be assimilated into our collective thinking about the issues and problems that the current reform movement is attempting to address. She calls for a more cohesive model of science education to replace the existing adhesive
one. Pre-service elementary teachers presently enroll in approximately nine hours of science in a haphazard way during the first two years of college and in one science methods class during their final two years of college. They are then placed in student teaching with teachers who do not teach science well if at all. The belief system that drives the current practice of teacher educators must be challenged so as to uncover the mental models that sustain it. This is at the heart of future research. As the picture of reform issues becomes less blurred, more cohesive programs for our future teachers can be better planned.

The Montana Systemic Teacher Excellence Preparation (STEP) was started in the first year that NSF funded these collaboratives (Thoresen, 1998). She identified fifty-two course that were either revised or created because of the initiative. It is important to look at the more mature initiatives to draw from their insights as well as their shortcomings. I feel that the CETP initiative studied here lacked resources and collaborative support. STEP was developed from a broader base of participants. It included teams composed of faculty, graduate teaching assistants, and K-12 teachers who met regularly to create and redesign courses. They embraced a view of assessment that was closely tied to learning. The initiative at this university had quite a range of perspectives on assessment. Participation in this process may affect the other courses that the participating professors teach. Questions that emerged in the STEP program are beginning to be answered by studies like the present one: What faculty beliefs about learning are changed? Are faculty designing and carrying out classroom and program assessment themselves? Is the formal reward system changing in response to a shift in campus orientation to support quality teaching?
What is the nature of communication among the faculty, departments, and colleges about course reform?

Bruckerhoff and Bruckerhoff (1996) found shortcomings in reform initiatives. One of particular interest identifies a powerful component of belief systems that is addressed in this report.

A common mistake was the belief held by ordinary college faculty that what they do is above (in hierarchy of occupational status, knowledge, and methodology) and not mutually dependent upon the collaboration, knowledge base, curriculum, and instructional methods of their colleagues and their K-12 counterparts. This false and self-serving belief contributed to a number of easily recognizable negative results … some college faculty (including teacher education faculty) proposed projects that ... followed the “from-the-university-to-the-school” paradigm. There was not even the spirit of collaboration, much less the practice. (p. 20)

The Educational Development Center (1995) of the NSF produced a review of Educational Reform Initiatives. Of the twenty initiatives, only two specifically identified university level involvement. The majority were aimed at the K-12 level of education. The current study found that science professors have not generally desired to write educational type grants because of the prestige involved in advancing discipline specific knowledge. It is important to note that the reward system in place at the university, the cultural expectations of professors, and science/industry grants provide a summer salary.

The research that I have reviewed provides a basis for emergent research. This research serves to address some of those elusive issues found in the current literature while also forging new ground toward understanding of the mental models of key participants in science education reform.
Definition of Terms

**CETP course.** The CETP course is the course in which this study took place. It will be referred to as the reformed course, the Natural Science course, or Arts and Science 121 throughout the narratives. They are one in the same.

**Dynamical knowledge.** Dynamical or perceptual knowledge results from the construction of our own meanings. It is perceptual in the sense that it is what a person actually believes and perceives at the moment of action. It derives its power from deep meanings and intrinsic motivation (Caine & Caine, 1997a).

**Espoused theories.** Espoused theories are formal explanations given for actions that frame what one does in a more sophisticated light (Caine & Caine, 1997b). Espoused theories may not necessarily reflect mental models. “Although people do not [always] behave congruently with their espoused theories [what we say], they do behave congruently with their theories-in-use [their mental models]” (Argyris, in Senge, 1990, p. 175).

**Locale memory.** O'Keefe and Nadel define this as memory for locations and interconnected events that operates in a rich physical context (as cited in Caine & Caine, 1994). It is also called the spatial memory.

**Mental model.** Mental models are deeply ingrained assumptions, generalizations, or even pictures or images that influence understanding of the world and how action is consequently undertaken. There is often not a conscious awareness of mental models or the effects they have on behavior (Senge, 1990).
**Surface knowledge.** Surface knowledge is the product of rote learning. It does not matter whether the learner understands the content (Caine & Caine, 1997a).

**Taxon memory.** O'Keefe and Nadel (1978) link this type of memory with extrinsic motivation such as reward and punishment and “memorization” of disconnected or isolated facts (as cited in Caine & Caine, 1994). It is quite resistant to change and is not initially meaningful.

**Technical/scholastic knowledge.** Howard Gardner (1991) alternately refers to scholastic or conventional understanding. It consists of ideas, principles, and procedures that are traditionally regarded as the core content of any subject or discipline. Scholastic knowledge lacks a quality that makes it available for solving real problems or for dealing with complex situations (Caine & Caine, 1997a).
CHAPTER 2
PROCEDURES OF DATA GATHERING AND THE
PROCESS OF ANALYSIS

Conceptualization of the Study

The reformed Arts and Science 121 course was taught for the first time during the fall of 1998 (see Appendix A). It was unique in that six professors from four different departments collaborated to develop and teach it using an integrated thematic approach. I was a part-time science methods instructor and was invited in October 1997 to attend a planning meeting for the development of the course. There was no full-time science education professor working in the department at the time. I became involved in subsequent meetings as a representative from the education department. It was during these meetings that I decided to use this as a study for my dissertation.

All six professors agreed to participate in my study so there was no issue of population sample. I set up an initial meeting with each professor in order to describe the nature of my study. I gathered pertinent contact information, presented them with a survey of thirteen questions, asked them to consider potential interview dates, and set up a follow-up meeting (refer to Appendix B). At the next meeting we negotiated three interview times and dates. I shared the informed consent form along with the three interview questions (see Appendix C). We agreed that these would be signed and a copy given to each participant at the first interview meeting.
Procedure 1: Survey/Questionnaire

A survey of thirteen questions (see Appendix D) was given to each professor. Each was asked to provide narrative responses. Written or word-processed responses were either handed to me during the first interview or emailed to me at a later date. The questions were based on the six indicators described in chapter one. These indicators served to elicit responses that would place professors along a continuum of perceptual orientations (see Appendix E) and instructional approaches also developed by Caine and Caine (1997a, 1997b).

Survey questions.

1. When you are teaching, what decisions about what you actually do in your classroom do you believe others govern and what decisions do you feel free to make yourself? Please list.

2. Where do your ideas for how you teach come from?

3. How do you organize your ideas for teaching? How do time parameters influence your planning?

4. How do you deal with diversity of students within your classroom?

5. Describe any differences that you see between an activity and an experience.

6. What are your sources for the curriculum you use to develop a course that you teach?

7. What does “order” in your class mean? How do you maintain order? How important is this for you?
8. What is your approach to grading and evaluation? Please be specific.

9. How do you accommodate student interests and needs? Please give examples.

10. In what ways do you create a challenging curriculum?

11. Teaching linked to real-life experiences can have an open-ended quality because there is no one correct answer. How can teachers teach this way without feeling a loss of control over students and what they need to learn?

12. What assumptions do you bring to your science class about non-science majors?

13. What are your beliefs about abilities of students going into elementary education?

Procedure 2: Interviews

I used Seidman’s (1998) in-depth interviewing technique. This required that I conduct three 90-minute tape-recorded interviews with each instructor. Each interview was guided by one main question.

The first interview question, “How did you come to be a science educator in the context of reform?” allowed the participant to reconstruct his/her experiences that lead towards the teaching of science in context of reform.

The second question, “What do you actually do as a science educator?” provided the professor with the opportunity to reconstruct details of his/her present experience in terms of teaching science. This question elicited information on the
teacher’s relationships with students, colleagues, and others in the school as well as provided insight into perceptions of science educational reform.

The final question was, "Given what you have said in the first two interviews, how do you understand your position now and where do you see yourself heading in terms of science education reform?" This phase of the research provided a better understanding of each participant’s experiences that have lead to their present concept of teaching science. It also aided in the identification of their espoused theories of teaching science. These findings provided a comparison with their theories-in-use that were seen in the classroom observations.

Each interview was transcribed. I called these the "Final Transcripts." My comments were cut from the transcripts and a version containing only the participant’s comments was crafted. These transcripts were given to each participant and they were asked to provide clarifications and corrections for terms and phrases that were possibly not transcribed accurately (e.g., spelling of reference to locations, people and organizations where they used only the acronym, and areas where the audio quality made it difficult to transcribe). I wanted them to see the data from which I would construct their profile. The revised transcripts were then reread while listening to the taped interview in order to make them as clear and close to what was actually said as allowed by the technology. I called these "Profile 1." Each transcript was reduced from approximately 200,000 characters (including spaces) to about 40,000 characters in the final profile. The profiles were created in the words of the participants, but there were occasions where I made the judgment to delete language in order to enhance the coherency of the spoken language when translated into the
written form (e.g., um, ah, I think, you know etc.,) were removed unless they seemed to be intentionally stated. The final profiles were named “Profile 3.”

Profile 1 from each participant was used to code the passages and develop themes that would inform the research project. Although the indicators mentioned above provided a beginning basis for coding, I was open to coding emergent issues or themes. I felt that using the indicators in both methods would be helpful in the comparison and analysis between the three methods of data collection since these were essential to the identification of each professor’s perceptual orientation and instructional approach.

Each participant’s Profile 3 appears in the results of this study. These are subject to interpretation by readers because of the unique life experiences that have lead each reader to this point in time.

**Procedure 3: Classroom Observation**

A third component of this research involved approximately 47 classroom observations of the Arts and Science 121 course. I observed the class on Mondays, Wednesdays, and Fridays from 1:30-3:20 P.M. Informal observations and interviews with participant instructors and students were conducted during this phase of the research. This research component yielded information that helped build an understanding of instructors’ theories-in-use (mental models) dealing with reformed science teaching.

The course began with a module on the scientific method presented by a professor with electrical engineering as her area of expertise. An astronomy module, two chemistry modules and two biology modules followed this.
I observed the professors’ behavior in the classroom so that I might compare this to what they had said in the surveys and interviews. I was looking for (in)congruence between their espoused theories and their mental models that drive their behavior. As the course began, I looked at the classroom, the students, and the professors. I observed professors’ methods of presentation, interaction with students, discussion and questioning techniques, and their methods of assessment. I looked for evidence of integration between the disciplines as well as for connections to the theme. Individual and group dynamics kept my interest as I recorded content, espoused assumptions, non-verbal communication, and student self-grouping. I used indicators as provided by Caine and Caine (1997a) that might help identify where each professor might be located on the continuum of perceptual orientations. I was open for additional indicators or issues that might emerge as the course progressed.

Data Analysis Process

Throughout the entire research and analysis I attempted to stay close to the research participants’ feelings, thoughts and actions as they related to the focus of this inquiry; to understand the phenomenon under investigation (see Creswell, 1998; Seidman, 1998). This allowed me to develop propositional statements derived inductively from a rigorous and systematic analysis of the data. A defining characteristic of qualitative research is an inductive approach to data analysis. What becomes important to analyze emerges from the data itself, out of a process of inductive reasoning (Maykut & Morehouse, 1994). I used the constant comparative method (see Appendix F) developed by Glaser and Strauss (as cited in Bogdan & Biklin, 1992; Lincoln & Guba, 1985; Maykut & Morehouse, 1994).
The first step was to code the data from the transcripts so that all excerpts could later be traced to their original source. I "unitized" the data according to Lincoln and Guba (1985). The transcripts were combed for meaningful words and action of the participants. These smaller units served as the basis for defining larger categories of meaning. Each unit had to be able to stand-alone and be understandable in terms of my focus of inquiry; belief systems of professors involved in science education reform.

Some units of meaning were lengthy, which is inherent in studies where participants are telling life stories (Maykut & Morehouse, 1994). The initial six indicators presented above were used to code the units for meanings pertinent to what ultimately emerged as components of the professors' belief systems. Two of these a priori indicators did not develop into identifiable categories while several others emerged in the process.

The next phase, which actually was occurring simultaneously throughout the unitizing phase, was a process of discovering categories within which all unitized data could be placed. These data either identified some important words, phrases or topics that migrated towards one of the existing categories (or indicators) or formed new ones. I thought of these categories initially as the themes, which were to elude me until the later stages of the analysis. The constant comparative method of analyzing qualitative data combines inductive category coding with a simultaneous comparison of the units of meaning. Each unit was compared to all others and was subsequently grouped. Lincoln and Guba (1985) provide a useful description of the categorizing and coding process:
The essential tasks of categorizing are to bring together into provisional categories those cards [unitized data] that apparently relate to the same content; to devise rules that describe category properties and that can, ultimately, be used to justify the inclusion of each card that remains assigned to the category as well as to provide a basis for later tests of replicability; and to render the category internally consistent. (p. 347)

Some units obviously fit into more than one category making this aspect of analysis more difficult. Ultimately, some were used in more than one category while others were selected to better fit into one.

The "rules for inclusion" of data into categories revealed the components in which all data ultimately fit. These came to be known as the components of a belief system, which were based on the focus of this inquiry. These espoused belief system components were taken from the interview transcripts and survey narrative responses. They were later compared to what was actually observed in the field. From these components and the professors' respective philosophical relationships to them, I was able to discern themes regarding the efficacy of the reform initiative. Themes that emerged were trends along the lines of their perceptual orientations. Instructional approaches are derived from these perceptual orientations. Although I used the PO1, PO2 and PO3 as categories, not one professor could be placed into one exclusively when looking at all the components of their belief system. The contradictions found between their espoused beliefs and their actual perception makes it even more difficult for placement into any one category. The categories can help practitioners identify their location on a continuum with regard to important belief system components and facilitate the transformation process through reflective practice.

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Caine and Caine (1997a) identified PO3 as one that aligns itself with the present notion of reform. It is from PO3 that IA3 develops. Teachers of this orientation are associated with following attributes:

(a) An inner appreciation of interconnectedness;

(b) A strong identity and sense of being;

(c) A sufficiently large vision and imagination to see how specifics relate to each other;

(d) The capacity to flow and deal with paradox and uncertainty; and

(e) A capacity to build community and live in relationship with others (pp. 21-22).

Even though this is one study with a particular theoretical foundation, it can help others to understand the educational terrain of reform and thereby sustain the transformational process.

**Trustworthiness**

The phenomenon, as it has been presented in this study, is a narrative based on what I heard, saw and came to understand through this experience. I addressed the issue of trustworthiness in four ways described by Lincoln and Guba (1985) and supported by Maykut and Morehouse (1994).

**Multiple methods of data collection.** It was through a convergence of patterns between data from interviews, questionnaires and observations that the belief system and behaviors from these professors have come to meaningfulness.

**Building an audit trail.** I have established a permanent audit trail according to current literature in order to maintain trustworthiness (Bogdan & Biklin, 1992;
Lincoln & Guba, 1985; Maykut & Morehouse, 1994). Anyone who would care to review the volumes of coded pages, reports and field notes would likely come to see many of the same patterns that are presented here. It is inherent in qualitative research that the researcher brings a set of beliefs and experiences that influence the attitude and processing of the data used to establish the outcomes. The data can support more than one perspective, but from a broader view, this would add more meaning to the study rather than detract from it. I welcome others to partake.

**Working with a research team.** I did not have a research team per se. I was in contact with members of my committee that had expertise in what I shared with them all along. The dissertation defense also served as a team review process, just not in the way the literature defines the research team. I had a graduate student review all coded materials and she helped in theme development along with the analysis. This is a limitation of the dissertation process and an area that might be looked into if qualitative research is to remain as a viable alternative to the quantitative paradigm. From this perspective, it was a lonely journey, but one worthwhile in establishing a meaningful path to future research along the qualitative line of inquiry for me as a researcher.

**Member checks.** Each participant professor was provided with a complete Profile 1 from which his or her public profile and belief system components would eventually be crafted. They were asked to read the entire transcript of the three interviews and were allowed to clarify, add or delete material. All but one professor complied with the request. The final dissertation is open for review and any feedback I receive will affect any “spin-off” publications that may ensue. I challenge the
professors to read the dissertation in its entirety in order for them to get a global view of what I did as well as for them to use it in their reflective process on the journey toward transformation.
CHAPTER 3
OUTCOMES: PERPSECTIVES FROM THE FIELD

Profiles

This research is aligned with and informed by the naturalistic paradigm as a means of maintaining focus on the lived human experience (see Lincoln & Guba, 1985). It cannot be reduced numerically nor analyzed statistically. Participants became vulnerable and acted in an unselfish way to allow my participation in and observation of their lives.

Although the profiles speak in the participants’ own words, the readers of this work are reminded that they were generated by reducing the content of the total transcript by approximately two-thirds. Deciding what to leave out was a somber task for it had the potential to allow for bias and miscommunication. I had the central aim to select those passages that could come together and reveal a story as it related to participation in the reform effort. This was the object of my research. It is important to also keep in mind that interviews are indeed communication events that are contextualized and are informative in and of themselves (see Hurd, 1997).

The intention of the interviews was to come to understand the professors’ experience from their point of view. We can begin to uncover how their individual experiences interact with powerful social and organizational forces inherent in the shared university context. The interrelatedness must be understood if meaningful transformation is to occur. These stories shed light on the power that pervades the
daily interactions within the educational context, particularly in the arena of science education reform.

In the spirit of being faithful to the words of the participants, it was with much attention, perhaps even a degree of trepidation, that I added or removed any wording in order to clarify or minimize the effect of characteristics of oral speech on the written word. I eliminated “unessential” terms such as “uhm, ah” and “you know.” Ellipses indicate material from a sentence or between passages has been omitted. Any words that I added to improve clarity are placed within brackets. I expended great effort to keep the profiles consistent with the sequence of the three interviews. On occasion, when a particular topic resurfaced, passages were transposed in order to keep the reader from becoming lost during transitions that are common during oral dialogue.

The following profiles provide an opportunity to come to know each participant as a science educator in the context of reform.

**Adrienne.**

I knew I wanted to be an educator from middle school on. I don’t remember doing any science in elementary school.... My first taste of what I thought was real science was in junior high. It really became exciting for me in eighth grade. They opened a new school, which was about a block away from my house, so I watched them build the school. Before it opened, I wandered through the school and met some of the teachers and I met my eighth grade science teacher. He was an amazing man. He asked me to help him with the bulletin boards and we put up neon colored stuff with black and pink and bright yellow and things that would really catch the eye when you walked into the room. His hypothesis at the beginning of the semester and the year was that there were gremlins. Those gremlins were what made things work, and they were the ones who were pushing and pulling against things and causing things to go and the made the whole universe work. I was intrigued with his idea. I knew it wasn’t right, unless we want to call gravity gremlins or electromagnetic fields gremlins. But his ideas intrigued me...
because I didn’t know how to prove him wrong, and I found every science class after that to be extremely exciting....

When I went to high school I would come back and work with my geometry teacher, and help prepare the algebra stuff for classes and when I went away to college I’d come back and I was a substitute teacher whenever they would have me. I also got a job with the Board of Education one summer, helping to put together some of their science programs. So, I guess my involvement with my teachers was critical. It made me feel like I was a part of what was going on and it gave me a little bit more of an insight as to what’s involved in the learning process. I thoroughly enjoyed teaching and working with the students, helping them understand things and trying to come up with things that would help them relate to their math. One of the big problems was when I would go out to do some tutoring.... Part of the reason they were having trouble with their math is because they didn’t like it and it wasn’t interesting....

One example was a student who wanted to work with cars. He saw no reason why he needed to know any of the math. I think we were working on fractions and so I got to talking with him [and got him to] think about the quarts [of oil] that go into the car. Sometimes you don’t use a full quart, sometimes you do use a full a quart, and sometimes you have to use more than that. The nuts and bolts were not whole sizes ... they were actually fractions.... He seemed to enjoy our sessions together and then I was told to stop tutoring him....

When my junior high school first opened there was a fellow there who was in charge of the science department. His name was Dr. Johns. He was the first doctor I had ever seen who was not a medical doctor. I was impressed with that and so I decided that science was so wonderful that I knew I was going to teach. I actually wanted to teach in the middle schools. In order to teach I [felt I] needed to prove to myself that I know the material well. So I decided a Ph.D. was what I wanted to get and I set off to get my Ph.D. That meant getting my bachelors first. I wanted it in physics or math and I wasn’t quite sure which I wanted, so I did both. While I was there, since I knew I wanted to do education, I went ahead and got my teacher’s certification at the same time. The philosophy of my college was to get your degree in your science area and the certification is the minor as opposed to education being a major and you take a bunch of other little classes.... They were basically high school teachers.... I don’t think we had the program to really prepare for elementary school teachers.

Once I finished my bachelors degree, I decided I wanted to go ahead and get the doctorate. I’m a theoretician at heart.... I’d rather sit and contemplate things, do proofs, and try to figure things out and do puzzles, anything that’s brainwork. I don’t really like the hands-on stuff myself but I know that’s the way you reach most people.... I knew I was getting more and more into theoretical stuff, and I said, “Well, if I really want to be a teacher, I just can’t go off and do theory unless I’m going to sit in the corner and just be
by myself. If I want to teach, I need to know applications and how things work," so I decided to do electrical engineering because that was more applied than the physics was.

I came here to ... where they gave me a teaching assistantship and I started to pursue electrical engineering. I learned that having a Ph.D. doesn't mean that you know everything in your subject. It meant that you knew a lot about one little teeny tiny thing in the whole world of all many possibilities. I didn't realize that as you get more advanced degrees you keep narrowing down your area of expertise until you know a lot about very little. .. [Sigh] So many delusions.

I've taught a very wide range of students.... [lecture] is one of the easiest ways to "teach" something. I would like that teach to be in quotes because I'm not always convinced that teaches anything. All a lecture does is explain some of the theory. It might as well just be on TV or any of those videotaped things, because there's no interaction. Not all [students] learn that way ... I find that I can lecture on something and then have a student come and ask me questions that show that he or she obviously did not understand what I did in class. There was no connection. I like the idea of getting away from lecture. I'm not quite sure exactly how to do it when class sizes are thirty to a hundred students in size. I'm not satisfied with the way the teaching is going at the university. I don't think it's as good as it could be. Just because you have a Ph.D. in a particular area does not make you a teacher. I think it's so funny that we hire Ph.D.'s and insist on people being Ph.D.'s and being experts in their field without really testing them to see if they can teach. We hire them for their research capabilities. We don't hire them for their teaching abilities. The [professor] candidates give a talk on their specialty which, of course, they should know. I think we ought to give them an exercise on how they would explain something they're going to have to teach. I think we're going to have to have some reform at the university.

Our department had a workshop on teaching strategies, on how to work in the classroom, how to teach better, how to work with the students, how to have the students actually work problems in class... besides just sit there and listen. I think our department is beginning to make an effort in that area and I have to admit I'm not perfect either. It's still easier just to stand up there and give a lecture than it is to try to involve the students. This spring semester I tried to have them do little projects in class and the fifty minutes was not long enough to really get in to any of the little projects I wanted them to do. Just about the time they start getting to the point where they can do something, ah, time's up and they have to go. So we've got this thing called time constraint and it does present a little bit of a problem....

Elementary school teachers are some of the busiest people I've ever met in my life.... They have to be able to do everything. I think some of them are overwhelmed with what they already have to do.... The mid-school teachers and the high school teachers, once that bell rings, I can't get hold of them. They're not very open to getting to know me. The elementary school
teachers are a bit more open because they've got smaller classes.... It doesn't completely rest on the teachers' shoulders, so I was willing to help out there and I found out that some of the teachers don't necessarily do science and I'm not quite sure why. If they did do science, they didn't do very much and they certainly didn't do very many experiments. I got to the point where every year I'd publish a little blurb that I hand out to the teachers at the elementary school that said, "I'd be more than happy to help you put together science experiments. I'd be happy to sit down with you and show you how science can fit into your curriculum so you can integrate it into the whole year." Not one teacher has asked me to do that ... so I started having students come in during lunch. We'd sit there and we would do science.... We called ourselves science interns.... My motivation for getting involved there is because I love science and I want to share what I know and I've got something. That's one talent I have....

An outsider's perception is that college professors have it really easy and they're lazy. "They just teach two or three classes and then that's it." I've got a total of one hundred students to keep track of. Then I've got the grading and the homework and all those things to do.... My office is always busy during office hours, it's always busy at other times and so you've got students coming in asking questions, trying to get answers to things. I'm also a freshman advisor and a lot of the people in our department have other duties with graduate student committees, faculty senate, or whatever, and they take their duties very seriously. I'm responsible for labs, working with my student teaching assistant and then there is research which most faculty are expected to do to some level....

Assessment has always been a problem. We get into debates about it in our department and I still don't know what is right.... I try to be very fair with assessment. When I was doing graduate level classes I really got hit hard on this one. I felt that with my graduate students if they could show me they understand the material, I will pass them whether they've done well on the tests or not. My colleagues really didn't like that at all. So now I'm not allowed to teach graduate classes anymore [pause] — that is part of it. They don't think I'm competent to teach graduate students. Since I'm not in a tenured track slot, they've barred me against doing graduate work. I see their position to a point, I mean, I'm not published. That's part of the problem too. That's part of why they don't think I'm competent, because in my research I don't have any main publication. I have tech reports, but I don't have any publications in journals and so I have not been through the peer review process and they don't really think I am qualified to be teaching. It really bothers me, but there's not much I can do about that. I'm trying to continue to work on my research and I'm going to try to get more things published, but it's hard to do when I'm teaching freshmen because they're so time consuming. I'm sort of caught in a no win situation. I have to decide whether or not I really want to go back to the graduate level or not....
I wanted to have the freedom to be able to say, "No, I don’t want to do this because I want to spend time in the schools." I felt it was important to have a presence in the schools ... especially with science because there are some teachers who will not do science at all unless someone else does it for them. There were some teachers [at the elementary school] who were not doing science when I got there and they are doing science now. I have seen some changes. I’ve been over there now since the school opened and the teachers keep saying, "Oh, well she does so much," but I don’t do anything for that teacher in particular.... At the elementary school [my efforts are] certainly [valued] by at least some people....

Tenure and promotion is based on how much research dollars you bring in and how much you publish. There’s starting to be some change there, but it’s slow. Our department head has said he does not want promotion and tenure to be based solely on research. He wants to incorporate the teaching component as well.... I’m freshman advisor so that’s a quarter time. I’m doing two classes each one of those is quarter time. My research is quarter time, it adds up to full time. Well, where’s my community service? I do give a whole day to the elementary school ... leave the university to go work at the schools. The faculty here at the department will be happy to give you a couple hours here or there if you do a special request, but not a regular basis ... because they have other things they have to do....

I admit, when I started out teaching, my biggest fear [was] getting up to teach students [that] were going to ask me something I didn’t know the answer to. I felt I had to know the answers to everything. With years and maturity I’ve learned I don’t have to know the answers to everything.... We can figure it out together as a class, or we can go look it up, or we can find the answer some other way.... I can make them come up with the answer themselves, but that comes with experience. I wasn’t like that my first year teaching. If you perceive a teacher as someone who knows everything, you limit yourself. The teacher is someone who helps others learn....

I’ve been teaching at this university for over twenty years. I started off as a TA when I was working on my degree. I was a TA then an instructor.... Mostly I’ve been teaching here either part time or full time since we came out here. I think that’s why they like me in the freshman position right now because I’ve been through the whole gamut. I know what’s expected at the graduate level.... I’m part of the curriculum committee and one of our charges is to try to update our curriculum and work on that to make it better. I think they thought my experience would be helpful since I know the loopholes.

[When I got involved] with the reformed science class ... it was during either summer or January.... The department of engineering, in collaboration with a few of the other colleges on campus put together a colloquium. It was not just for trying to get grants ... It tried to get other types of monies, other types of solicitations for work that we wanted to do. I went and participated in that and while I was there I sat with [a colleague from the university’s biology department] and she’s a parent at the elementary [school where I
volunteer]. We were talking about some of the stuff we were doing [there] and she told me about the science class that she was working on developing [at the university]. This science class was being developed with several different faculties and different departments working on it ... I think it's so needed because the teachers at [the elementary school], from my observation anyway, are reluctant to do some of the science. I think they were afraid of it or just couldn't fit it in to what they were doing. I thought it would make a whole lot more sense, especially for elementary school teachers, to have a course that would incorporate the different sciences and show how they went together. They could apply what they learned in [this reformed science course] directly into what they were going to do in the elementary school classroom. I told her that if she needed any input or information I would be more than happy to supply that for them because I would really like to see some changes done in the way teachers were prepared to do science. I tried on occasion to get students who were preparing to be teachers to come over and work with me in the science intern program, but that never really got very far. Part of it is because students don't get paid to participate with me and I didn't have too much support from [the College of] Education.... I haven't tried since then to contact the education department. So I saw this as a way to start changing the teachers who were coming out to help them maybe enjoy science, to find out that it's not something scary, that they really can understand it ... All they needed to do was follow some certain guidelines and the children could just pretty much take off with it. Perhaps they feel they need to know everything and have all the answers for the students. That's not true in science classes.... I didn't necessarily intend on teaching any part of it, but I did want to be there to hear what they were going to do and to give input if I thought they were going the wrong way. I was very pleased when I got to go to a meeting with [the collaborative professors].... It was really interesting to hear some of their ideas and to see where they were going with it....

My students in engineering won't study unless there's a test to study for. In general, freshmen coming in tend to not work unless you make them work. With upperclassmen, it sort of varies. There were some students in my engineering classes who took the attitude, "Well if you don't assign it I'll do it anyway because I know I need to learn the stuff and so I'm gonna go ahead and learn it." Those are what I call good serious students. Then you've got other students who maybe really aren't quite so serious yet.... I know that if I don't assign stuff for them to do to turn in so I have it to count, they won't. Maybe I don't motivate them enough, but they just aren't interested in what we're doing as much. I try to make classes more interesting and yet I still notice that on a given day a third of students will be absent. It's frustrating.... It doesn't bother me not to have tests and I'm sure it doesn't bother students. Then there's the question of how much they really learned. If they're a serious student, they'll learn a lot from it. If they're not a serious student, they probably won't take a lot with them.
I'm not convinced tests give an accurate view of what the student knows. I think homework gives them much more of a chance to delve into things.... The only problem with that is cheating. I don't know whether students are working on their own or working as a group and sharing the information... whether the student is just copying the information from someone else. Now, if they were all little Pinocchios... I'd have no problem with assigning any type of work I like.... I would change what I did [in the reformed science course]. I liked the way I started it [with the scientific method] and I liked the way we went into it. I liked the way we gave experiments for it, but they really missed one big section of it. That was the research part of the scientific method. I think most of them came away with the idea that what we did in class was research. We didn't do any research in class because we didn't have any materials to go out and look and see what had been done previously, and so they got a false idea of what was meant by research; searching the literature, that kind of research, as opposed to experimentation....

There are some students who, I don't care what you do, they're not going to learn anything sitting here and being lectured at.... They need to be able to perceive it, to visualize it, especially getting in with their hands and actually experience it by actually doing it, putting it together or actually seeing it work. Engineers tend not to be that way, but there are other learners who are that way.... Those who are not fail out the first year and therefore never proceed further and hence all the engineers are that way. Or is it really that only certain people who think that way are going into engineering in the first place?...

[The elementary where I help out] has a very high Hispanic-kind of an interesting mix [of students]. I hate to say that the boys tend to prefer the kind of cut-em-up part and the girls prefer not to. That's an over-generalization. That's not always true. We have some girls who do dissecting too, but the tendency is that the girls are squeamish and tend not to do the actual touching. I don't see very many girls at all [in engineering].... I don't necessarily see much difference in the grades between women and men in the class.... There are about 50 people in both classes. Maybe ten of the students are women....

I hate to pick on middle school, poor middle school, but I know when my daughter went there, she was interested in science. When she left she hated science. My son went to middle school. His first few weeks there, he didn't like the science class he was in. All he was doing was watching videos. He found nothing more boring to do. He wanted something more hands on, where he actually does things. We got him changed to another science class and he's enjoying it a little bit more. But, they still haven't done that much hands-on type science. There's still a lot of reading and filling in blanks, writing, mainly ditto sheets, that kind of stuff. At least it's a little more science oriented, you have to think a little bit better. There's a great fear in me that his love of science is going to be destroyed in middle school just like
my daughter’s was. When I see the kids come out of middle school they are not into science anymore....

When the students came in [at the elementary school] to look at the different experiments, they immediately started playing with everything. My first reaction is, “Oh no, don’t play with the stuff! Do the experiment.” I got to thinking about it and thought that maybe they need to play with it first and then they can do the experiments and try to find out [about the] why [of] what they’re doing. I really had to stop there and say, “Wait a minute. What’s important? They’re not really damaging anything yet.” It makes me nervous when they start playing with magnets because I know when they start dropping them, they start losing their magnetism. I don’t want them dropping them.... It’s probably just important for them just to play with the stuff. They are not wanting to listen to what the experiments are [about] right now.... Maybe after they’ve had some fun I can slip in and show them what some of the things are supposed to do.... That took an awful lot of discipline on my part to not flare off and start getting angry with them for not doing what I wanted them to do....

I have had debates with teacher friends of mine and we start discussing curriculum. She believes that if the kids are interested in knowing this stuff that she teaches, that’s what they work on. That’s what they do whether or not it’s in the curriculum for that grade or not [at the elementary level]. I don’t think you could get away with that [at the university].... I think it is important for everybody to have enough education so that they can read, and think, make up their own mind, make their own decisions independently of others so that they don’t have to be brainwashed by something somebody else tells them. They need to have enough math that they can handle anything they need to do mathematically in their lives. They need enough science so that they understand what laws are being made now or the controversies that are going on now about assisted death or about abortions or nuclear generators for energy.... It can also be used to help someone learn information so that they could go on and work in a particular field that they’re interested in. My first definition is basically for public education and that everything else would be basically a private education that you could go on and do yourself, whether it was in college or trade school or other specialties....

There’s the American Society for Engineering Education, which I really should belong to. I just haven’t done it. Of course, it costs money to join. All societies do. I do belong to the IEEE, the Institute of Electrical and Electronic Engineers. I belong to my specialty area in which is the communications group. I really haven’t made any conferences from there, but I do go to the International Telemetering Conference. I’ve been to three of those. I went to a computer systems and control conference once also. I’ve been to a few conferences, but not perhaps as many as I should. The main reason being is that they usually hold their conferences during the semester and I’m reluctant to take time off from teaching to go to conferences unless I’ve got a very good reason to go. That usually means giving a paper or some such thing. Now at
the ASEE, I had no research that sponsors me or would sponsor me there. At least I don’t yet. Maybe I will in the future. I do have research sponsoring and stuff that takes me to the International Telemetering Conference.…

There’s supposed to be faculty meetings. I think they’re supposed to be like at least once a month. Unfortunately they’re at a time when I haven’t been able to come. I don’t ever go to the faculty meetings which is a definite negative because I know I need to be there, especially now that I’m doing all this stuff with curriculum. It’s important that I be there. But, it’s supposed to be … Tuesdays at four o’clock. Unfortunately, that’s when my daughter has her stuff so I’m having to run her around. The one plus is that my husband is in this department too so he’s supposed to bring me feedback from the meetings … not quite the same as if I was there. We also have an informal get together on Thursdays where the faculty, whoever wants to, goes and we’ll go out and have lunch together. Sometimes I’ll ask our people for advice about different things. If a question comes up, I know I can email anybody I want to or call them up on the phone or stop by at their office and visit them. Because it’s usually that I have so many people in my office throughout the day that I don’t have time to go around and visit the different faculty. But every now and then some will drop in right here.

I keep going back to elementary school and one of the things that just fascinates me is the relearning concept of the student as teacher. I see how the teacher does it in elementary school, but she’s got a whole day. I want to see how I can do it with my fifty minutes because the way her philosophy is. Each student’s an individual. You teach that student as an individual and you encourage them individually so that you’re not teaching to the middle, you’re teaching to all of them and giving them all the appropriate things to work on. I think that’s one of the best ways to do it. I just want to see how on Earth I can do it with my class of fifty students when I see them for only fifty minutes a day, three times a week…. That and assessment are the two things right now that are causing me the most grief.…

Instead of having fifty to a hundred students in a class, if we had more of a block type thing where you met with smaller groups of students, ten or twenty at a time. You could go maybe even teach the lab in a place for lecture as well as having the lab set up where we could actually do some lecture and incorporate a lab into the lecture that way. That would certainly be time intensive. Getting faculty to buy off on that, spending much more of their time teaching would be less time for research because if you broke the classes down into tens or twenties out of a hundred you’re talking five to ten more classes instead of one class. You’d have to have a faculty member doing all that, so realistically I don’t think that’s going to happen … then you could actually do it right.…

I think this natural science class that we’ve worked on is an interesting way to help them see the different connections between the sciences. I think that’s important. Ideally, what I would love to do is take teachers in. I’d love to have them be a part of my program teaching science to the kids. [I would]
have them come over and let me teach them like I teach the fourth and fifth graders.... They can see what happens and ask me questions and we’ll do it just like we were science interns. I think they could learn an awful lot that way and find out that it’s not hard. It’s not scary....

I don’t think [science and engineering professors] think about [learning theory]. None of the professors that I know ... except for maybe my husband and myself have had any education courses at all, courses dealing with learning or psychology or any of that. I don’t know that there is any thought that goes into professors’ thinking, “Well, how do these students learn best?” I think they just work from what they’ve been through, what they enjoyed learning from or what they thought was a good way of learning for them and that’s what they apply in the classroom. I think we definitely need to look at that [as part of reform]. I think professors think that they don’t need to be concerned with how they teach for the most part. We had a department head organize a seminar for us to improve teaching and retention of students.... Only maybe ten of our faculty showed up for the first meeting and somewhere between six and eight finished [out of forty or fifty faculty]. I don’t know what to think. I know that when I sit down and talk to faculty members individually they do care about students, about learning and teaching.... I don’t know that they necessarily think, “Well, this method is better than this particular method.” They don’t think that way. They’re all basically lecture-based people because that’s how they learned. Of course, I do that too. All of my college and graduate classes were lectures. That’s what easiest for me, but I’m not convinced that’s always best. Whether there is a real difference in the way they [college and elementary students] learn, I don’t know. I think if something is meaningful to someone, they can learn it sitting in a lecture or they can learn it doing the hands on stuff if that’s what interests them, if they have the motivation. Most of the students in our department are motivated because they want to graduate and get good paying jobs. I think they’re motivated then to learn information not necessarily because they’re enjoying it, but because they see, “In about four or five years I’m going to get myself a job and I need to be able to do well in my job interviews. So, I need to learn what I need to know to get to that point.” It’s different motivation....

I’m digging through a lot of different things, but I don’t’ know that I necessarily will make too many changes. [That is] partially because the system’s big and I am tied in to time. In fact, I can only do so much in fifty minutes of class. That reformed class managed to have a very strange time. It’s like two hours.... If he [the organizing professor] was able to arrange that, I suppose I could arrange it too if I decided to really work at that. But we have to also work with scheduling and making sure we’ve got space. The way you make reforms, in my own teaching here in my department, if I want to do what I was just saying, we would have to completely change the way we do our labs. I don’t see that happening because the lab space that we use right now is used for another class and their labs. I still don’t have as much
flexibility as I'd like because I'm still going to have to work around at least the other class.... I could probably sit down and actually look into that more and see if it would actually make a difference. I don't really know where to look to see if doing more hands on will make a difference or not. The students say they enjoy the hands on more, which is why we have the lab. You can do your hands on stuff in the lab and you've got your lecture where you do your talking and if you coordinate those, they can compliment each other.... I don't know if it's a cycle as much as a tradition [to break out of]. I'm not going to say that I can't.... I just have to expend effort and I'm not quite sure how much effort I have to expend.

The reform effort is affecting the supposedly education majors, which is a small part of the campus. It's not affecting their own teaching style in their own department. We're driving away from the research. We're driving away too many students. Too many people are quitting the sciences and going off, even if they're not considering being science educators. The number drops tremendously after freshman year, sophomore year. In college they're not going to be spoon-fed anymore. They're going to have to work. Now that doesn't mean they necessarily were spoon-fed in high school. Sometimes the teacher there gave them most of the answers. I think [that] if the students learn that the teachers don't know all of the answers, then they can start in elementary school.

I think there's definitely that perception [that science is hard].... The more I think the more I don't have the answers. That's the part I find most unsettling about everything because when I start thinking about science and where it's been and where it's going and what it does and what is right or not right. I mean, I can talk to a person one minute and they can convince me 100 percent they're right. I'll walk away from that and come across someone else who has a totally different view and I'll listen to that person and I'll say, "Well, they're right too. It makes sense." Now they both can't be right. Or can they? All I get then is just more questions. Is what I'm doing right? I failed five students in one class... gave a couple of Ds, mostly As and Bs. So, maybe I am doing something right. I mean they seem to be able to do the test I gave them.

Maybe what I'm doing is right for that particular class. Could it be more right? I don't know. I thought it was kind of funny I had only one senior in my class. [I gave] several As, a large number of Bs, one little C, few Ds and some Fs. It's so funny, one little C in the middle, all by itself in the center. What's going on here? It just doesn't make sense to me. It either means that maybe they did understand what I expected them to do. They were able to take my tests and answer my questions. At least the work that they turned in reflected the ideas and concepts that I was trying to test on those particular tests. So most of the people did fine. I guess. Did they learn what I really wanted them to know? I don't know. Can they retain it? I don't know.... I've got more questions now than I did when I started. I don't know that I have any answers. I still have questions about assessment. I'm still not certain whether the tests will show me what I really want to know. What I'd
really like to know is can they take the information, remember it and actually use it. I try to design my tests so that that will tell me that.

I certainly could [ask them to actually construct something], but the question then is, “Are they going to do it themselves?” That’s the hard part. It’s because I can’t trust the students to be completely honest. I feel I have to impose something that I don’t want to impose. Unless I had them do a competition among themselves. Which is possible, but I still don’t know they would work. If there is a weak student there, ideally the weak student would become stronger in working with some other learner. In the non-ideal situation we’re going to have some students sitting back doing nothing and getting credit for it. I need to guarantee that I’m not going to be passing students with As and Bs or whatever grade I will arbitrarily assign. I use that term on purpose because I sometimes think grades are arbitrary. It just wouldn’t feel right knowing someone’s getting by and not knowing it. I feel I’ve got to have some control ... Like I said, if they were all Pinocchios and their nose would grow when they told a lie, then I would feel so much more comfortable without doing lots of other things. I’d say, “Okay I want you to work this homework problem. This is a design problem. I want you to take this and design this. I want you to do it on your own.” Then if I asked each one of them, “Did you do it on your own?” I’d like to be able to believe them. I can’t.

[Assessment methods that could capture what the student learned is] what I want, but I haven’t found satisfactory ways to do that, given the range of students that I have. I do find that they can be very creative about getting around things. [They] look it up somewhere and finding someone else who’s done it as opposed to just doing it themselves. Granted, I would say ninety to ninety-nine percent of the students will do it on their own.

I think the university is going to be the same [in five to ten years] because they’re cast almost in stone and we’re almost immovable.... Now what drives universities? Money and tenure are the two things that will motivate a faculty member. When you have someone in a tenure track position, maybe they need to do some activities in order to improve their teaching. Then you have to get the departments to buy into that. Not all departments want to buy into that because that takes time and money away from them doing research and research brings in money. Educational reform in the sciences at the universities is slow and I think [it is] because of that....

There’s no reason why they couldn’t [involve freshman]. Most of the research involves graduate students.... A freshman really doesn’t have a lot of the skills that our faculty needs in the research. It doesn’t mean you can’t teach’em ... then that takes time too.... They need to be able [to] work in a lab at least semi-independently. Usually they’re hirable by their sophomore year.... The reason I don’t think it will [fly] is because the faculty will then have to work with that student one-on-one to show them what they want done.... You don’t have to spend the time with [graduate students] showing them what to do. So the faculty has more free time when the graduate student
[helps] ... rather than having to be there, like an apprenticeship. We're talking lots of time and one thing I see [is that] our faculty don't have is time....

I have no idea what I'm going to be doing [with reform issues]. I've got research right now that I haven't been able to touch except for four days this whole semester. I don't know how the other guys in the department do it. Once I start teaching, I don't feel I can shut the door on my students and say, "Go away! Leave me alone. I need to do some work." I always feel [that] if they've got questions, I need to try and answer [them]. I basically have an open door and they are welcome to come in and they do....

I [have] contemplated going back and applying with the schools to be a middle school teacher. I do that with the full knowledge or prejudice [that] I don't think they would even hire me. They wouldn't even look at me ... as a possible candidate to teach in middle school. I think I could do a much better job teaching science in the middle school than what they're doing right now. I guess that's prejudiced. I keep going there and offering to help and do things and furnish things. I keep getting turned down. I had heard from one of the teachers over in the middle school [that] they were looking for a middle school teacher and I called over there to offer my services. [They said,] "Oh, we've already hired someone." And they wouldn't even talk to me about it. I don't know that they're really open to wanting to hear what people have to say about what's going on in the schools. I'm not really sure that the universities are open to hear what people have to say. I think everybody's very happy to criticize everybody else, but "Don't criticize me." The university is saying, "Our students can't do math. High schools are failing us. Students come here, they can't do the math. The high schools are doing a lousy job or the math department is doing a lousy job." [They] never say, "What can we do to change this? How can we look to improve this? Are we doing such a good job ourselves?" ...

The university went through a whole evaluation process.... They came up with all these changes that should be made and immediately they got attacked.... It got reduced to almost nothing.... They toned it down so that it all sounds like [this is a] wonderful university and nothing needs to change. I couldn't disagree more. I thought they had really worked hard to come up with something, really some good ideas. They ran around and interviewed all the different departments. They asked for feedback from everybody. Some people just decided not to give input and when the evaluations came out against them, then they of course yell and scream, "We need to have input." They were given a chance to give input and they decided not to.... It would have shaken up a lot of things here on the campus and I think it would have been good. We all would have had a lot of change to go through. But that got squashed. [Sigh] Territories and tenure. Politics, and from what I've heard lately, politics on campuses is a whole lot worse than politics in D. C. and that is bad because at a university, it shouldn't be politics it should be academics. I get very frustrated at the whole system. Can one person make a difference?... I'm not a tenure track faculty member. I don't carry a very big
voice. I will never be a mover and a shaker unless the tenure track faculty listens to me. Who’s going to make them listen to me? Or you? Or anybody else? I don’t have that power. Does the department head have that power? He has the power if the department gives him that power....

Our now acting dean is open to reform, open to change and open to evaluating faculty on more than just research. He’s interested in the teaching component and is interested in assessment and evaluation. As electrical engineers, I don’t know that we necessarily know the best ways to evaluate and assess, yet we need to be able to do that. [The] American Board of Engineering has established ABET 2000, which is what we’re going to be evaluated on in two years. One of their main points is assessment and evaluation. Every single engineering department needs to reflect on what they’re doing and come up with assessment tools. Somehow they have to find out ways to be able to convince ABET that we are achieving our goals. Our goals have to be consistent with what they think our goals should be. Then we have to find ways to show ABET that we are meeting those goals. ABET has really put emphasis on this.... ABET wants faculty to buy into whatever the department is saying it’s supposed to be doing. I find that the faculty will have the tendency to say, “Yes, we agree with this,” and then they don’t do anything. “Yes, we should graduate engineers who can practice engineering.” They are being called on by ABET to actually try to do some thinking of what we’re doing instead of just doing it. They are the ones who are supposed to be doing changes that are going to be occurring. As of [the year] 2001, every engineering department will have to follow the new guidelines if they want to be accredited by ABET....

Trying to get the faculty to move on it is a cumbersome path.... That still doesn’t mean we’re going to change our way of teaching or necessarily re-evaluate our way of teaching. What they’re going to do is try to get assessments from students. I have a feeling that most of the students are going to say, “I learned what I needed to learn.” They aren’t the ones who dropped out and changed to a different major. It depends on the feedback we get back. According to ABET, if you want to meet that accreditation you need to take the comments we get back and act on them. I guess I have to take back the statement I said earlier about there not being any changes. There’re going to have to be some changes. I think ABET is heading in the right direction....

I’ve been asked if I would consider being the person who will take on the ABET work and be granted the title of assistant department head. I don’t know if I want to do that. I may have a very big part or no part at all with all that’s going to be involved. I think whoever does this ABET thing needs to have some leverage with the faculty. I can’t make decisions on the same level that tenured do. For that reason, I don’t know that I’d have the power to have people change. The problem is you can’t make people change. You convince them that they need to change. If they don’t want to change they’re not going to change. Somehow they still have to find a motivation for faculty to want to
change. I don’t know if the ABET evaluation is going to be enough of an incentive.... I want us to pass. So far, everyone who’s come up against the ABET 2000 criteria has failed.... [Sigh] It doesn’t look good....

Hobart.

My interest in science and particularly in chemistry really goes back to high school.... I always liked math and when I took chemistry and there was math involved and also seeing how things worked and having a great chemistry teacher is what got me interested in chemistry. There were different faculty members that I admired from high school through my undergraduate degree program in chemistry... particularly a professor that did instrumental analysis where it was way ahead of his time. It was really a hands-on course. The instructions were fairly broad, there wasn’t a recipe step-by-step do-this-do that for any of the experiments....

I was on a teaching assistantship [in graduate school] and very much enjoyed it. I enjoyed the teaching interaction with the students probably more than I enjoyed the research that I was doing. That was partially the reason why I stopped with a masters and then worked for six years and went back and finished my Ph.D.... I’d say [that with] many of the approaches [I used in teaching], I was emulating what [I] had seen other people do and so it was probably a fairly traditional lecture format, which worked to varying degrees. [I feel that] you save the lecture for sort of showing the big picture connection between things. I’ve always been interested in doing laboratories that weren’t just plug and chug or verify the value of a universal constant where the students would sort of discover something on their own....

I started in 1974 [when] a lot of the students had been in the military and had come back. [These were] older students that were sort of a more mature group. Traditional methods worked pretty well for them.... [In] some respects [our classes were] a traditional format, but they had less lecture, two hours a week, and then two hours with teaching assistants and discussion sections. Much of the teaching was done in the context of working through problem sets to develop the concepts.... The role of the lecture changed from providing all of the information to showing the big picture and connections. We also were fairly heavily involved in technology in some of the real big courses. Instead of lecture there were sort of short documentary video taped lessons and they were designed to be more interactive. There were actually detailed instructions for the TA and these students would meet four times a week with the same TA and there would be instructions to stop the tape here and work an example.

After eight years at Illinois, I came here and the situation was very much different. Illinois pretty much gets the elite students and I think just about anything will work with them. Illinois, Berkeley or an Ivy League school is probably the way to try [reform innovations] and make them work. Students [from these schools] will make anything work. Here, the preparation
and background of the students is much less.... Here we have huge dropout and failure rates. If only 30 percent Ds, Fs and Ws are happening in the course of a semester we think it was a pretty good semester. Not all of that is the fault of the students not having the background. Some of it has to do with the way we deliver the course.

I think after seeing that with the bulk of [my present population of] students and not having abnormal population like I did at Illinois that [I concluded that] traditional lecture doesn't work. Packing the course with endless lists of topics and algorithmic problem solving doesn't meet the goals that we want our students to get. They do a mind-dump after every exam. I know if you talk to anybody in any science department about what they want the students to be able to do when [they] get out of the course, [they will probably state that they] want them thinking critically, using data, using scientific observations to come to a conclusion, evaluating complex problems ... and things that can involve higher order levels of thinking. But we test them on burping back definitions and algorithmic problem solving.

This is the kind of thing that very often you're forced into when you have large classes. I would say that frustration ... led me in general to the idea of reforming the way we do things. My primary interest is in reforming the mainstream large general chemistry courses. About the second or third year I was here they had submitted the CETP proposal once and it didn't get funded. They tried to get somebody from education and somebody from the sciences and then somebody from engineering. They could never really agree on what they wanted to do and made an eloquent plea for the need for course reform [in our state], but didn't have any idea as to what they were going to do. I guess there was sort of an unfriendly parting of the ways of the people involved there and in looking for somebody to get involved with the proposal, the dean suggested me. At about at that same time I was getting more interested in doing things with good teachers so I sort of started doing the advanced placement for chemistry courses for high school chemistry teachers. If the high school teachers are teaching more rigorous courses, they will have a little better background in chemistry and the students will be a little better prepared. From those encounters somebody suggested my name to get involved with the CETP program ... The first project within arts and science was to produce this course for the elementary ed students. I started looking into more of the brain-based learning and I guess the kind of things that I have always leaned [towards]. I am convinced something like that is the way to go. And so in some respects I came to it over a long period of time and then maybe more radically recently.

Students and TAs like textbooks that have chemistry labs where there's a step-by-step procedure and you fill in the blank kind of tear out sheet. [That is] because it's easy. It's very straightforward and I have always hated them.... The laboratories we're are using now in 111 and 112 are quite different. They involve what is called small scale.... They hate them because it's not beakers and burettes. The students and TAs think that, "Well this is
different, it's not real chemistry," when in fact the chemistry is much more sophisticated than the chemistry from a typical lab tear-out sheet. There are lots of instances where the students have to design an experiment. It puts pressure on the TAs and on the students and they don't like it. [Students] like structure and these are more unstructured. They feel threatened when they have to design and experiment where the questions are very open-ended. They are used to seeing everybody turning burettes and you sort of remove the technique from it. The labs aren't there to learn mechanical operation anymore, but to learn chemistry, and that is a big thing on the part of both the students and the TA....

My first chemistry course was in 1962. Actually, it was in the midst of what they called course reform ... to produce more scientists and engineers. It was brought on by Sputnik and the Cold War and the country was afraid we were behind the Russians and so there was a big impetus to produce more scientists and engineers. [These were] sort of the glory days for the National Science Foundation ... Before then, both the college and the high school courses were very much what we call descriptive chemistry in nature.... The movement in the sixties was what started to introduce a little bit more theory and so there was more talking about models and chemical bonding and atomic structure and trying to relate that to the properties of the elements, reactions of the elements. And over the years the books became almost all theory and very little reactions and properties ... Now you have these freshman chemistry courses that are encyclopedic in nature and ... they have gotten so big that applications are being left out. I think the trend I see emerging now is trying to cut back on things ... at least in the curriculum materials I've seen that appeal to me the most. They start out with the context and an application to give you a reason for learning the chemistry....

Dudley Hirschbach [from Purdue] published the first papers in chemistry literature on Piaget. Chemists caught on to the hands-on part and it had a pretty big effect on laboratory instruction. But, they sort of neglected the minds-on. A year ago I read in the paper that described the learning cycle using the 4-Mat method. It looked at the learning style of students and what struck me was that the students would pick their learning styles and have a different question that they wanted answered about something. In order to understand some body of knowledge you've got to answer these questions: Why is this important? What are the fundamental principles or concepts? How do we use it? What happens if you do something different so that you can extend something that you learned from one situation to another?

Something that I've tried to do in organizing the traditional lecture part of classes is to use modules because you start out with concepts and answer the question of why and then refer to [research materials] on a need to know basis. That's the way you do research too. If you identify a problem and if you don't know enough to solve the problem, you go to the library or you go to the laboratory to learn more. I think that in a research problem you go
through that complete cycle and the Tobias book shows that successful undergraduate programs have strong research components....

When I first taught I taught pretty much right out of the textbook and it has changed much.... I still use exams, but the nature of the exams changes a lot. This course was small enough so I could get problems and essay questions that were much more conceptual than the algorithmic problem solving ones. You are calculating the number for a purpose and the answer was maybe a qualitative question. Averages on the exams were lower than what I expected, but the quality of the written assignments they were turning in was higher than I expected. So where the assessment becomes a problem is going to be in the bigger courses. Where they have to involve the TAs in grading the final reports, which are probably much more difficult to grade than a lab report and getting consistency of grading. I think the best thing I’ve gotten out of grading AP exams, other than the people that you meet there, is insight on how to write an exam, really how to grade them.... [using] the rubric for assigning points....

In the big classes that have more than one instructor, we use common exams. There will be more than five hundred students taking the exam at one time. It’s still a Scantron multiple-choice kind of thing.... In the smaller course there may be ten to fifteen multiple-choice questions and then the bulk of the exams ... are problems that have short answers.... I’ll give them the equation and [ask], “What is this used for? What does this equation mean? What is the underlying principle behind this equation?” And particularly in the final exam, I’ll put several questions like that [where the students] are looking at trends, things where they interpret from graphs. I’ve had to put a lot more of that on exams where they have to write a paragraph or something to identify what is going on....

The students ask fewer questions now and they don’t respond if you ask an open-ended question. I tried the thing that Eric Mazur from Harvard is credited with. You pose this question in terms of a multiple-choice question. You give them a choice of answers and you ask them to discuss it and vote on it. “Now we’re going to vote on it, but I want you to discuss this question with the person next to you and you both have to agree on the answer.” Then I’d stop. Actually, it was hard to stand there and not do anything for about a minute or so, but they actually thought. You could hear the classroom come alive. There was lots of discussion going on. They were talking to each other and I could overhear some words here and there. It wasn’t “What are you doing after class? Where are you going to lunch?” They were actually talking about chemistry.... The advantage is then you can catch misconceptions.... Maybe twenty-five percent of those had never raised their hands. I think it’s they don’t want to look bad in front of their peers. I think they probably care less if they look bad in front of me. I think that goes along with the other part of the passiveness in class where they sort of sit there and they don’t want to call attention to themselves....

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When I graduated with my bachelor's degree in chemistry there were nearly twenty of us in our class and I think one was a woman. It was particularly bad at IIT being an engineering school. But even teaching the mainstream chemistry courses at the University of Colorado, two-thirds to three-fourths were men. Now, it's relatively equal, probably forty to forty-five percent women. I certainly hear that the classes are more diverse....
Here, probably most of our science classes reflect the population in the state much more. I think the way I've dealt with it is to treat the students with respect. They're individuals. You're there to try and help them. I don't have a preconceived notion that just because you're black or a woman or Hispanic you aren't going to do well in science. Anybody can do it if they are willing to spend the time with it. There's nothing that I've seen that's the reason one ethnic group over another is smarter, dumber or better in science or worse in science. One of the best students this department turned out was a black kid who graduated last year. Some of the Hispanic students I've had have been some of the best students in my classes. [There] doesn't seem to be any ethnic preference for it. I think a lot of it is more emotional ... if somebody's emotionally ready for the University. I think one of the biggest problems that we're having with students is that, particularly for the 18-year-old freshman, is six months before they were children, somebody told them everything they had to do. And now they get to the university as adults and they are on their own. There's a lot more fun stuff out there to do than studying for your classes. And I think that's a bigger factor, more so than any kind of ethnic background. The biggest difference in schools here is that students from a small rural school may not have been able to take four years of math or three years of science.... Maybe it's more of a resource problem at a lot of schools, not the individual kids....

I guess, where I've had the most opportunity to influence others has been since I've been here [with regards to reform efforts]. And that's certainly where I've been the most active.... There are some pretty conservative faculty members that need convincing. I have the freedom to try, but I have to convince people to do it too. Again, there are lots of people involved with any course and so my approach has been to try it in the smaller courses where I'm the only one involved and see how it works. I would not have somebody, who may be resistant to change, trying what hasn't been tested for the first time or trying something where I'm not sure what the pitfalls are or what to look for. When they hired me ... course development is considered my area of scholarly activity. The classroom is my laboratory [where I do] both my teaching and my research. When we do our goal statements and you apportion how much is teaching and research and service, the dean and department head know that it is teaching or research, or it's service for pushing a paper for the general chem. program. The distinction there becomes kind of vague.

In a research university, they value the time spent on teaching a little bit more than at Illinois. At Illinois you can be a horrible teacher, and if you
have the grants and the publications, you're going to get tenure or you're going to get promoted early... Here it's kind of an experiment at the college. The dean and department head said that the professional development kinds of things in my area of research are also scholarly activities. The talks I've given at meetings and papers I've submitted have been involved somewhere with the courses that I've taught.... In chemistry, every now and then you see a position advertised at a school looking for somebody whose area is chemical education....

I have a position that's present in many chemistry departments that have large number of students taking freshman chemistry. I'm sort of the administrator for a freshman chemistry class that involves everything from scheduling, working with TAs, training, and sort of coordinating the courses and providing direction. The big courses, particularly the courses that AG, engineers and biology students take, involve multiple sections with multiple instructors and multiple lab sections with multiple TAs and it's sort of coordinating that. It takes up a lot on my part, not so much as an educator, but more as a paper-pusher administrator and just keeping things from falling apart. I hope some of things we're discovering in the [reformed] natural science course will provide a trickle down that gives me evidence and reasons to convince my colleagues to try and change teaching techniques in larger courses.... building consensus and exposing some of the other faculty members who may be more resistant to change to some of the things that we know from cognitive research about how students learn, which is something that I'm learning myself.... I'm more aggressive in pushing it or exposing my colleagues to it since it's something that serves as a compelling interest to me changing over the way we do some of the laboratories, maybe changing some of the things that we do in lecture in having more student work going on in the lecture either in groups or alone... That is probably the most difficult task; getting the larger lecture sections more active....

I've gotten involved more as a science educator by becoming more involved in both pre-service and in-service teacher training.... The teachers are out there [more] for further training in the area of content than pedagogy. They've had a lot more education courses than I've ever had. They're probably more aware of what's happening in some of those areas than I am. Many of the high school teachers are teaching high school chemistry with having only one or two years of chemistry in college. I would like to find a way of delivering some of the chemistry content through distance learning....

All of our graduate courses are oriented towards a research career in chemistry. Essentially the pre-requisites to take a graduate course is that you have a chemistry degree which is not the case with most of the high school teachers around and it's geared toward a research career in chemistry. There's a real need to fill that void with some courses....

In terms of the reformed course, I sort of have two roles... I'm sort of the point person in the arts and sciences college. The organization of the natural science course then kind of fell to me to coordinate several different
people with several different ideas into offering a reasonably coherent course. In that case it’s not so much convincing other people because I think that the folks that got involved bought into the idea of hands-on activities.... It seemed that we got through to the students what we had set out to do. The core instructors developed materials for future instructors by teaching a segment of the course, then two or three of us can feel comfortable doing a whole semester. This smooths out the logistics from the college’s standpoint of who gets credit....

In terms of changing my teaching style, I think that I made a pretty drastic change through my career. In particular, by getting involved in large classes that had mostly been a lecture format with a laboratory that may or may not be connected with what’s going on in the lecture at that time. Sometimes laboratory leads into the lecture, sometimes the laboratory follows the lecture, and sometimes it’s uncoordinated. But, I decided to take the plunge and more or less try and do everything hands-on. I [began] to start everything with a question, doing some sort of experiment that actively involved the students, followed by a discussion and prodding the students to come up with much of the information.

I [get my ideas] from talks at meetings, discussing things with colleagues, with teachers that have taught at the elementary level ... and the frustration with doing things in the traditional lecture format.... We want our students to be able to handle complex problems, have a conceptual understanding behind a calculation, or deal with variations ... So we talk the talk and hope what we teach is what we’d like the students to get out of the courses. The natural science course sort of provides a nice arena because the other people involved in the course volunteered to do that pretty much as an overload with relatively minimal return of salary and so on. Other people involved are already believers so that the selling job isn’t there.... I think the main reason and that people resist change ... as we went through our careers we always saw lectures, bad lectures, and so it’s the way we were taught ... particularly with high school teachers. I think a lot of high school courses are taught from the lecture format. Even though those teachers had the methods courses where they talk about effective methods from cognitive research ... maybe a hundred hours of instruction that way and thousands of hours in the classroom where it was different. It’s hard to break a habit.... I’ve spent a lot of time working on lectures, lecture notes, demonstrations, visual aids that you know, very often it’s a pretty good show, but it’s passive.... Nobody would ever claim that he could learn how to play a musical instrument by watching somebody play the piano or by going to lots of concerts. Yet we insist that that’s the way to learn something like chemistry, by attending concerts and not practicing....

The bottom line is the easiest thing to judge people for promotion and tenure is how many papers they’ve published. So the time you devote to reforming a course that you teach means that you publish one or two papers fewer by the time you’re up for tenure and that you might get lower teacher
evaluations. There’s not much in it for a beginning professor to spend that kind of time. I think it’s not as bad here as it is in some schools. I was hired so that my scholarly work is in course development or curriculum development in teaching reform. I mean that’s one out of a department, one out of a college. A lot of it was administrative need for somebody to take charge of the whole chemistry program and maybe update it. The biggest problem we have is the failure rate and so course development, textbook writing, and materials development was considered part of my scholarly activities. The presentations I give at the ACS meeting, the papers I submit are along that area, rather than traditionally in chemistry. I [spend my time] much as a [regular] faculty member involved in research, reading the literature, going to meetings, reflecting back on what we’ve done in a course.... The most valuable thing I find is the discussions that I have had with colleagues at other schools ... I try and bring in an educational oriented speaker at least once or twice a year....

I think [integration] has gone reasonably well. I know it’s primarily the meetings that you attended a year ago where we hashed things out and reinvented the wheel every time we met and decided we’ll go this way and then completely changed the next time. I think the level of interaction is going to have to increase the next couple of times we do the course where we’re going to have to train each other and have some content material [developed] so one of us can do the whole first semester.... [We need to look at] integration from the faculty members’ standpoint. Some of us are going out of our comfort zones. Five years ago I couldn’t imagine that I would have been doing some of the things that I was doing in [the CEP course] this semester....

I think in some of the other disciplines [such as] the humanities, English, literature courses or social science courses, that there is still more discussion. There’s more ambiguity. In traditional science, you limit the scope to situations where there’s a right answer, but it’s sometimes removed from reality. Even a literature course is based on reality to the extent that may deal with emotions or the human condition. Something you can relate to in social studies courses ... is subject to interpretation and how it relates to your world or your life.... [Maybe] you can put [science] back into a realistic context so that you can see there is a reason for calculating the percent composition of a compound rather than cranking through the formula....

In an ideal world, [curriculum] comes from a problem-based kind of learning. I would say [to use] the research model, you start with a problem, you make observations. If you don’t understand some aspect of the problem, you go to your references [including textbooks] and you find out more about what’s going on. It’s the way scientist function. A lot of my friends [in chemistry] I talk to have gone into industry. They’re dealing with things they never have really talked about in the classes.... I think the role of the professor becomes more of a research advisor, providing some resources and questions and direction. You don’t get down to the one-on-one mentoring like you do
with a research advisor. I think [in education that this is] prohibitive. If we had six hundred chemistry faculty advising [all of the] students who take freshman chemistry, [it would take a] fifty-story office tower just to house the faculty and that would be a little bit expensive....

I think [we should develop] the ability to think creatively and critically, to appreciate the things around you, to have appreciation for art or architecture or music. Sometimes it's at school where you get exposed to that. It has to be based on experience rather than just being told. There's a lot of emphasis on training for a job, particularly in the sciences and engineering. There are professional standards that are set by the accrediting agency in engineering. It is the American Chemical Society or Professional Engineers Exam that drives some of the curriculum.

We play that card, "Major in chemistry and get a job." We play it when we go for resources to the dean. We say, "Our people are going out and getting jobs and donating zillions of dollars to the university." I think it's unfair to some of the other disciplines. "Why do I need to learn this? Why do I need to learn chemistry? I just want to be a civil engineer." So, there is that driving force for vocational training.... The process is important, how you solve a problem is how you gather information. You can't cover everything. I see it sometimes in new faculty members ... but sometimes with graduate students and TAs. And it's the idea of, "Well, you've had my course and you should understand all the nuances of chemistry that I have." Even though you've taken just one semester of general chemistry in college. I majored in Chemistry for four years, spent another four years in graduate school doing nothing but chemistry and three years getting a Ph.D....

In the past, I've looked [within the context of reform] at what I can do to improve my teaching. Because the nature of my position of being involved in running the general chemistry program that other faculty work in and my experience from the [reformed] arts and sciences course, I guess the role of disseminator or facilitator becomes more important. I think convincing my colleagues that what we've tried in the arts and sciences course works and that it's transportable to our big service courses in chemistry sort of changes my viewpoint. I'd say that's maybe the biggest way in which I see my view changing....

I think all of the previous ones [reform efforts] have been faddish and I can't remember where I read it, but it was an article that was really what chemistry reform involved was changing lists of topics and packaging the same stuff just in different ways; not looking at how we teach or how we present the material, how we engage the students or the context within which we present our material. I think the realization of the effectiveness of problem-based learning, the effectiveness of actively engaging the students and less lecture, I'm convinced that it works more and more.... What's different in my job is spending more time discussing strategies and approaches with colleagues rather than getting together at the beginning of the semester and come up with a syllabus and we say, "Okay, this is what we

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have to do and the order we do it in.” Then we’d go off and do our own thing, which was still essentially the same thing because we were all brought up in the old traditional lecture format. Seventy percent of the students slept through seventy percent of the lectures when they showed up. I think the nature of the reform is different. I think it involves more interaction between people doing research on how students learn and using those results in looking at how we should approach a course, how we should present a course, or how we should teach. I think that the other important feature of the focus of reform now is more on student learning.... Putting the emphasis on student learning rather than on how good a show you do in lecture is another important aspect of this kind of reform and I think [that is] what makes it different, what makes it refreshing....

We need to work more of that in ... something besides exam scores to go on. Pulling that off in big courses is going to be the trick because in a big course, to make it manageable, the evaluation has to be done at the lab-section level. Training inexperienced teaching assistants as to what they need to look for and consistency is going to be a very big issue, particularly in things like chemistry and probably in biology and physics courses and maybe math courses. Scores and exams are still going to be a component and how to adjust those to what you are doing is a major effort. In the arts and sciences course, we haven’t had to concern ourselves with exams or scores because we’ve been able to do evaluations based on written responses, discretion, reports, papers, and oral presentations because we’ve had the manpower and the small number of students....

I found out in this class, when I present things and give them the opportunity to do things, there is a considerable amount of enthusiasm. We sort of see the curiosity coming out. It would have been nice if everybody had really gotten involved in the thing. Some of them were still pretty passive. I think even the more passive ones, when they’re in the group, were still participating to an extent.... That’s not what’s done in lecture. When we had the first discussions of 121, we were worrying about topics and outlines and what we’re going to cover. Although I still spend some time worrying about the content, it’s more thematic.... It was, “What could we do in class that’s going to engage the students [more] than making a specific point?” The content was really much more the general idea that I wanted to get across, the idea of [how] the properties and structure were related.... You don’t see things that broadly in any chemistry course.... [The 121 class] started out with the properties and then looked at structural relationships between the atoms and the molecules. The actual kinds of structural things we did were towards the very end of the segment. I don’t know if I was spending more time on it because those kinds of things were more new or more boring to me....

I’d like to get my other colleagues doing it more, the others that teach the multiple sections of general chemistry.... We need to find a way within the department structure to be worth it for the people willing to do that extra work ... like having them spend a couple of weeks in summer ahead of classes....
I think there was this gap between the science departments and the education schools. There’s this animosity, “The damn students coming in, don’t know anything. High schools are lousy. There are all these lousy teachers. They have education degrees and they don’t know any science.” Well, if they don’t know any science it’s your own damn fault because they took your science course.... Look at the requirements to get an undergraduate degree through the education college ... That doesn’t leave much room for the science courses. Or you’re looking at the requirements for a science degree ... there’s not enough room to get a chemistry or biology degree and take enough education courses so you can be certified to teach science at the high school level.... One time I made the point that probably the science method courses shouldn’t be taught to the [education] students. There ought to be science method courses that the faculty [must] take. During the first semester in a teaching job as a new assistant professor you probably ought to take the science methods course over in the education college....

I think there’s certainly a body of research that tries to address [human learning]. I mean there’s still one of the more wide-open areas of what you might call neuroscience and developmental psychology, but there’s certainly a body of knowledge there. I think ... the bulk of the people who are teaching at universities are ignorant of it.... You have to search for alternatives....

I think what’s good about the NSF doing it [supporting reform initiatives] now is that they’re insisting on some institutional buy-in. Once the grant is over, you’ve made an impact and I think some systemic change. I think their goal is that not only do you see some systemic changes in teacher preparation education, but that there is going to be ... changes in that all of the science courses are more attractive. I can see how it works. Within the framework of Arts and Sciences 121, I’m seeing that these different things work and are effective. They really accomplish what you wanted to accomplish. You’ve got the evidence now ... let’s try it in all the other courses. What the NSF has done, which maybe hasn’t been done before, is put it in a framework that at least there is going to be some institutional buy-in....

There’s maybe two conflicting things, but I think they are both true. One is that reform comes in many respects from below. There can be some encouragement and incentives that come from up high, but it takes the faculty to do it and then only if you have that strong leadership and encouragement and reward system put in that [ensures] you’ll get credit towards tenure for being involved in these kinds of activities ... that if you publish a paper on a reformed course, that counts just as much as a research paper. The rewards and the leadership have to come from the deans and the colleges, vice presidents and chancellors and so on. That’s one of the things NSF is trying to do. [Over time], the CETP programs have changed. If you see some of the early ones that were submitted, the PIs and the co-PIs were all faculty members. On our grant, the PIs and the co-PIs are primarily administrators.... Our dean does buy into it....
We've planted the seed in most of the science disciplines with this one course. We talk about how some of these things can be applied to our big courses.... I wouldn't be surprised if many of the other faculty members are going to be looking at it in the same way. That's sort of the natural scientific curiosity that I think that anybody that goes into science is going to have. Another way of looking at it is, we've done an experiment and with one set of variables and one set of students, the experiment seems to work. Is the experiment going to work in the more general... maybe a different specific environment? If I phrase it that way to my colleagues, it doesn't sound like educational mumbo jumbo in their mind.... More will go into next year's annual report in my portfolio for promotion this summer. They'll always have to read that we did these things in this course and got these results.

It's starting to break down some of the barriers between departments... maybe because the research faculty are collaborating with people outside of their department and we aren't so parochial in terms of our own research.... Research and teaching aren't that different. You have to make a point with research faculty... What is the university's role in conducting a graduate program and research? They say, "To increase their knowledge and understanding." The reason it's going to get you support from the state at a state university is this part in the educational role. You're educating people now to take leadership positions in your discipline. Whether it's a leadership position in an industrial laboratory, industrial setting, or it's a leadership position as an educator or faculty member, it's education and I think the faculty members that see the graduate role as an education role are going to understand that and see applications for the courses. The ones that are in it for the ego and the long list of publications and getting the reward or recognition may not cut it in class. I see it in our department....

You can't learn everything there is to learn in chemistry in one introductory course. You can't do it in an undergraduate degree. You can't do it in a Ph.D. degree. You branch out into a different area on your own and certainly in industry, you hardly ever end up doing what you did in graduate school. What you learned in graduate school was how to gather information, how to use it, and how to perform experiments.... If you learned how to learn and solve problems in your graduate program, it doesn't matter if you go into another area. The goal has got to be learn how to learn and then what you choose for content are some pillars. You probably ought to choose some of the more important topics than ones that are maybe just peripheral. But you don't have to do everything in every course if you have that focus on learning.

Patrick.

I think my interest in [science education reform] started really at [this university]. Prior to that time, I wasn't real engaged in an active way in the teaching of science. So it was when I first arrived and started to actually teach in the classroom that my interests in how to convey the material better to my
students arose. The main motivating factor I think was that it was clear, based upon student performances, particularly on the comprehensive final exams, that the students were not grasping the material even at the conceptual level as well as I thought they should be. I was surprised by that because I really thought that the book was well written that the lectures were good, but had generally very few questions. I had to assume that the students in turn were understanding the material. The shock came when [I] examined the performance on the comprehensive exams where they were asked to write, in the form of an essay question, responses to questions we had covered in class. It was clear based upon those responses that they just did not really understand the material. The reason that that surprised me was because on prior examinations, which were given more in terms of multiple-choice exams, student performances seemed to be much better. They seemed to suggest that the students actually were learning the material. Therefore there was just a disconnect between the exam process leading up to the comprehensive exam and seemed to suggest that the students in fact knew the material and understood it versus what I was seeing in terms of a final product. So that led to a search for different strategies that one could use to help the students learn the material better. I tried a number of them, most of which were unsuccessful.... Those experiments focused on my own presentation. From these efforts were to appear better notes for myself, transparencies that illustrated the concepts or to adopt transparency sets provided by book publishers. All of those items that I thought would lead to greater student understanding of my field turned out to be to be incorrect. That, I think, is how I became a science educator as opposed to a science instructor.

A science instructor is a person who goes out and gives a lecture about course material whereas a science educator is one who is trying to educate the students in the material. Science instructor and science educator are not equivalent, sadly. The science educator part of me reflects the science part of me as well. That is, you’re seeking for a solution to a problem and you’re just trying different experimental techniques to arrive at it. I don’t believe that in my case that I would go back to say my high school experiences or things like that. It was more, in my case, an internal desire to just do a good job. I wanted my students to be able to learn the material well .... I had some [instructors] that I thought were really great ... It was more my own desire to just not waste my students’ time, not waste my own time by just playing the educational game....

I think that [I developed] alternative strategies based upon teaching techniques that I’ve seen others employ that looked like they were being successful. Other strategies you just are told about and you’re told that they were successful even though you haven’t personally seen them in action. You can occasionally see a segment from the PBS news program that deals with education that shows different ways in which instruction is being conducted.... episodes that influenced [me] ... were two courses I took. One
offered by the department of English was called Writing Across The Curriculum on how one can use writing as a tool in instruction. Over the course of several years it sort of built credibility in terms of what I was seeing in the classroom. Finally, I was willing to bite the bullet and actually try it in the classroom because that seemed like an extreme strategy that would generate a tremendous amount of work, not only for me, but for the students. The other strategy, called Computer Based Instruction, was offered in the Center for Educational Development. It basically revolved around using the computer as a tool for instruction. That must have been ten years ago. As such, the technology wasn’t what we have today. So, it seemed to me what one could do was rather crude and very limited.

On the other hand, writing is open-ended and it allows the student to explore any topic in any way really that they choose. So you can ask the question and find by reading the response that the student really understands it quite well.... I [did not] immediately incorporate this into my classroom instruction. I guess there was some resistance [on my part] because it was different and required additional work for me to implement those strategies. It was only when the frustration sort of became overwhelming after doing this same teaching process. It means I’ve got to do more work. My lecture notes were already done so it’s easy for me as an instructor to go in and use basically the same lecture notes semester after semester. I can modify them a little bit, but the material that you’re teaching the students at an introductory level generally doesn’t change that quickly. So, it’s relatively easy to modify your notes ... developing new activities is time consuming.

One of the things that you find out [when] you become involved with the university is that [it] will find ways of taking up all of your time. [Then] it’s easy to say, “Well, the lectures aren’t that bad. The notes are comprehensive. I just will go with that.” That generally works for a while until the comprehensive exam where a certain amount of frustration then sets in.... Your students are telling you that you’ve got to make a change and your available time is saying, “Well, you know, I’m not really sure I have the time and I’m not really sure what kind of change to make.” So that is why it took a long time for the frustration to finally build to the state where I decided it was just intolerable now to continue with a method that had been in my mind for many years.... I got the same message from other faculty in the department. We’re using the same instructional format and they were similarly frustrated by the responses that they were getting from their students....

You just have to make the time.... I started developing the activities and thought that this was such a good idea that I submitted a grant to the National Science Foundation so I could call it research as well as improving my education. I worked with members of the department of English to help me with that. It was sort of a merging of the two that, as I already explained, it wasn’t clear what to do. You knew something was wrong, but the solution wasn’t clear. That’s really the essence of science, that you try and study a phenomenon and it’s not clear how to explain that particular phenomenon. I
wanted to find a better way of conducting instruction so maybe at some level I
looked at that as that being research....

It was a building process. I suppose the first year wasn’t successful
within the normal lecture style. You say, “Well, that’s because it was the first
year.” The next year you try it and say, “Well, actually it was a little bit
better.” The third year you say, “Well, my lectures are a little bit better yet
the students on your exams don’t seem to be doing any better.” A subtle
realization begins to build. “I’m doing the best I can in my lectures. I sort of
maxed out in terms of how good I can make that, but my students are not
showing additional improvement.”... It’s through a process of elimination that
you find that the basic instructional model that you’re using is flawed....

I think this is one of the reasons why new faculty have a hard time
adapting to different methodologies because they haven’t proved to
themselves yet that the methodology that they’re using is going to be
ineffective. So it’s very difficult to talk to new instructors, new faculty and
say, “You know, you really ought to try this,” because that’s a model that
they’re unfamiliar with. That’s a model that they didn’t even grow up with
and they just don’t feel comfortable with it.... It was more than intuition. It
was the building up of the evidence; the elimination of the other possible
reasons to explain why the students weren’t.... [My pedagogical methods are]
based on the formative education that [I] went through. You start out teaching
the way you were taught.... I was unaware really that there was any other
technique out there....

I’m not sure I remember how I got involved in it [CETP]. I think that
I’ve tried enough different approaches and been on campus long enough and
my teaching evaluations have been strong enough that I have a pretty good
reputation on campus.

I’ve been [teaching] since 1976, so that’s well over 22 years.... It was
in many ways similar to what I had developed into my NSF grant with the
English department. I thought that it was a good idea. It looked like it would
be productive and therefore I’d be willing to participate in it. [Laugh] I hope
that’s correct....

Our education majors needed this kind of class. A class that was more
of a general science class than a class in chemistry or biology or astronomy.
I’ve believed that for a long time that we were educating our education majors
in science in the wrong way.... Nowadays I’d say there isn’t a whole lot of
difference [between instruction for education majors and the rest of the
population]. I think the university structure of educating its non-science
majors is flawed. Fundamentally flawed in the way in which instruction takes
place. Chemistry teaches its students chemistry. Astronomy teaches its
students astronomy. After two classes, that’s usually sufficient for the
undergraduate to fulfill their science requirement. I think that model, what we
call our science education for non-science majors, is used throughout the
country and has led to the development of the scientifically illiterate
population.... Most faculty haven’t even realized that their own teaching technique is flawed, let alone [that] the teaching at the national level is flawed.

The educational process differs for non-science majors because they are able to recover from the terrible job that we do in our survey-level classes. Terrible, not in the sense that their instruction is bad, but terrible in a sense that we’re teaching very narrow concepts of science.... By the time that student graduates, half of their science requirement was worthless because they didn’t understand the subject. The astronomy component they might understand, but now all they know is a little bit about astronomy. In our survey level classes we generally teach the facts of the discipline not the way in which the facts were arrived at or the method which science uses to uncover those facts. We produce excellent science majors, but the reason I think for that is eventually those students are going to be doing the science. In our freshman level classes we generally don’t ask our students to do science except for maybe in lab. In the lecture, they’re just there to listen. They’re not there to become a participant. They’re there sort of as a sponge, but our science majors are actually asked in subsequent courses to demonstrate that knowledge by solving problems by getting directly involved with the subject matter....

Providing a thematic approach is only part of it. The other part of it is you have to get your students involved in the instruction. My fundamental belief on this is that the students only learn the material by interacting with the material.... Using a pencil to actually sketch out a concept to write a short essay or solve a problem. Until the students are asked to do that, I think that the best that we can ask our students to do is to rely upon memorization of facts.... Unfortunately, because of the way in which our undergraduate science education process is set up, it’s rare for the students to take two classes in the same area. Even if they did, I’m not sure that that would be enough courses to really begin to see how the process works.

I’m not sure it would be that productive at an entry level [to involve undergraduates in the research] because I’m not very sure what kind of research project they’d be able to participate in. The level of research at the university tends to be pretty high. What you might find is that your students are doing kind of mindless activities. If the faculty member could really give a thoughtful project to the student and actually work with the student then I would say yes. That would be a way of motivating your students, but at a level of, is it practical? There are just far too many students to do a good job than there are faculty.... That’s a really tough issue. How do you get personal interaction at a freshman level? At the mentoring level it’s very difficult. I’m working with three undergraduate students and that taps me out. I can’t imagine trying to do it with twenty.... If science majors stopped at freshman year, they would do terrible too. [Laugh].... I’m not so sure [why they persist in science]. Some students, of course, are just interested in it before they ever came to college. Their dad maybe was a scientist or an engineer and they’re
going to become a scientist or an engineer. It’s also possible that in introductory classes the better students find it interesting....

I think that the college of education has been unstable in terms of its science education program. [Chuckles] I mean, you know, here today gone tomorrow. [The science educator] used to be in that position for several years, but then he kind of came, went, and came back again. It seems as though the College of Education hasn’t made a commitment in terms of science education. The best support I’ve seen has come from the Center for Learning Assistance, the Center for Educational Development and Writing Across the Curriculum. To my knowledge, the department of astronomy has never been called from anybody in the College of Education asking about the types of things we’re doing in our classes.... I think part of the problem might be that faculty in the College of Education are overwhelmed by the number of people they have over in education. There seems to be this invisible boundary between colleges.

I think [teachers] do a very good job in elementary school, a good job in middle school and a worse job in high school ... In elementary school, you can’t stand up and lecture to your elementary school students. It doesn’t work and the teachers know this so they have their students working with whatever it is that they’re teaching. It’s successful at that level. In mid-school, that model of having your students work with material is still there, but it begins to decline. Oddly, some of our science scores begin to decline. By the time they get to high school, it’s more the model that we use in college. The teacher stands up and talks about the material and there we see the science scores plummet....

I grew up on the east coast in a small town. [There were about] seventy to eighty students in my high school graduating class. It was a small class. I went from there to the University of Massachusetts, Amherst. Got my degree in astronomy, which is essentially the same program as physics ... I went from the University of Massachusetts to the University of California at Santa Cruz. [I] received my masters and Ph.D. from there in 1975 and I came here the following year as a post-doc in the astronomy department.... [That was] kind of unusual in the sense that I was a post-doc, a visiting assistant professor, an assistant professor all at the same university ... I was promoted to professor around 1991....

I can’t recall [any non-traditional instructors in my education]. In the sciences, the curriculum is so hard and fast that I had a very good lecturer in astronomy my freshman year at the University of Massachusetts, but it was a lecture. Every other class I had was a lecture. I guess you could argue that graduate classes are more interactive by their very nature. There are only a few students and you do lots of problems so it’s highly interactive, but I wouldn’t say it was cutting edge in terms of instructional methodology.... I can’t think of a single instance in my entire education where I can point to it and say, “You know, that was a really different format.” ...
I can’t recall [trends in student quality or issues of diversity].... We don’t have an undergraduate program for astronomy so I don’t have any experience with the undergraduate product. At the graduate level, I can’t say that I’ve seen any difference minority, non-minority, be it male, female. I think they perform equally well. I have seen a change in the discipline in the sense that there are now more females in astronomy than certainly when I started. I can’t say there are more minorities. They’re such a scarce commodity....

I [have been involved with the public schools] basically for a selfish reason. My kids were then in elementary school.... I applied to NASA several years in a row for several thousands of dollars and set up workshops for elementary school teachers because that’s where my kids were at the time. We’d take two teachers from each school and each one of them would get something like a thousand dollars worth of equipment for their classes... modules that we had developed during the workshops are now part of these kits I developed.... The primary difference between what I am doing now versus what I have done in the past is I try to incorporate into the class as many interactive activities as I can. Interactive activities to me go beyond a demonstration because I don’t feel that those are always interactive. The instructor’s engaged in an activity, but the students are simply observers. When I refer to interactive activities I mean something that the student is doing. The instructor in fact may not be doing anything at the time. The student will be doing the work. The mode that I prefer for that is writing. The mode that I like to do in classes is give students handouts that are designed to be done.... I think that we sometimes make a mistake in science education in thinking that unless the exercise is terribly difficult, terribly complex, it’s just not worth asking the student to do. In reality, I think what we’ll find when we look at our examination of these students, that it’s not the in-depth kind of concepts that they’re having trouble over, it’s more the surface level concept that they’re having trouble over. [Chuckles]. As long as the exercise is at a level that guarantees that the student will be fairly successful. So the process that I would use for that would be to introduce the subject before they’re given the activity. I then would go over the activity without saying I’m going over the activity.... Generally, students don’t have questions.... They expect you to just lecture and expect to sit there and listen....

The student’s attention span is not an hour and fifteen minutes.... After the first half of an hour, we are pretty much talking to ourselves because the students have sort of drifted off. They’re still trying to take notes, but I’m not sure how much real exchange of information is taking place. After a half of an hour or so you might stop, hand out this activity and after fifteen minutes it’s done. You then move on to additional material if the students are ready to do so.... You could wake up the class in many different ways. Show them a filmstrip, for instance, show a movie or have a demonstration. That’s not directed at student learning as much as asking them to actually perform the
activities.... Ten years ago I didn’t expect them to do any work in class. I just expected them to come and listen.... Some [students] are irritated about [having to interact in class rather than receive a lecture]. I get comments like, “We don’t have to do this in our geology class....” I try to be very up front at the beginning of the semester when we go over the syllabus. It’s clear what the ground rules in this class are, that it will be interactive.... They will be working on projects that I give in class. I also point out that if they don’t like that they can always transfer to a different section ... or they’ll poison the atmosphere of the class. They’ll bring down the morale of other students. You want to weed those students out as quickly as possible.... The biggest argument against [interactive instruction] ... is class size ... if you have a hundred to a hundred and fifty students? I think instructors have a fundamental misunderstanding of what interactive means. It doesn’t necessarily mean interacting with you one-on-one. That would be clearly impossible with a class that size. By interaction, I mean they can interact with the material, the activity that you’ve given them....

When we talk about anxiety in our classes, there are two anxieties. There’s the student anxiety and there’s the instructor anxiety. We have been talking about what the student anxiety is. They’re afraid of science and they’re afraid of math. The anxiety that the instructors have is I think of trying something new. They’re afraid of failure. Even though they’ll admit that what they’re doing is wrong, they’re more content to continue to do what they know is wrong rather than to try an alternative.... What they get intimidated by is maybe the loss of control. I know I was when I first started to do this. Then, all of a sudden, instead of the classroom being quiet and the sitting attentively, they’re actually talking and it seems disruptive and noisy. That is not something that we were brought up with. When the classroom got that way when we were students, the class was out of hand. The teacher usually had to take some kind of remedial action to get us back in line. This is what you want to have happen in this format. The more noise the better. So that’s different to an instructor and what’s different is often kind of frightening.... Are these students really learning or are they just talking about me or talking about whatever? So I think there is some resistance to it....

Another problem that we all have is I think we tend to buy into our own scheme. If we develop something and we use it in class, we feel that it is just great ... because [we] developed it.... It then becomes hard to make a change.... I think that what might be going on here is that it’s so far divorced from their research area. They’re seeing a trained astronomer so when they think of research they think of astronomical research. It’s not that they would necessarily argue that trying something like this in the classroom is research. It is just so foreign to their concept of research that I don’t think they get to that point where they can see it as just another research project that they could do. I’m a researcher, I know how to construct tests to see whether something’s effective or correct or not. Why don’t I apply it in my
It takes a certain amount of time to build up a database that is compelling enough to convince you that you need to change. But it takes time to be convinced that the thing you’re trying is not effective.... You’ve addressed all those issues over the course of time and found that wasn’t the key. That wasn’t what was causing your students to perform at a level that was not up to where you thought they should be. You need to be convinced of that as an individual....

I think part of the problem goes to the lack of at least some kind of bona fide literature that professional scientists are familiar with. We’re used to evaluating the facts. We may not like the facts and it’ll be painful to accept them. Over a period of time we will accept them, but education hasn’t worked like that. It seems like we continually go back to the beginning.... There is no, “Well, we’ve already done this and it doesn’t work so why don’t we begin anew out at some level different than where I started at?” It’s unfortunate because the people who pay the price are the students.... Maybe some of it goes to the lack of a literature, a refereed literature that says in a convincing experimental way that the lecture format is not effective. You can read it ... in different kinds of educational books on ways of teaching. They all say it, but when you ask, “Where’s the evidence?” it’s pretty subjective. “My students just didn’t seem to respond as well as when I did this.” as opposed to, “I demonstrated this by having control sections and normalizations of the class.” Then the comparisons between test scores and things like that that a scientist would then have to accept and say, “Okay, I now have a reason to start at a level other than the same place that traditionally we’ve all begun at.”...

You’ve really got to show them that what you’re doing is effective in the experimental reproducible way. I think you can make more headway, but we’re far from that in the present time. There is no, “Here’s my proof.” It is more opinion.... If you had some kind of way of documenting that this actually does work, then your conversation ... would be, “The experimental data shows this.” It is a lot harder to dismiss what the experimental data shows.... Documenting success or failure is becoming more and more important in terms of proposal acceptance at the National Science Foundation. The problem is that it’s been done so seldom that even on the review panels the panelists themselves are in a quandary as to how to evaluate something like this. NSF is asking us to do it, but the literature on how to do it is so sparse that it hasn’t really built much momentum....

I’m really not in favor of the multiple-choice kinds of exams because I don’t think it shows a particular depth of the student understanding and it lends itself to the memorization of facts.... The exams are a useful tool, but they’re generally given so infrequently. You might have two exams in the course of the semester and the final. That’s pretty much the norm for introductory classes. That’s terrible! What are you going to do if you find out your students aren’t with you and you’re a third or even if it’s the second
exam you’re two thirds of the way through your class? I’m much more in favor of giving lots of in-class activities.... [with] the vast majority of your students at least you know where their limitations are based upon the in-class activity.... One-on-one you can ask the student where it is that they have a problem. The instructor can still do some individual help in the activities by just glancing at it [there on the table], not picking it up and grading it.... If the students want to try to fool you, they probably can by just putting anything down on the paper. If you don’t read it, how do you know it’s not right sort of thing. You’ll find out on the exam, but generally I find that most students are not like that. They really are sincere.... In-class activities provide that vehicle for them to identify specifically what it is they didn’t understand based upon the lecture....

I think the best kind of exam to give is a written exam. We have short answer questions where the students have to express in writing what their thoughts are about a question because it’s a lot easier for an instructor to judge where the level of a student’s understanding is.... The students evaluated on the depth of their knowledge and the instructor can evaluate his own teaching....

The oral exam is comparable to the written exam, maybe even a step above. Maybe it’s the top-level exam [because] it allows you to probe.... An oral exam allows the instructor to listen to what the student is saying and ask a follow-up question.... This is something you weren’t able to do in those other two forms of exam.... Unfortunately, when you have large classes, you can’t give individual exams.... In a perfect world, where there was nothing called time, I think that the oral exam would be a superior way of judging the overall competency of the student. That’s what we use in higher education when we have our people take their masters and Ph.D. exams....

Their workbook of in-class activities is another way of doing that. Now you can collect them at the end of the semester. It’s not like I read every answer there and say that it’s not quite right here. What I do is look at the portfolio in an overview sort of way and ask myself, “Does the student understand what’s going on here?” as opposed to asking, “Does the student get every one of those questions right in detail....”

I’ve been working with the English department on how to construct written material that will actually aid student learning.... We’ve decided [that] there were really only two classes in the university that everybody is going to take. Everybody’s going to take math and everybody’s going to take English. So we started a project where we said we want to reach everybody.... We decided not to target math because the students who come in here already have anxieties about math. We thought we’re basically dealing with an audience that at some level has already admitted defeat before the battle’s even begun.... Part of the problem that we have in assessing written documents in our classes is that when students enter our science classes they have left behind their English education. They don’t transfer that knowledge. They come into our science class and they act as though they have never had a
class in writing in their life. All of a sudden students who got As in their English class can’t write a complete sentence in a science class. I asked my colleagues in English why that was so.... Their response was that they had taught them how to do this.... The problem was that the students are caught compartmentalizing their education. They feel that in English they have to write complete understandable sentences, but in science, for some reason, we’re not interested in complete sentences. They [feel that] English and science are so fundamentally different that they don’t even have to bring over the skills that they were taught in English ... We have a multi-year, funded project by the National Science Foundation because they thought this was so terribly unique.... We’re trying to draw up a curriculum within English 111 that will address some of the science. We’re trying to teach the methods of science in English 111. It turns out that the scientific model applies to all fields.... The students don’t recognize that because it’s not taught that way. They will help the students realize that when they leave the English class that the same skills they learned there are the same skills that are being asked of them in their sciences classes. [They should be able] to evaluate something, to describe something, to suggest where a fallacy exists, to suggest where a test can be made, [ask] why an argument is correct or incorrect. Those are all things that are part of the scientific method that are being supposedly taught, but not transferred. We’re going to be getting together with the people in the science departments as well as the English departments and asking how is it that we can improve, not the science curriculum, but how can we improve the English curriculum? When the students come out of English 111 and go into these science classes they’re going to be able to say [that they have] seen this process before....

We say that sometimes there’s this difficulty of scientists talking to people in the humanities. It’s really true at some level, much to my surprise. I thought it was all just rhetoric, but it’s actually true that when I talk to my English colleagues, as a professional, some of the terms they use have very specific meanings. I just have a fuzzy feel for it. I think I know what they mean. For them it’s a matter of definition. It’s interesting to try to communicate at that level where you’re trying to deal with an issue as a scientist while uncertain about the terms being used. Talking about educational issues, like on how students learn, is difficult because we’re not trained in the vocabulary whereas the English people are trained in the vocabulary.... I’ve found that interaction interesting and sometimes frustrating. I feel we’re talking about the same thing, but we’re not quite there. Part of the problem is the language barrier. We’re supposed to be speaking English, but as a novice educator I’m trying to speak to a specialist using terms that I don’t know the precise meanings of. They assume I know the precise meanings, but I don’t. I don’t have that same kind of problem when talking to my science colleagues because we’re all at the same level of ignorance in terms of what the real technical meaning of this might be.... I don’t talk to people in the College of Education. But it’s probably true
[chuckle], in talking to people in education.... It's too bad that we don't do this more often.... This is the problem our students have, isn't it? Our students are not specialists. We are specialists. We major in specialized terms. If you're not used to those specialized terms, what's the result? A certain amount of confusion, isn't that what I just described in English? I don't think the faculty realize ... they tend to think that the students speak our language. You know what? They don't speak our language. You know how to make faculty realize it? Have them try and communicate with another faculty member in the humanities.... Maybe the words have different meanings and when I say I want to be interactive I mean I want my students to do something. Maybe when somebody else says they want to be interactive they mean [they] want to give a demonstration. I think maybe that's one of the reasons I'm concerned about this CETP class. I'm wondering if they have trouble in my class understanding me. They've got five instructors over there, all from different fields, all speaking a different language, none of which they know. After several weeks, when they finally get comfortable with one language they now can interpret, they're thrown [in with] a different instructor. We want [students to make] those connections on purpose as opposed to by accident. Maybe, accidentally, a light went on in our class. That's a shame, isn't it? I'd rather have it planned. I think we blew it.... If this class lives, somebody else is going to teach it. Nobody has a global view of this class except you and the students who have taken it both semesters. It's not clear to me how a faculty member or a new faculty member fits into this scheme. Even the ones in it don't have the global view. How can you expect the person coming into it fresh have any idea what they're supposed to do in this class? Maybe we have got to get at least a syllabus and lay them on the table and say, "Oh, you just happened to talk about what I talked about." And then we could say, "Well, it was all planned." We could say there's the framework.... We still need to get together and have a debriefing there.... How do we improve if we don't know what we did? ...

This is not an area that scientists are trained in, science education.... When we start out in the profession, I think that we're basically geared towards becoming a productive scientist and education is important, but certainly secondary. You hear that today on university campuses where the phrase that new faculty members seem to be indoctrinated with "Publish or perish." It's not, "Do a good job in the classroom or perish." The university sends a signal to its faculty, as does the department itself, that although education isn't to be dismissed it's not to be one's primary concern.... As a scientist you just cannot be happy working with a model that produces less than satisfactory results. Your scientific training will begin to overwhelm the considerations that the others tell you about. You shouldn't give it a high priority. If I think you're a good scientist, then you look at things beyond your immediate discipline in the context of the way you work in science. That's going to point the direction of science education reform. I think this is something that naturally evolves in faculty members, perhaps not at a
conscience level that they are thinking in terms of this ... It eats away at their resistance. That is both within you in trying something new and is institutionalized in the context of the university’s promotion and tenure system....

I’m interested in science education reform now because I think I’ve identified something that will work well.... [It] is an area that’s becoming more and more popular among scientists.... Ten years ago all you would have found at [the American Astronomical Society] meetings were reports in the different areas of astronomical research [dealing with] galaxies, planets, and stars.... At the last astronomical society meeting just held in Austin this January there were at least two sessions that dealt with science education. Both of those sessions were very well attended ... I see the professional astronomical community sort of evolving from a society that was really interested solely in astronomy for astronomy’s sake into astronomical education. By definition, these projects presented at the meeting automatically fall into the category of reform.... Generally that is not a straight lecture....

The problems that I see with technology are that they really haven’t been proven effective tools.... It could be that our computer-based instruction is headed in the same direction [as the optical disc]. It’s the current “wow” technology, but ultimately people look at it beyond the “wow” aspect of it and ask, “Is it effective? We’re now in the evaluation period for this kind of technology and I hope that we’ll begin to see more evidence that this technology is useful. If the proof is there, then I think I’d want to use it....

I have seen advertisements about web-based material.... I’m still not convinced that those modules are any more effective than if you just gave the students a sheet of paper with problems on it and asked the student to work the problems.... Presently, people are enthralled with making the modules [without] testing their effectiveness. They assume that because they made it, by definition it’s effective.... I was just on a board over in the College of Arts and Sciences looking at putting in proposals to the National Science Foundation on science education. One of the people there was just adamant that we had to revolve around the web.... I asked, “How are we going to specifically use the web, as a teaching tool?” The response I got was, “We’ve got to use the web.” It’s just become the catchword of the day....

Changes are not always beneficial. I think that educational reform is almost like science.... One of the realizations that we need is that science reform is a process. It doesn’t necessarily have a conclusion. Why would I want to go back to something which is ineffective? I guess it’s a scientific method. It’s an evolving model. Models rarely go back in time, they go forward....

I love the term disequilibrium ... We’re looking for an absolute truth [and] we’ll probably never recognize the absolute truth anymore so than we do in any other sciences. It doesn’t mean that we don’t continue to plod on. The analogy is we’re plodding onward. We’re not going to go backwards.
The problem is what’s true for one individual is not true for another. Although I’m ready to move onward, new faculty have just started that journey. They’re coming in at the place where the model was ten years ago. The sad part is it doesn’t make any sense to keep going over ground which is ineffective. Without the body of data to show the new faculty that this is not the correct approach, they’re going to plow the same ground. It’s almost guaranteed. The faculty in [the CETP] program are not new faculty. I’ve been around for a long time, [the earth science professor] has been around for a long time. I don’t think we will break the cycle because we’re a nut in a big machine. We are a cell in an animal. We’re just not big enough. We’ll effect our students, but our students are a dozen so that’s not going to change the system. If we can develop a good model and show that that model is effective, then I think it will be adopted elsewhere. This is why we really have to get together to make sure that what we’re doing is developing this good model ... What we should be looking at is getting this thing outside of the walls of [our institution]. If you want to change the structure, you’ve got to reach the people who are in command of the structure. And they’re far beyond the walls of [this university]....

People are interested in the change, but you come away with the frustration that we’re not sure which change is the correct way to go because none of them presented evidence that their change was the correct way to go. I agree that there may be many correct ways. If that’s true, there may be many incorrect ways. By and large, science instruction is carried out at universities in lecture format and the consequence is a scientifically illiterate population.... [Tobias’] book presents some models that have worked, but it also presents some different things that didn’t work at universities and that it’s difficult for a person who’s developed a model to admit that that model is not correct.... Why are people using ineffective models? They’re using ineffective models because they devised those models and what you’re seeing is that resistance to let go of something. It might be that we’re not as far away as we think. We don’t have to invent another instructional tool like the Web. We don’t need the Web. The Web’s not our salvation. We’ve already got the tools. It’s just that we haven’t realized how to put them together into an effective format. Or the Web might be one of those tools that we still haven’t learned how to put it together into an effective framework.

When instructors are sent textbooks ... They are now subconsciously slaves to this book and they have got to teach what’s in the book. You get so caught up with the material in each chapter because students are going to read it and [instructors] have to be prepared to say something about it. You lose sight of what the goal is. You’re more ... content bound. It becomes irrelevant as to whether it’s relevant or not. The relevant thing is it’s in the book.... The book really isn’t intended to be an instructional tool. The book is more intended to be an encyclopedia of the field as a reference. Maybe that’s why we’re accused in the science classes of just teaching the facts.... I don’t think we ask if this book is particularly student friendly or what is the global
aim of this book?... Most textbooks in the sciences teach facts. If it [teaches] processes, it revolves around minuta, the small things in the context of the science not in the context of reality or beyond the science.... The way in which a teacher presents the material is [influenced by] the textbook, not some higher vision of science education. I think I do [look at alternatives], but maybe I don't. I do use a textbook, so maybe I'm just as guilty as the next person and I'm just criticizing them where I should be criticizing myself.

I think that most instructors have [a reflective] moment at the end of the semester when they're looking at their final grades ... When it's over, it's kind of like an avalanche of material and you're right there before the avalanche hits, surveying the scene. Then, all of a sudden, you're overwhelmed into the turmoil of events. Those pleasant thoughts that you had kind of fade with the reality of creating another semester's worth of material for [your] students. I think what we're saying here would be a shock to the university administration who feels this is what we do all the time. The instructors spend significant amounts of time reflecting on what it is we actually want our students to learn, how we're going to get there and those sorts of questions. I think they'd be shocked to hear that that's probably closer to what's actually going on. I think it's something that should be done. But it's not something that the university itself seems to value in terms of promotion and tenure....

I think a good example of an educational system out of control is the College of Education. The number of classes that they require for their teaching certificate is ridiculous relative to the content of some of these classes. They need to get their act together and ask a similar question of their own majors. What is really important here? You have your poor students taking sixty hours in education classes beyond what their major requires.... Whenever I talk to real teachers in the trenches, they tell me that eighty percent of what they got from the college of education is worthless. This is really sad ... Maybe these teachers don't tell this to the College of Education.... I'm not familiar with classes over in education, but the same things that are being taught in one class are being taught over in [another] class. That means you could sort of combine the information given in six classes into one. It's a great saving of time for our students. It could be perhaps spent more productively. What I would hate to see happen is that this reformed science class is successful and therefore the College of Education requires it of their students in addition to everything they're already taking now. If it's good it ought to replace something that wasn't good. Generally, "replace" is not a word the university uses very frequently. The credit hours that some department will lose could add to the resistance to accept it.... The problem is not all with our students, is it? The problem is institutionalized. I think universities move perhaps at a glacial rate of reform. Although we claim that this is a hotbed of reform at the universities.... We didn't get into this situation overnight. We're not going to get out of this situation overnight. People recognize there's a problem. They're struggling for a solution.
I’m not sure we’ll ever get there in terms of a perfect solution. I think we’ll get there in terms of a better way of doing things. How much time and how many students are going to be sacrificed on the pillar of inactivity at the university? It’s an unfortunate fact that maybe goes back to what I’ve been crying about in the last few times, data, data, data. When you have very intelligent people with their conflicting opinions, what is the reason for one to change and another not to accept that change? Without the data, I don’t think there is a compelling reason....

I’m not sure what [the reformed course coordinator] has got in mind. The first semester was just really wrenching in terms of just trying to come up with a consensus on anything. It seemed like we were just perpetually going in a circle. We’d all agree on the catchwords even though we didn’t define the catchwords the same way ... It was a surprise to me that we even came to a consensus. At our last meeting, [the coordinator] sort of announced what our consensus was. I didn’t see us evolve to that..... I think that was mainly [the coordinator realizing] this new semester’s only a month away and he felt he had to do something rather than [doing] a thoughtful thrashing out and building of a consensus.... It wasn’t [that] we didn’t share the same goal on to how to get there even though we all had our own individual goal of how to get there.... It’s a starting point. We all lived through it. In the future we will presumably get together and look at what we did. Then we’ll evolve it, which is great.... It’s now time to discuss if we want to continue the initial model....

This experiment that you’re running it’s sort of a microcosm of a bigger world at the university. You’ve got six faculty and there’s hundreds of faculty out there. It’d be interesting to see how we six, who are presumably kind of the radicals among the faculty, have the same vision or is it truly chaotic? Even the radicals don’t really have any clear unity of view as to what’s to be done. So it’ll be fascinating from that perspective. The hopeful result will be that there is sort of at least a consensus on some issues among the radicals. If that’s true, then there’s hope for that to trickle down and maybe infect the rest of the faculty. We’ll see.

David.

I’ve always been interested in science from as little as I can remember.... It must have been something to do with the way our parents brought us up. It started off as a love of nature. I was always interested and curious about what made animals behave the way they do. In grade school I would find and look at and examine and bring home all sorts of things.... I always sort of gravitated towards the sciences in terms of what I did kinds of things that I excelled at.... I knew I was going to go into one of the sciences.... But one of the things that I was always interested in was fisheries, I don’t know why,... probably because I came out of the northwest and there was water all around us. A lot of undergrads wanted to become marine biologists.... I was always wanting to do research of some sort.... When I was
going into grad school I was really running on the assumption that I would either work in the private sector or I would work in the government some place and I really wouldn’t be involved in teaching and education so much. I took a lot of interest in terms of teaching on an individual basis. The researchers that come in and are new hires think as scientists. I always was noting that students coming up at under-grad had a really wide range of capabilities. A lot of them were so inefficient in terms of being able to [apply] what they had learned in classroom. In a sense, they weren’t taught how to think and so we were having to sort of re-educate [them]. You have to re-educate students on how to think critically, how to think scientifically, how to analyze data and how to take the observation and make sense out of it.

How to ask questions is one of the things, it’s almost innate, but it’s brought about by your own experiences through educational processes. [Scientists] sort of mold that curiosity into questions and eventually answers. After I got my Ph.D. I was working in a government job. I got out of direct interaction [with students]. I found myself missing interaction with the students. Then I found out that as I got away from graduate school, I was missing that atmosphere and missing some of that enthusiasm that students bring. In the academic setting there is interaction with students. As you get out of it, you start to get jaded more and you think more cynically and that’s what happened.... I had never taught a class, never TA’d a class, even when I was in grad school. Because my assumption was that I probably wasn’t interested in teaching college.... I got my Ph.D. in 1991. Incidentally, I was a post-doc or post-graduate for almost 5 years before I came here. I was working for a government institution and private sectors in joint ventures.... I didn’t particularly like the environment that ... And I was thinking that after it was all said and done a lot of what academics have to offer was really what I was most interested in doing.... I would be spending a lot more time on the job in this position than I was in my previous position. This position offered me more of what I was doing and that was really I think to not only stretch myself into doing research, but also being involved in teaching, and [mentoring] graduate students.

I came out of a very large institution where the classes had several hundred to easily five hundred. That’s one of the reasons why this was so attractive to me, I saw the sort of a mass production factory mediated way of undergraduate education where I came from. For some students it was fine, for others you really need that individual attention. It was really an impersonal approach to teaching and [since] it was a research institution, the professors did not focus on teaching.... I saw this as an opportunity to correct some things that were lost in the major institutions. Where I was, interactions with the professors were almost discouraged. They really did not want you in their office. They didn’t have the time or the inclination. There are not a lot of things one can do when you’re sitting in a lecture hall that looks like a movie theatre where you have tiers and you might be on the second balcony
looking down at the lecturer. [Maybe] hire more professors or hire instructors to give the class....

I give handouts for every lecture that I give. There's a synopsis of the lecture as a way of giving the students a greater opportunity to listen rather than to listen and write at the same time.... I still form my classes on lectures and exams. And then I give out problem sets that are take home, that are open book so they can talk among themselves. They come and see me as a way of facilitating individualized thinking and to give them the ability to have access in the classroom and then to encourage one-on-one interactions within themselves. I encourage them to come and see me. I keep office hours, but I don't really, if they knock on my door. I give them a little bit more support than what's available rather than strictly lecture and having them listen to what I have to say. I have actually summarized some of that important information so that it really points to some of the concepts that I think that are important. It helps give them a roadmap so then they can ask questions.... Can they demonstrate to you and can they take that information and synthesize it, come up with some sort of response?
The first year you go in totally blind. You have no idea what the student's backgrounds are. People don't know what to expect and I had never taught this class before. I found out that students snap up certain parts they are very interested in and teaching is really pretty simple. The only hard part is figuring out how we can limit what we can cover in a semester. You present topics and you hit upon things ... in certain lectures there won't be much response and in other lectures you just generally answer questions.... If a student comes to me and says, "You know, after taking your immunology class, now I really want to study immunology." To me that means I've done my job. I stimulated interest in a discipline that now they are beyond the course they're interested in pursuing and to me, at a 450 and above level, that's really one of my jobs.... In immunology and virology you'll find me saying, "I don't know." That sort of peaks their interest. We should get to a level where the instructor doesn't know what the answers are. If we're really brushing up on the edge of what is known and entering the unknown. That is a revelation.... When we start to talk about unknowns, then they realize science is a continuum as ever expanding and when you reach a certain level at the university, you're at that threshold where the beyond is the unknown.... our level of understanding is as far as it goes....

When I first arrived, I was told that there's a certain segment of the population in a class that is going to get an A, even if you stand up in front of the board and inspire gibberish. Then there's some segment of the population ... that is going to struggle ... they're going to get Ds and Fs. I think that's right.... There is always going to be nine or ten percent of the population ... somewhere along the way that gets derailed because there wasn't enough support or the teaching style wasn't correct ... Maybe they ought to be doing something else that they would actually be better at. Some of that sort of
people that have sort of fallen through the cracks maybe simply due to a mismatch of their expertise....

CETP is a two-way street. I see it as an opportunity to educate students, but I also see it as an opportunity to educate professors. And with my background, with limited teaching and high skewedness towards upper division classes, I didn’t get the opportunity to teach or to interact with freshmen and sophomore students. What I see is that students have already been shaped by three years of undergraduate education.... Part of [my involvement with CETP] was education on my part. I wanted to see if we could do some of the things that I’ve been wanting to do or I could have done with seniors ... it was sort of an educational experiment ... and to get some experience with different kinds of students.... We don’t have any formal education in terms of teaching and so we’re learning ... to see if some of the things that we talked about in that course could actually be transcended into some of the other classes. There may be some things that apply, especially in some of the lower division.

Sooner or later I will teach 211. So I will get an opportunity to interact with freshmen and sophomore students, but I just haven’t had that opportunity, so this will be a good learning tool.... In a sense, teaching is easier in upper division classes because most of them have defined what it is they want to do.... By the time they come into immunology, they really want to learn about immunology. That may not be necessarily the case when you’re teaching incoming general science class. So it may be more important to create the atmosphere and ask the student to be more proactive.... I wouldn’t approach the CETP class the way I would approach the upper division courses. They’re completely different objectives in terms of what I’m trying to do. With the CETP course, there were really two things that I was looking for. One was just increasing their awareness and understanding of science ... and then also to begin to instill some notion of teaching.... As an instructor, I’m always interested in being better, putting myself in situations that make me do things differently.... In every class that I teach, I’m also learning what’s working, what’s not working. Sections of what I presented appear to be well understood and other sections are a total loss. Critical thinking that I thought I was being encouraging was not. And so, constantly I’m evaluating what I’m doing. This was a chance to grow as an instructor....

I don’t remember who told me that this CETP thing was going on and they’re really interested in promoting science skills ... and enhancing the quality of science education. That’s how I sort of got into it, almost by accident. I already felt like there is a large segment of the population who is turned off by science and that we aren’t doing a very good job with outreach ... I was reaching only a segment of the population.... I thought about it and said this could be kind of fun. It’ll be a chance to interact with a totally different group of students and to actually talk to more experienced professors and see what they have to say about teaching ... at the same time spreading my horizon in terms of the way I view teaching ... I don’t have the formal exposure to teaching. I just thought that this would be kind of a neat little way
to actually be a little bit more proactive.... Some people are more proactive and are very innovative in the way they teach. Others are not....

I was just at an ASM [American Society of Microbiology] meeting last month and they were talking about ASM funding curriculum development for undergraduate microbiology. One of the things they were doing is probing online education ... interactive courses that instructors can integrate into their courses.... The society is interested in new approaches to traditional science. I need to maintain a pretty heavy focus on writing, but I feel a responsibility towards my teaching too.... the clientele that I’m really reaching for on a daily basis is really the science majors. I’m training graduate students ... training people to be interested in that respect.... If innovations are done early, I will have students that are better prepared for course work. Instead of twenty students, I may have fifty students. Instead of having ten minority students in my class, I may have thirty minority students. We might see a greater representation of students in what we want to call hard-core science classes.... In this country, if you look at the graduate programs in let’s say microbiology, and I think most of the sciences are going to see more and more foreign students in the graduate population. Why is that? One way to interpret that is we’re not doing good enough job educating our American students to be competitive and to want to go to graduate school. There could be a number of reasons for it. One is graduate school is not easy.... There’s a lot of sacrifices.... These students are more competitive than our homegrown students. There aren’t even enough applicants to recruit the necessary graduate students. Our scientific base when we talk about recruiting in science is just not, we’re losing a lot of women. In spite of affirmative action, in spite of everything that we’re doing, you still see very small numbers of minority students. I think it comes back now to this basic science at the primary, secondary and the undergraduate level. Even though I’m at this level doesn’t necessarily mean that I’m immune or don’t understand what’s going on in the lower level and that whatever goes on in the lower level doesn’t affect me.... So they’ll do better in my class or I could teach at a higher level....

Generally speaking, the level of preparedness of undergraduate students for science disciplines is not the way it was. I always notice that every generation says that. Technology is changing and our students are changing with it.... The general thought is that the level of graduate students is deteriorating quite a bit in the last fifteen years. We’re seeing less drive from the students.... I think television, students tend to have shorter attention spans now. Expect results sooner. They are less likely to maybe think through processes. There is more of a tendency towards instant gratification. They don’t read as much as previous generations. The environment’s changed and so maybe our teaching methods have to change....

I try to get my classes so that they’re late in the morning or early in the afternoon. I spend an hour or so going over what I’m going to be talking about that day, getting out the material that I’m going to be covering for that
day’s lecture ... incorporating or redoing lecture notes, getting Xeroxes ready for class time, reviews for the upcoming exam or something like that.... I’ll have students come in with questions ... the more questions people ask, the better vibes I get as an instructor.... If they don’t ask questions, either I’m not interesting or I am so far above their heads that they don’t even know how to ask questions. In order to ask a question you have to know something. A third option is I’m so intimidating they do not feel comfortable coming in. Anyway, all those things I treat as bad vibes, especially if it’s coupled with very little interaction going on in the lecture.... On average, maybe twenty to thirty percent of the class would actually ever come by, the rest of them won’t or don’t.

I do the advising for pre-health, med school, dental school, veterinary school some, any kind of physical therapy any of those post graduation specialty areas. A lot of my time is spent mentoring graduate students.... I expect Ph.D. students to be more independent, to be able to produce independent critical thinking a little bit more organized and at a higher level than a masters student. A masters student is going to require a little bit more day to day managing on my part.... My job, at the masters level, is to encourage them to develop skills so that they are as independent as possible, but not to the level of the Ph.D. [Their research] is related to research that I’m interested in. Normally, on the masters level, I pretty much give them a project and then it’s their individual capabilities or abilities that dictate how much involvement I have from there. I tell them what the question is, what the project overall is going to be and then I’d like them to fill in as much of the details as possible with as much help from my end as needed.... My research is being carried out through my students because I don’t have time. In order to be keeping moderately productive in the laboratory, I need to spend at least half of my hours in the lab and I can’t do that on a regular basis.... I probably write six, seven, eight grants a year, but I am not writing a grant right now. That’ll change in the next couple of weeks. Grant writing is an instrumental part of training the graduate students. Without the grants, they don’t have the supplies, I can’t get them on RA-ships ... Another part of it is has nothing to do with teaching is management, results of our research, sometimes through article writing. It may be that one of the students gets first author and writes the thing with my help. Or, I write it and then co-author, it just depends on the student, the situation they’re at and their contribution to the research. That’s the ultimate thing. In a research discipline like we are in, when they write their CVs [curriculum vitae], one of the things they’re going to be looking for is whether they have any publications coming out of their graduate training.... My goal is to have every student that comes through here give presentations at scientific meetings, at least have the opportunity get themselves in publications. Remember, I haven’t been here very long. I’ve only had one masters student go through and now she’s in the Ph.D. program. I don’t have a big track record here.... As a research institution, and being in a department that is producing M.S. and Ph.D. students that are supposed to do
research, one of the major functions that I have is producing graduate students that are capable of competing at the national level. And so this part of the education process is very important to me because it is very dependent on my ability to get tenure. I make part of my personal objectives to train graduate students for the work place ... Realizing that there is a lot overlap between teaching and research. I don’t know if [involvement in CETP] qualifies as service. That might go under teaching....

I’ve never come in contact with any [high school teachers in our graduate school]. That would be tough in a science discipline because research takes a lot of time.... I think what might happen is that they get their masters first and then go back, and they teach. There is the option of a non-thesis masters. I actually do know of one, I think he just graduated in fact. He was a non-thesis biology masters degree student and his objective was to teach....

We have evaluations that we give at the end of every semester that students fill out and then you can take that information and assimilate it to figure out where your strengths and weaknesses are. I use that quite a bit as a way of determining where the students think I may need to improve.... basically you’re on your own [to improve pedagogically]. You can talk to colleagues about this such and such, sitting on a lecture and have them evaluate your teaching style. You’re encouraged to develop a teaching portfolio, but not required to do so. It’s to keep sort of a log of what changes you’re making, what kinds of things are you trying to integrate, how you’re trying to improve your teaching skills, documenting your philosophy about teaching, how it’s changing all the time. Sort of a teaching evaluation of your year-to-year progression or evolution of yourself as a teacher. You can put it in as part of your annual review and when you come up for tenure. I haven’t used peer evaluation...

Every student learns in a different way. Obviously you’re not likely to be able to approach every student in an individualized way.... I made the decision very early on that I would rather have students write less and listen more than have them mindlessly writing down what it is I’m trying to say and maybe not really listening. Then I would have a detailed list of certain kinds of questions. Some are very open-ended. Others are very specific on things that I think are considered important. I give them the opportunity to use that as sort of a guide to things that I think are important or that gives them an opportunity to write because you learn by reading, listening and writing. Typically you learn at different levels. Listening is usually the worst way of learning. Writing and being proactive is going to be more conducive to remembering.

Their grades come from exams and problem sets. Learning is the acquisition of knowledge. Depending on how you ask the question, it does not only measure the amount of learning, but it also does measure their ability to take what they’ve learned and interpret it and formulate it in a question. The graduate students aren’t being evaluated on the ability to go to presentations. It’s more for their benefit than it is for us. It’s a way for them
to acquire tools that I think they need when they get out. I almost see that as a secondary objective. My primary objective is to give them opportunity to put themselves in a learning situation.... [Presentations] are not necessarily a tool for me to evaluate their progress. That’s where the problem sets come in. I can’t do that on a test. They don’t have that luxury of time. Nor do I want them to be evaluated on ability to write fast. With the problem sets, I have the luxury of not having them be done in that period of an hour. They can take it home and talk to me or talk to others. They can interact with other people and then begin to answer the question. They can go to the library, they can read articles if they want to do that. They can have time for innovative thinking.... So it serves two purposes. It serves the purpose of exams and the other as another mechanism to encourage them to be pro-active in terms of keeping up on what’s being covered in class. I don’t like take-home exams really, as sort of a philosophy, unless you are open-book, open-note, open-conversation because then you run into problem potentially. Other students are depending on what rules you set for that take-home exam, whether those students are really abiding by those rules. I have not done it, but other people in our department have and they’ve had problems with students not abiding by the rules. So rather than tempt fate [chuckle]. We catch students cheating on exams, even in the lecture hall they cheat. You have to have documentation. You have to go through prescribed procedures. And then you have to be prepared to be sued.... In a sense, a lot of the action has been taken out of our hands and it’s been replaced by administrative process. I think students feel that the certificate is more important than the process. And for the instructor the process is more important. [They] are more prone to memorize than really understand because they can get a good enough grade by memorizing even though maybe the level of understanding isn’t that great. In the short term it doesn’t matter, but in the long term, it may. I think at the university level there’s not much you can do except create environments where cheating is hard to do. I think that the value system is being instilled at the grade school and up through high school and they’re already sort of set by the time they get to college.

In the reformed 121 class I gave out projects. There’s a danger in projects. And it goes all the way from primary up to college. Where if you divide up your classes [into groups], maybe you’re going to get unequal participation from the students. One or two of those people may give more of themselves than the other, but in the end they all get the same grade. I pointed out that that’s part of life, willing to work together and interacting and then coming out with a product that everybody feels comfortable with. That is a real life scenario on a sort of a scale that’s actually outside of what we’re actually teaching. And that’s interaction and organization skills that a group develops in the course of that project. So that in the end product is something that they all feel equally a part of. It’s also sort of a secondary skill.

I always think about increasing my ability to link what you talk about in your class. Making it more approachable, making it seem more real.
Attentiveness starts to go up.... it's a barrier to learning when you don't see the relevance.... I think that's one of the axioms of that 121 class, was to instill relevancy instill sort of a relatedness to what we're talking about in our own lives ... I'm always curious about, and can I deviate from some of the standard methods that I'm doing now? I thought it was refreshing. It didn't change the way I perceived [non-majors] at all. I think it reinforced what I thought, that the student population is made up of a broad spectrum of individuals and when we teach at a given level we are only seeing a minority of the population. When we start to look at the rest of the population, then your teaching skills have to change. The breadth of knowledge of just basic skills can be pretty low for non-majors or even majors. And sometimes that's discouraging that the students are not at a higher level of understanding when they come into the university scenario.... Some of [the 121 projects] were very well put together. I told them not only to think of them scientifically, but think of them as PR, as a way of disseminating information to a lay audience. Some of them thought about how to attract the attention of people and so they integrated that ... and so that might be an exercise that I could instill in my courses or some facet of that. [Long pause]

If you are entertaining the idea of getting into teaching, then that's probably not a bad thing [to get technology and methods training]. I think that would definitely help in terms of at least giving some support, organized support for Ph.D.s that eventually go into teaching.... In the CETP format, what happens if your class is now one hundred and fifty? Can this format work realistically looking at resources? Can you do this now ... for everybody in the program? We need to break the class down, so it won't work, I don't think. What happens when we have some team taught by a number of professors? Instead of one section, what if you had ten sections? How does that work? Impossible. So there's the problem and then what do you do? The select few might get this opportunity? That was one of the questions that I had for [the 121 coordinator]. He said that this is a trial balloon. Assuming it's a superior approach and that we see tangible advantages to this approach, what if students wouldn't want to do this in bigger numbers. I don't think we can measure what effect it had on these students. I'd like to see them in the classroom when they're done, teaching their classes. I'd like to see how they're integrating their science into the curriculum and how that curriculum may be different ... some sort of tangible measuring ability for whether or not this was beneficial for them. There needs to be some sort of outcome assessment on the course. If you added up the man hours that the professors put into making this course, and then add that up the man hours of a single individual generating the one semester of biology, I'm going to bet that the professors poured into this class a lot more in total hours.... The people that take Biology 111 and that are taking it to satisfy this general education requirement, what portion of that is actually fulfilling the general science course? What portion of those students are
actually there because they want to be biology majors? When you get into these creative methods, there is the tendency that you go down in class size. Instructor to student ratio also drops. It's going to cost more money. It's going to take more resources to get this.... If your audience is general education students and then you have an audience that's taking the same class that want to eventually go into one of the sciences, can you teach both groups the same way and be equally effective for both groups? In this innovative format, one thing that happens is that you are able to cover much less material and I'm not saying that's good or bad, but you can't cover as much material in the innovative program that you can in a more traditional lecture format.... It may be better suited for the general education groups, but may not be as well suited for a person going into one of the sciences....

I wonder if you restrict their breadth of knowledge ... there may be gaps in their information ... I'd like to see scientific evidence that suggests that you can do innovative teaching focusing on major concepts and really looking at not so much breadth of knowledge but intensity of knowledge. Take and put the students through and compare it to a group of students of a like background and then do a study to see if you can measure differences between the groups. I think until you do that, then I feel uncomfortable because I don't know if we should commit to a system that we don't have any real knowledge as to whether it actually works or not.... We already know that what we're doing now works at some level. But for us to say we're going to not junk it, but we're going to modify it significantly to a different system, I would have to have some confidence that that new system was going to be at least as good if not better than the existing system.... I think anytime you're asking somebody to make some change in anything they're going to want to see some evidence that is persuasive and scientifically sound.

I don't disagree that for a certain segment of the population, this approach is preferable. If we target the dropout rate as the clientele that we really want to get them to drop the dropout rate, we've really targeted a population. Whereas if we say we're going to take the entire population and we're going to now change the curriculum for the whole population, then I think that's asking a different question at this point. You have to be more careful than taking the population that right now are not doing the job. This is not working and taking what we think would work for that segment of the population and altering it to make that group better.... I think it goes back to that every student is different. I don't know of any one process that can hold the attention or drive the learning for everybody. I think the student teacher ratios are something that was always discussed. And the assumption, it may not be a good assumption because the assumption is that the lower the ratio the better the quality of education. That might not be true, but I think it one component of higher education is to decrease class size.... I'm an advocate for individualized tailoring of students to not try to make students perform necessarily to one way of doing things and try and say that one way is better than the other way.... What I'd like to see is that the base of science be
elevated more so that the whole populace in general understands science better than it is now.... If we improved education from K-12, then when we get those students that come in to the college that maybe we can still use a fairly traditional approach because now the bottom has been raised.

I have not been educated as an educator. A lot of what I do is on-the-job training. My involvement [with CETP] was to learn alternative teaching methods and also to educate myself about aspects of alternative teaching.... I'm not involved in introductory science courses yet and I’ve only been here a few years. Now I'm very interested in continuing some involvement with CETP. I have learned a lot more about what alternative teaching is really all about and actually being able to use some alternative methods and applying it to our teaching. Some of which I may be able to incorporate into upper level biology courses. And so I have a vested interest from a lot of different angles. Also, in addition to the end result is that I see more and better students coming in to my classes. I would like to take part in alternative teaching especially towards the introductory courses....

You're asking if at the undergraduate level whether we should have instructors that are dedicated as teachers and then we should have researchers who do the research.

I think the argument for having research institutions also teach or teaching institutions also doing research is that then you have the opportunity of research impregnating an experience from research impregnating the courses. If you have an instructor just doing teaching and no research, you may be leaving out a dimension.... I know that in some institutions they have compromise. In the lower division, if you’ve got two courses and they may have instructors, then the upper division courses may be taught by research professors or professors that also know research. And that might make sense too because in the upper levels maybe they have greater opportunities to interject more research. That’s not completely true either. Even in lower division classes you can add texture to whatever it is that you’re teaching if you can directly have personal experience and directly interject that into the course. It gives it some sort of reality. I don’t think you can necessarily say experience from research is not important.... I know that at any institution there are some professors who really do not want to teach. But because of where they’re at they have to teach and they’re effort reflects that....

I think it’s the training of the teachers that are going to be teaching K-12 classes, in terms of their science knowledge or their comfortableness with science. It’s their being trained in teaching methods. Having the resources in those areas so that there is a student teacher ratio and equipment and so on ... And then that sort of carries on once you get into the university but I don’t think you can fix the problem at the university level.... One is the education of knowledge of the students and the other one is the ability of the teachers to teach science. So CETP is one of the things that we’re looking at, quality or development of teachers ... the development of students, I think should be concentrated on earlier during the formative years when the impressions are
being made. By the time they’re seniors at high school, they’ve already made their decisions as far as wanting to pursue science or not.

One of the ways to address that is for the university to put some resources in the educational process of the primary educators. At the very rudimentary level, if they’re shaky with science when they teach it, it’s going to reflect it... we need teachers that are as excited as comfortable as if they were teaching English or something. And most of these teachers are going to be teaching everything... And they learn not just the science but maybe how to integrate that science in the classroom.

Change at the university level might be more doable if you were asked to reform one of your courses rather than taking on an extra class, like the 121 course. I’ve thought about integrating... If I were just teaching, and my evaluations were based on teaching, that’s a different environment so I may be more likely to make some changes... The best way to learn is by doing. By being pro-active, by doing what you’re teaching, but in many cases that’s practically difficult. You’ll certainly learn more about microbiology if you do microbiology... but we can’t teach everything that way. It takes many more time to teach that way. There are ways of doing things without actually doing them [problem sets]. I think you have to understand something you have to teach. So teaching is a really good way to understand something. I retain a lot more of what I teach... I want to make science available to all. I would be interested in getting involved in approaches to answer educational issues. I think CETP is an example of that opportunity. And so those opportunities present themselves again and the timing was right and the resources available. I think when Biology 211 pops up... I will be keeping the ideas of CETP and trying to be a little bit more innovative. And more pro-active in terms of getting the students to learn in multiple processes... when opportunities like that pop up I will use what I learned and try to incorporate some of that into the presentations... I did talk to a couple or three professors about that. All of us are really working long hours and we hesitate to get involved in something that requires more time. And it certainly is difficult working on something (where you have to spend additional time preparing for it). Then you have to make a judgment decision as to how important it is. [Long pause]

One of the things you could do, if you got resources, is to hire instructors to teach the general education or science reform of primary and secondary science majors. It’s going to be, resources permitting, easier because here you can ask those who are devoted to that where that is one of the main functions and that person [can] be available all the time.

**Sophia.**

I don’t come from a professional family, but instead grew up as a suburban kid very interested in nature and the outdoors. It was through schooling efforts outreached by some of the universities in the metropolitan area where I was growing up and through things like public TV that I became
aware of science as a career option, especially for a female. I majored in biology in college at a large state university; as I came to know more faculty members and graduate students I became aware of the tension between research and teaching as areas of focus for biology professors. I became more interested in teaching myself because I saw how important those professors had been for me as a first generation college student in a state university. I wanted to be in a position to do something similar for other students who maybe didn’t visualize themselves as scientists or as being capable of understanding or enjoying science. As I got closer to graduating and started thinking about graduate school I was interested in college level teaching as my real focus. At that time the Danforth Foundation was still funding graduate fellowships that were aimed at people who wanted to become professors; people who wanted to teach in academia as opposed to people who wanted to be research scholars only in academia. I was fortunate enough to get one of those Danforth graduate fellowships. That’s probably the experience that first helped me think critically about professors and what professors do and take something other than the traditional scientist content centered approach to teaching.... It had workshops and conferences that really encouraged people to think about the teaching of science as an endeavor separate from science itself.

In graduate school and then in my post-doc I became seduced by research as an end in itself and I started to think of myself in more positive terms as a scientific contributor and not just as an educator. In the end, I was happy to land a job in a research university, but one where teaching is important as opposed to seeking jobs only in a liberal arts college where teaching would be a much larger or almost the sole activity expected of a professor.... I’ve been happy to combine teaching to both science majors and non-majors with my research program. The nature of the students that we have encourages those of us who are interested in being effective teachers to explore alternative options, not just assume that we can teach biology the way we as professional biologists related to it. In teaching our non-majors courses and teaching our general education courses I’ve kind of been forced into looking at alternative methods of presentation.

I’ve long been a member of the education section of my professional society that also encourages non-traditional, non-conventional approaches. I’ve worked with the public schools both before and after my son became a participant in the public schools. That’s also encouraged me to think about the preparation that these elementary school teachers have and how comfortable they feel in dealing with their science curriculum. When I was approached by the CETP project, I was primed to think of it as an opportunity to try some different teaching methods, to try and reach students who aren’t very well served by the existing courses in biology and to do something cross-disciplinary because in my own scientific research that’s been very important. It’s very obvious to me that science is not compartmentalized. The natural world’s not compartmentalized. So it makes sense to me that an integrated
approach works. For all those reasons, I was pretty enthusiastic when I heard the direction that the CETP project was taking in developing this integrated science course.

I was involved in an initial proposal to NSF to fund something similar.... I didn’t hear anything for two more years and then I heard from the dean that a proposal similar to that one has been funded.... There’s been a lot of push, not just in the last five years, but the last fifteen years, to incorporate something more closely approximating scientific investigation into the laboratory experiences we give even introductory students. We recognize that sitting in a large lecture room, memorizing facts given to you by the presenter, has nothing to do with what science is. This is how we expect to introduce students to science. It’s very ironic. At least in laboratories there’s long been a push for more investigation-like activities where students collect data and have to think about it in the context of answering a question or where they learn to formulate questions to begin with. In more recent years, AAAS [American Association for the Advancement of Science] especially has been pushing scientific literacy and reform of science education aimed at non-scientists....

Currently, the biology department curriculum, as revised a few years ago, now does not have a separate majors and non-majors course for freshman. We have a single general education approved sequence of two courses. One does require chemistry as a prerequisite; that one is not taken by nearly as many non-majors. The introductory concepts don’t really require chemistry as a background. It is open to both majors and non-majors, but the majority of students in there are non-majors. It also serves agriculture students, our own biology majors and prospective majors. They’re in there elbow to elbow and they’re exposed to the same concepts and vocabulary in the lecture. They’re also going through the same laboratory exercises which have been completely redesigned to be focused on inquiry and formulation of questions and hypotheses ... We very much use those principles in reforming our own introductory curriculum. From one semester to another, the reaction of the non-majors [varies as to] how they feel about being in there with majors. Most of the time the non-majors find it a very rewarding experience and they’re actually kind of “psyched” to be in there sitting next to students who are very motivated and very excited from day one....

I’d love to have some students from the college of education involved with our general biology labs. This is the first year that they’ve seemed to have a tenure track science educator over there that you could form some sort of long-term relationship with.... I’d be very excited about-trying to provide some support for our own graduate students who are thrust into teaching, maybe never thought about the teaching process, have no idea of education research, or what the issues are in science education reform. That would be very good for us, very helpful. Attitude is everything. [Chuckle]....

I think the one tension that we’re not able to resolve with regard to majors and non-majors is in [their] being in the same course. There is an
assumption in the other biology courses that people who've come in through the introductory sequence have mastered a certain set of vocabulary, concepts, and so forth. We restructured those introductory courses to be a two-semester sequence rather than a one-semester overview for majors so that they'd have time to master some of the more difficult concepts. Then you get to their sophomore year and you have to repeat it over and over and over again because they didn't really get it the first time. The problem with majors going into an integrated course such as the 121 is that there's no way that they'd be exposed to enough vocabulary or concepts to move on to any other biology course.... They do need to master a certain amount before they can get into a pharmacy program or a medical school or before they can take the MCAT or the GRE or move on to a technician's job or many of the other things that biology majors do after they graduate....

One reason I'm very excited about [the CETP course is because] I have worked with some of these elementary teachers. They have that bad taste in their mouths about science and they haven't grasped that doing science is asking questions rather than being a whiz at memorizing and taking very difficult exams.... I've been frustrated that we have a number of upper-division courses that are great for giving a student the flavor of carrying out scientific investigations. We almost never have education majors take those courses even though they may have had general biology and therefore they meet the prerequisites for taking those courses ... once they're in the teacher education program their curriculum is so well defined for them....

I have to base my opinion about [the effect on science professors that participate in a reformed course] on my colleague [that did participate]. I don't think he was ever involved in any professional teaching improvement activities before he participated in that. I know that he found a number of the concepts much more novel and much more foreign to the way he had been taught and the way he thought about teaching. He thought it was fun to be able to try things out in a smaller setting. When some of my colleagues, who've not thought about teaching as a professional activity, have been exposed to some of these innovative teaching techniques, their initial reaction has almost always [been], "Sounds great, can't do it when we've got three hundred people in Biology 111." ... We have colleagues who are very concerned about what we perceive or what's sometimes perceived as declining level of background with which people enter the university and university science courses.... With conveying information, it's easy to maybe come up with ways of hands-on or first-hand or manipulative kinds of experiences that will make up for or reach out to a broader range of people than those who are comfortable learning out of a textbook and learning from lectures. The quantitative reasoning, the mathematical reasoning which is so important to so much of science, that's harder to figure out how to address.... I think a lot of us perceive that [we are picking up the slack at the university]....

It wasn't until I went to graduate school that I started, and really until my post-doctoral experience, that I started thinking of myself more seriously
as a scientific contributor, as a researcher.... The faculty seemed equally excited about their Ph.D. graduates going out and getting jobs teaching at small colleges or at state universities as they were about their Ph.D. students going off and getting great research institution type jobs. I thrived on that atmosphere, very encouraging, supportive and a very diverse place too....

I came here in 1987 as an assistant professor. I was thrilled to be back in a land grant sort of setting ... very happy to be in a department where we do a lot of teaching. We have a lot of involvement with undergraduate students. We are also a Ph.D. granting department and we have fairly high research expectations. I really like that balance between teaching and research and thinking of ourselves as scholars in addition to being teachers.... The real pressure against participating in something like that [CETP] course is that we were asked to do that on top of our own teaching which is already a pretty heavy expectation. Something that allowed us to invest in our own courses here would probably have been easier or welcomed by a larger number of people, but there aren’t that many people who voluntarily take on a teaching overload.... I mean, many of us are happy with that balance, but we always feel stretched to the maximum ... In fact, if that course is successful, that will hurt our department by taking student credit hours away from our courses. There aren’t that many people who would volunteer to do that. Both of us felt committed to the idea of improving elementary education and the education of elementary educators and we felt interested in having an opportunity to develop our own teaching skills and try out some different techniques and think about science and about teaching in a different way....

There’s three sources that people might go to [for input on alternative teaching methods]. One is the Center for Educational Development on campus. They have monthly teaching seminars. Many of our faculty have attended some of those on occasion. I noticed that they tend to repeat the same ones year after year after year.... At an institution level there just doesn’t seem to be a big investment in improvement of instruction. Within the department, a lot of people talk to each other to get good ideas. Some of us, who have gone through the Writing Across the Curriculum workshop over in the English department, have brought back ideas from that and then those have really spread around the department pretty widely.... Those ideas then get talked about and transformed and applied to many different classes from an experience like that.... then interest kind of dropped off and I think people are so busy that they tend not to go on a regular basis to any scheduled seminars or activities.... In my own field, two out of the three main professional societies that I belong to have specific sections devoted to education.... They have developed educational materials for curriculum and resource materials like slide collections, book of laboratory exercises, web-based distribution of materials, web-based interaction among instructors or a syllabus exchange at the national meeting.... Recently several people from this department went in on a proposal. They were invited to submit a proposal to participate in a workshop that’s going to try and build more inquiry-based
approaches into the design of field biology courses. They are supposed to come back with specific ways of incorporating first hand or hands-on activities and inquiry-based activities into some of our upper division courses. What proportion of our faculty seek those out? Maybe half.

Even though [this university] says that research and teaching are each important parts of our job, we all know who gets the salary increases and who gets summer salary; people who have grants. The reward system is definitely skewed toward research. And my primary professional society has recognized that. One of the big projects that education section is running is aimed at the reward system within colleges and universities. They’re finding deans and vice-presidents and provosts to participate in these workshops, to talk about how can you build rewards for improvement of instruction, teaching innovation, teaching effectiveness. Science itself is what gets you grants that can generate your salaries. It’s what gets you a publication record that generates recognition. What most of us have experienced is that research grants are very comfortable paying summer salary for nine month faculty, but when I apply for a grant that has to do with undergraduate research experiences or undergraduate mentoring, usually PI salary is explicitly excluded. They assume that the institution supports its educational efforts. If it has anything to do with education, you can’t ask for salary. Why should it be that the College of Arts and Sciences provides seed money for research activities, but not for improvement of instruction? It’s because the dollars they use for that come from research grants’ indirect costs. Often when you apply for an education-related grant, indirect costs are very sharply limited whereas in a science-based research grant, they’re aware that there are many costs to research and that’s the basis behind indirect costs. Where’s the university going to get the money to improve instruction? The other thing is where do we all do our Ph.D.s? We all got our degrees in Ph.D. granting research institutions. You want to be like your mentors; big successful scientists, not big name educators. The culture is definitely oriented toward scientific research publication, toward grant getting as a measure of your success. The internal institutional culture doesn’t do a lot to counteract those pressures. The other thing is that people who are quite successful as research scientists, to the point that they attract substantial outside funding, they publish regularly, they have a national or international reputation. Those people are heavily recruited for jobs at other institutions. Therefore, the university often coughs up extra salary dollars to keep them here. It’s much less common for someone whose focus is science education to be recruited out of one basic science department into another. [The] citation analysis is very competitive, citations and grant dollars. That’s what it’s all about.

Our academic dean contacted science department heads and asked them to find faculty who were willing to participate in the development of this integrated science course. Our chair knew that I’d been involved earlier and asked if I was still interested. I was one of two representatives from biology who started participating in those planning meetings. Our job descriptions
are essentially fifty-fifty teaching and research. There's a slight discrepancy there where fifty percent of our formal job description is teaching, forty five percent is research, five percent is service. The reward structure is such that it's kind of silly to think of research as meaning less to our jobs than teaching does.... Last semester, in addition to the integrated natural sciences course, I was teaching our largest general education survey course, Biology 111, which basically had two lecture sessions with two hundred seventy in a class.... I'm fortunate in that I have arranged a team teaching situation so I shared those six lectures a week with another professor in biology.... It's a very conventional course in most regards, very high proportion of freshman ... of non-majors.... We have a lot of people who are motivated to learn science and go farther in biology courses who need that pretty rigorous background. They are mixed in with a majority of people who are taking it as a general education course. It's one of only two science courses they'll ever take in their lives. They're intimidated by it. They're often very hostile to the whole idea that they had to take a laboratory science. We know we have kids coming in and sitting in that lecture hall for whom the two hundred and seventy five people in that lecture is more than were in their high school.... The lab is a separate course [and] is graded in a very different fashion. The laboratory has now been converted to a very inquiry sort of experience.... Some TAs give quizzes so that people come prepared ahead of time and become familiar with the concepts or the vocabulary....

The bulk of my teaching of [the CETP science course] came at the end of the semester. Both courses benefited from things I've done in the last few years to try and explore more ways of interaction in a classroom format. I've been to a couple of Tara Gray's workshops [in Criminal Justice] on innovative ways of dealing with lot classes, although her idea of a large class is like thirty-five people, not three hundred people. I also have been to a number of sessions through my professional society, the Ecological Society of America.... I've been to sessions that talked about ways of incorporating active learning into lecture formats. I made a very concerted effort in Biology 111 this fall to incorporate a number of those techniques beyond things that I had already been doing.... One of the reasons I really liked the [CETP] class is because it's so much smaller. It allowed me the opportunity to do certain things I would have a tough time doing in a lecture of three hundred, like the role-playing games in the ecosystem dynamics with the different trophic levels and various consumers going around consuming each other. That was very easy to do with a dozen students in the room. I'm going to use that in the course I'm teaching this semester, which has twenty students in the room. I could see doing it successfully with up to fifty or sixty students in the room.... I know the poster idea that [my colleague] used in [the CETP course] came from this. I came back from the Ecological Society meetings and I was talking to him about how this woman used that successfully in a class of two hundred people.... [My colleague] wound up applying that to [the CETP
course] even though the course was a very different course than the big standard lecture....

As an educator, the other major part of my job ... is graduate student education. Interacting with graduate students, my own and other people’s in the department, is also a very important component of my instructional activity.... I’m on somewhere between fifteen and twenty graduate student committees, which means students whose research I’m assisting with even though I’m not their major professor.... Then there are people who are having their oral comprehensive exams ... or they’re completing writing up their thesis or their dissertation so you’re reading drafts of that, providing feedback and then going to the seminar in the defense for that student....

Initially administration wasn’t something I had in mind at all. Teaching is what I thought I was interested in. Later, I became seduced by the idea of doing science and it’s really only since I got tenure that I’ve become more confident about myself as a research scientist. I’m very, very much more interested in maintaining my scholarly activity than I used to be. None of that had any room for becoming an administrator at all. The longer I was here in this department, the more interested I realized I was in the dynamics in groups, the interactions of us all as colleagues within the department, the welfare of the group as a whole, the department and the department’s programs as a whole. I came to realize that I was much more interested in those things than many of my colleagues were. I began to suspect that at some point I would be interested in taking on more group responsibilities, which is to say, administration of some kind. I did not anticipate doing it this early in my career, for various reasons that I’d rather not go into.... This is now the twelfth year I’ve been here ... an increasing proportion of our faculty get the kinds of national reputations in research that bring people here to do Ph.D.s with them. The proportion of our graduate students who are pursuing a Ph.D. rather than a masters has definitely gone up. The quality of those students by national or competitive standards has definitely increased.... We have had graduate students with [education] as their objective and we’ve turned out some very successful examples of people who’ve gone into high school teaching, people who’ve gone into community college teaching, but the Ph.D. students are primarily aimed at college and university teaching. We’ve turned out some very successful people who’ve gotten jobs at very good liberal arts colleges. There’s the student who doesn’t necessarily think that teaching is what they want to do or they feel that they’ve put in the time to get a graduate degree and teaching, having the low financial rewards that it currently does, finds other options....

The majority of our faculty will choose students who are aimed at research experiences, at research degrees aimed at either academia or some other research or technical position after graduation. The majority of our faculty, if given a choice, would probably not choose to admit and to train a student whose stated aim is to go into K-12 teaching.... You have to be admitted to the degree program. You can’t just buy a graduate degree....
They’re always assumed to be competitive admissions. In our department you cannot be admitted to the graduate program unless a specific faculty member agrees to serve as your major professor. I would say we probably accept half or fewer of the applicants.

I can’t recall ever seeing an application from someone who was an active teacher or who planned to be an active teacher who said, “I want to get my masters in biology so that I can be a better biology educator.” I actually think among our twenty faculty I’m probably as receptive as anybody to K-12 educators and I don’t recall ever being approached by somebody for entry to our masters program. The majority of the applicants either have no idea what they want to do [Chuckle] or they know what they want to do and they want to do research. Some want to get a Ph.D. and teach at the college level or they want to work for an agency ... or they want to work as a consultant. At least some of us would be open to a person who came in and said, “I need to have a masters because I’m a high school science teacher and this will make me a better science teacher. I want to do a research degree because having some first hand experience with research will make me a better science teacher.”

There are two kinds of selfish interest here. For us as teachers, undoubtedly anything we could do to improve the quality of science education in [this state] is going to make our lives more pleasant in dealing with our undergraduates and ultimately with our graduate students. What does me the most good as a scholar? Producing somebody that goes to teach at a small high school [in this state] or somebody who goes on from doing a Ph.D. with me to do a post-doc at Stanford and then gets a job at another academic institution and then they’re getting grants and so forth? That’s a much bigger feather in my cap, training that person. I think part of it must be the national reputation because all of us who did go through these Ph.D. programs are quite familiar with these academic family trees ... It all harkens back to the good ol’ boy network that pervaded professional [and] academic science for a long time. That outweighs, in some people’s mind, the societal good that comes from improving local or regional education. I’m a person who would have been receptive to the other attitude of training teachers. I walk over to [the education building] and hand flyers to the people in the advising center and stick them up on the bulletin board for pre-registration. I’m thinking some more about why is it that some of my colleagues would take a research oriented student over say an educator. If I train a Ph.D. student who becomes a collaborator and we continue over the next decades of our life to write grants together and to write articles together then those all contribute to my scholarly activity and my success and my reputation. I think that selfishness ... gets in the way. If you’re on an editorial board for a journal, that can be hundreds of hours of work in a year’s time. And then we have all the service work on campus ... go to faculty meetings, go to committees, go to the advising center. Then some of us do try to do various kinds of outreach. You’d be kind of foolish to spend scores of hours doing that when the only possible category you can report that under on your annual report would be
the service five percent. What's the difference between being ranked number one in service and being ranked number five in service....

I'm interested in teaching and I'm interested in encouraging girls particularly to go into science. I've become much more interested in ethnic and minority issues since I arrived [here].... I've always been more willing than many of my colleagues to devote at least some time to those kinds of outreach efforts. I'm also more oriented toward the group's welfare than maybe some of my colleagues are. I see pretty clearly how good outreach to the public schools may result down the line in more biology majors at [our university], which would be a good thing for us.... What led me to be sensitive to gender issues were my own experiences. Growing up and going through education in Missouri in the early to mid 70s ... It was a pretty patronizing place and time. As a kid who was interested in science, interested in the outdoors, interested in sports, these were things that were kind of unusual for a girl. And it was remarked upon and ... I wouldn't say actively discouraged, well in sports, definitely actively discouraged, but patronized is the best word I think and that included all the way through college.... I was 20 years old and it was being proved to me that there is no successful strategy for being female in science.... That there was almost no strategy you would come up with that would satisfy or placate these critics.... It was clear to me that women were being judged on the irrelevant issues and there was no way to really win or to optimize to satisfy those irrelevant concerns. It was a very frustrating experience.... I was the first female assistant professor, and still the only assistant professor to have a child, to be pregnant and have a baby and have to deal with infancy and so forth while teaching as a faculty member here. I never had the least negative response or reaction from any of my colleagues about being female in general or about being interested in gender issues, or about starting a family....

We've had a bigger problem with recruiting and hiring minority faculty members.... We had a Hispanic faculty member in our department for many years ... that was considered a great educator, he was [recruited away from this university]. He received a very attractive offer from this other university that really did want to build up its academic strengths and its minority faculty. And [this university] basically refused to even make a token effort toward meeting the pay and so forth that this other institution was able to offer. This is a reflection of an attitude that people have said was typical of previous central administrations and that many people still fear is typical of our administration today. That is, of viewing faculty as utterly replaceable, interchangeable, twenty more where you came from, if you can get a better offer somewhere else, good-bye. They spend resources on a lot of interesting things on this campus. That's the typical way universities operate.... [This professor's] story is used across the campus, unfortunately, as an example of how worthless teaching excellence is....

I see the major barriers as being structural or organizational more than personal. All of us as individual faculty members are liable to go out there,
get inspired to try something new. We certainly have a great deal of flexibility and freedom in designing our own courses, our own curriculum, our own course content and presentation methods. [There is] basically resistance in terms of inertia of the institution, in some cases, limited resources. Time and money prevent people from trying these innovations more frequently. There’s resistance on the part of the students as well to being exposed to some radically different presentation technique or expectation. Whether it’s resistance or it’s just lack of perceived moral and financial support, all of these act to reduce the energy that faculty members are liable to put into reform activities or innovations.

It’s hard for me to picture some of my colleagues going along with such a request [to participate in reformed courses].... If you could remove all [the constraints], then I think that the majority of my colleagues would be at least positively interested in such an experience. Some of them would undoubtedly feel uncomfortable being removed from the prop of a textbook and a standard list of topics that needs to be covered and vocabulary terms that need to be understood.... Most of us do teach courses very much like that. But they are the courses that are directed to the upper division students and graduate seminars and so forth.... We’re just not accustomed to thinking of it in terms of lower division students for non-majors, non-specialists in the field. I think many of us might have some hesitance at how successful non-majors or non-specialists students would be would be in such setting. We use this excuse because we feel like the students need more structure and top town direction and part of it is the external constraints....

I think we’ve all encountered students who were so frozen by fear that they essentially were unreachable by almost any method, whether it’s inspired lecture or some interactive kind of learning technique or hands-on experience in the laboratory. They know before they walk in that room that they can’t do it and that they don’t want to do it. That suggests that some of these attitudes need to be dealt with prior to college. I’m not sure that I think that elementary school is the critical stage at which most people who wind up with negative attitudes acquire those negative attitudes. I think elementary age kids are still very open minded, very inquiring and curious, very much natural scientists, very astute observers and questioners. I wouldn’t be surprised if it’s something more like middle school when pressures on them become intense enough that students begin to sort themselves into either talented at science or not.... We all know that what made science accessible and attractive to us were personal hands-on type experiences. People feel extremely frustrated not being able to provide when you’re standing up on stage in front of three hundred people.... I think resources and lack of a clear message from above have led to a pretty fatalistic resignation to the status quo for a majority of people....

Whether you use innovations or [not], whether you keep up with the current literature on effective science education and literacy or you don’t, it doesn’t seem to make any difference to one’s day to day life as a university
professor. Even if someone’s acknowledged as an outstanding instructor and they win awards ... there’s not that much impact on one’s day to day life in many science departments on this campus, or in any research university.... Unless they have some internal overriding motivation, they’re going to find it very hard to keep swimming upstream ... Most of us would say that the most positive feedback we get is from our interactions with students ... in the upper division classes where the classes are smaller.... In a class of three hundred, you don’t. Well, with a class of three hundred, they come in as freshmen, I don’t think they know the difference either. I’m overstating this badly, over generalizing, but I don’t think they’ve necessarily formed an opinion of what conventional teaching methods are....

I’d like to see there be more flexibility in the reward and responsibilities allocated to faculty. The CETP course, great idea. Having people work together and try something innovative to serve what to us is really a new student population.... It has the potential to take students away from our existing courses.... There are some real conflicts of interest that need to be addressed if you want wider and more wholehearted participation in these kinds of things.... This university has this very rigid procedure for dealing with allocating credit for a course being taught ... You cannot split credit for team teaching a course. I actually find team-teaching to be an extremely effective way of making courses more exciting, more topical or interdisciplinary, making them more fun for me, improving my own teaching because I’m given the opportunity to work with somebody else with different perspectives.... It just seems as if the bureaucracy makes things much harder than they need to be.... That mitigates against all kinds of innovations.

I see [resistance to change] hold true everywhere [including] my son’s multi-age classroom where there’re four different groups at different levels of math doing different things and it’s very interactive. There’s a lot of activity and moving around and some people are taken aback by that and feel that there must be chaos and the students are learning nothing. In fact, they are all extremely actively involved at levels that are comfortable for them. You see that at all levels right up to a college classroom, but I think because we were all trained in certain ways that those are the comfortable ways for us to fall back on along with some of the institutional pressures to go with what’s easiest. Go with what consumes the fewest resources. Go with what generates the fewest complaints....

I can be a little more proactive I guess with respect to my colleagues here in this department [by] trying to encourage people to seek out opportunities for professional development in the area of instruction. Most of us are quite comfortable with the idea of taking a sabbatical for a year and going off to work in somebody else’s research laboratory and learn new techniques or start a new collaboration or start a new research project. Surprisingly few people have taken advantage of any opportunities for getting resources to improve a course or getting resources to improve our curriculum or participating in a workshop that teaches them some innovative teaching
technique or that exposes them to these ideas of science education reform ... As a department head, I will try and make sure people are aware of the opportunities that are out there for investing in their own professional development as instructors and I will try and encourage people to view that just as positively as they view the other....

I feel as if I made some really valuable contacts with people who are overseeing the whole CETP program, but I feel at a complete loss as far as the tangible future of the involvement of biology. It sounds as if we’re just continuing this divorce between science faculty who are simultaneously science researchers. Somehow this is in a different universe from actual science education aimed at non-science majors.... The improvement, if you will, of the [CETP] course relative to the standard general education courses is not that the [it] gave them the opportunity for more direct inquiry or direct learning, it was the potential for integration among the subjects that was unique in that course.... In terms of the quality of the experience, the flavor of doing science and the simple quantitative techniques and observational techniques and formulating questions yourself and going after an appropriate method to answer it yourself, I think our introductory labs actually do an excellent job of that. The lectures, that stinks.... The professor is the one who’s up there on that remote stage with the microphone and it’s graduate students who teach the laboratories....

The whole idea of constructivism and the subjectivity of observers and what they bring as investigators to the investigation is extremely threatening to a lot of current practitioners in the natural sciences. It’s the source of a lot of heated debate about the nature of science.... It’s supposed to be to impart a flavor of what it is to ask questions, to challenge, establish beliefs, to act independently, intellectually and makes one’s own observations and derive one’s own interpretations....

I suspect that there are some quantitative data out there that would be very persuasive to my colleagues in terms of a better understanding ... of what percentage make it out the door of the high school [and] ... in the door of the university into a science course.... We are not familiar with those data by and large. They aren’t disseminated in the scientific community as widely as they could be.... It’s unusual to find a person who has read anything by someone like Sheila Tobias on student attitudes toward science.... Because most of us are empiricists, we’re very interested in THE facts, THE natural world as it truly exists ... and we’re not very attuned to what THE facts of our local population are....

It’s already too much for people. I don’t have a settled opinion about this because in some ways it sounds as if I’m making arguments to have separate researchers and instructors. I actually don’t think that that’s a good idea. I very much value the fact that we’re able to put in front of freshmen our researchers who are passionate about what they do and who can describe from the inside what the scientific experience is like.... It’s been interesting to
reflect on it and I am very interested in that course and how it evolves and whether it's seen as serving the purpose that it was devised to serve.

William.

Let's go back to the time when I became interested in becoming a science educator. My father was a superintendent of schools ... Prior to that he had been a high school chemistry and math teacher. When I was 12 years, old Santa Claus brought me a chemistry set. My dad took me over to the chemistry laboratory and started showing me the experiments.... We'd always venture over to the chemistry department. He would then introduce me to his old professors.... I always aspired to do that. When I went to graduate school, I majored in chemistry with the thought that someday I'd be a professor.... I went from [this university] to Ohio State and got my Ph.D. I observed my instructors and I knew which one's were good teachers. Everybody knows the good teachers when they're taking classes and I aspired to teach like they do. I learned by example how to teach.

While I was at Ohio State, one of my colleague's wife was teaching elementary school. She invited me to come over and do some chemistry experiments for the students. That's my first experience with teaching elementary students about chemistry. I kept doing that sort of thing. Over time I started reading the literature in chemical education and I found out that elementary school teachers are not prepared to teach chemistry or the physical sciences. They might be prepared to teach a little bit about biology but they have very little aptitude for teaching physical sciences ... and the reason for this is they dislike those subjects. When they were in college they avoided taking these subjects. They have very little background in those areas. The literature substantiated that. I thought, "Why don't I start going to schools illustrating ways to get kids excited about chemistry?"... [since] they turn students off to those areas because they themselves are afraid and have anxiety towards them and don't want to do experiments. In fact, one of the teachers, I remember, told me she had never taught science. She always avoided that subject. But after going through one of these workshops she'd never do that again. She's definitely going to start teaching science because now she wasn't afraid of it anymore. I saw a problem and I tried to do something about it.... Then word got around and all the schools started inviting me to come and do these things.... I've never really been into the methods except that I know what kind of methods work for me. My primary concern is that the teachers don't have the background in these areas. If you don't have the background in chemistry and physics, you're going to be afraid to teach ... and then the students can sense it. They'll also develop the same anxiety. So what my workshops have really been geared at is really to turn their attitudes around so that they think it's interesting, so they'd think it'd be fun to do those kinds of things....
I'm trying to remember the first literature I read about the subject or whether I knew about if before I read the literature ... Studies have been performed that illustrates that elementary teachers are ill-equipped to teach the physical sciences ... only fifteen percent of the teachers felt that they had the proper background to teach physics and chemistry at the elementary school level. When I got the Westtape Award in 1985, I gave a talk for my acceptance address. It was about the problems in science education. I was concerned there primarily about the illiteracy in the general population in science. That is where the major problem is. We need to reform science education in general, not just for teachers. There are several different avenues. Another problem is that when we teach it in college, we tend to turn students off, right? So there's multi-faceted problems, but the basic problem is at the elementary school level. You have to have teachers at those levels that can maintain that level of interest. You have to have teachers for those that go into college. You have to have teachers in college teaching the non-science students to maintain that.

I believe that teachers in college should be more attuned to the interests of the general population. If you're going to teach a general chemistry course, you should teach it with the idea that these people are not going to be chemists. They should come out of that course with a positive attitude towards chemistry. If you're going to learn chemistry and any other science, you still have to learn the basic concepts ... I think you should teach the basic concepts. Even if the people never really use those concepts. When I teach general chemistry, they learn basic concepts, they learn the practical applications of chemistry, they learn the fun of chemistry and they also learn to think. The vast majority of the students in Chemistry 110 actually come out with a positive attitude towards that course. That's what we have to do in all of these general courses. If you're going to learn chemistry, you have to know what a formula means. You have to know what a chemical reaction is. You have to know what a chemical equation is. I tell them, "Every time you balance an equation, you have paid homage to the memory of John Dalton who came up with the atomic theory. You're not doing it for any other reason except to pay homage to that individual." ... Students can sense my enthusiasm for it. I've had students that actually take chemistry 110 because they want to. [Laughs]... Some students still don't get turned on. They're in there because they have to be and that's it.

I have a certain philosophy of teaching ... I'm involved in chemical education. I go to national conferences and talk to them about this kind of thing. I like to use lecture demonstrations. I develop new lecture demonstrations. I go to elementary schools and middle schools and high schools and hopefully some of this will rub off, not only as far as the students are concerned, but as far as the teachers are concerned. I've been doing it for twenty-six years. These are big conferences that have a thousand, mostly college professors. There are some high school teachers there, but mostly college professors. They're there for the strict purpose of learning about
methods of teaching, laboratories, lectures, demonstrations and high tech stuff, all kinds of things....

We have several people in our department who are really excellent teachers.... In this department, in fact, we consider teaching to be important. Some of our faculty have high standards ... and so about half the students, the better half, really appreciate him. The rest of them, well, they’re taking organic chemistry, they’re taking it because they have to take it. They get turned off. He requires them to work ... and a lot of people like to go party. He has help sessions at night where they have problem solving. The students who are good students always show up for these things. They end up getting good grades. They end up writing letters of praise to him. They just love his classes....

I got involved [in CETP] through [the project coordinator]. He knew that I was very much involved in chemical education. You were at those meetings and you can see that my philosophy is quite a bit different than any of theirs.... Some people thought you should take certain issue like the environment or whatever and then develop the science, as you need it. Rather than starting with a science that’s developed and then show how they relate the two. I believe that you should learn the basic concepts in these sciences and then you can relate them to these other issues.... If you just teach the basic principles, never make the connections, never show any enthusiasm, then it doesn’t make any difference whether you start one way or the other. You [have] got to teach it with a certain goal in mind, that you’ll turn the students on. I taught a summer science course [for teachers]. I would teach physics first because the principles of physics are the principles on which chemistry is based. The way I would do it is teach physics first then chemistry and then biology in that order and then go in the fringe areas [of] astronomy [and] earth science. All those things area based on those basic sciences, but of the three basic sciences, the most basic one is physics....

We talk about inquiry-based instruction. You can do that in lecturing too. You have to engage the students.... I say [to my audience], “After years of experience I have memorized how many electrons, protons and neutrons are in each of the atoms of each of the elements. You just give me the symbol or the name of an element and I’ll tell you how many electrons, protons and neutrons are in it.” When the students say uranium or something like that, I look over my shoulder [and say], “There are 92 protons, 92 electrons and 146 neutrons.” And they’re kind of impressed, right? I do another one. Every time they ask me, I look over my shoulder. [They say], “We know what you’re doing.” [Laugh] See, we’re engaging, they’re thinking right? They’re thinking, “What in the world is he doing?” I’ve engaged the class. They’re not sitting there [with me telling them], “If you look at the top number, that’s the number of protons. The number of electrons equals the number of protons.” That’s the old way of doing it, right? Whenever I have a chance, I always use that. It’s an inquiry-based method of applying the lectures....

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[At conferences], I'm more of a person that develops new ideas. So those kinds of things I'm telling you about are my own ideas. When I go to conferences, I tell them about the new methods of teaching. I have new methods of teaching ... I like to figure out new experiments and new lecture demonstrations that people are using. My contributions are usually new ways of lecturing....

The sad story about [assessment] is that I used to not give multiple-choice tests. It's so much better not to. I'd give some essay questions, where you actually work out problems. When you teach 250 students and have exams like that, it takes all week to grade the exams. I just succumbed to laziness and went to multiple choice. I try to design the questions to make the students think. I like to design series of questions. Where it's not necessary to know each part, but one does lead to the next.... [Without time constraints], I'd probably do it like they do it in the honors class. I'd give them thought-provoking problems. In that honors class, one of the things that we do is we learn how Fisher determined the structure of glucose or the scientific reasoning and experimentation that went into it. He used optical activity and reactions and so forth.... We go through all the experiments he used, the logical reasoning he used, and then we work problems with different sugars and I give them hypothetical results and they determine what the structures of those sugars are. Then on the tests, I will give them something they haven't seen before, but I will give them all the different experimental data. They then have to take those experimental data and determine the structure of that sugar. They're using the logical reasoning, experimental results that Fisher used. They have to construct it so it's one where you can't memorize a method. You have to understand ... We'll have maybe 10 or 15 students in that class. You'll have every undergraduate college represented. And very rarely do we have a chemistry major.... They're only allowed to use the information that was known at that time in analyzing the experiment.... I guess we give tests when we have to. Wouldn't it be neat if people just came to school to learn and we didn't have to test them? ... I wouldn't have given any grades if I didn't have to. I mean, they were obviously engaging in the activities. They're obviously were learning. They were obviously excited about it.... There was no reason not to give them a good grade if they were doing everything....

One of the reasons I went into chemical education and got really turned on to chemical education was because I had good teachers here. I got my bachelors degree here and graduated in 1960. I took math from Earl Walden from which Walden Hall is named. I took English from Marion Hardman for which Hardman Hall is named. I took music from Dr. Jacobs for which Jacobs Hall is named. My fist job was in BSL and a got the job from Gardner from whom Gardner Hall is named. So I had really good teachers, not only chemistry, but [from] the whole university. I had a tremendous background. I was lucky.... I think everybody considered those teachers to be good teachers. I hate to memorize things. Earl Walden was just a fabulous
teacher. He was excited about math. He taught me freshman math. At that
time there were smaller classes and so they would segregate people. That
might have been another thing, but all the people in this particular class were
chemistry and physics and math majors. So, he was able to go a little deeper
in to it. Then I took freshman chemistry from Barrett. They had a chemistry
qualifying exam and I scored high on that so he had a small class in which you
covered both semesters of freshmen chemistry in one semester. So these
people had good high school backgrounds. And he then went into it in great
depth in a small class.... But in those English classes, standards were different
then too. People hardly ever got anything higher than a C in grammar in
freshmen English. Now they give all kinds of high grades. In second
semester I got a B in grammar. I'm most proud of that than any other grade I
ever got. I had good history teachers. I had a great German teacher. I don't
know how they teach in foreign languages now. I don't know about the
history department. I think it's still good, but at that time they were good
teachers.... I liked math and physics and chemistry, but I still enjoyed those
other kinds of courses. I got my Ph.D. and came here in 1964. Been teaching
35 years. So it's about time I started to get it right. [Laughs]

I'm going to retire at the end of the summer.... From then I'll be re-
rent on a twenty-five percent basis. Right now, after 35 years, I'm paying
the university for the pleasure of teaching.... That requires that I teach one
course and continue with our chemical education activities. I'll get to go to
schools. I'll get to do these workshops, all that kind of stuff. I'm going to get
a big salary increase with less responsibility. I won't have to go to faculty
meetings. I won't have to be on committees. I can just do the things I like to
do and things I'm best at doing. I should mention Alan Van Heuvelen. He is
involved in inquiry-based physics education. They're ahead of chemistry in
that regard. Well, it's easier in physics cause you can experience physics. It's
very difficult to experience atoms. Chemistry was the first science that had to
go to the microscopic level to explain the phenomena. Physics you didn't.
That's why Sir Isaac Newton was able to come up with his law of motion,
because he could see things moving. In fact he was an alchemist, did you now
that? He never could really get a handle on chemistry because you can't
unless you go to microscopic lessons. He is considered one of the greatest
physicists in the whole history. He was a typical alchemist trying to find a
way to make gold out of lead and never could do it. People don't know very
much about the alchemy part, but he actually spent more time in alchemy than
he did in physics. You cannot experience atoms and molecules. So what are
you going to do? You can develop ideas that will relate similar to what you
do in physics, but it's a little difficult. Alan Van Heuvelen inspired me to do
that kind of stuff. I still communicate with him about that kind of stuff....
He's at Ohio State. They hired him away with a big salary in physics
education. He's a professor in the physics department, but his area of
expertise is education now. He said that some of the members of the faculty
didn't really accept him. I mean they're pure physicists. Their program really
got a boost when one of their faculty, who was a Nobel Laureate in physics, decided to devote his efforts to physics education. Then the other ones said, "I guess he must be all right." [Laughs].... The university has been very supportive of my education academics. They recognize that doing creative things in chemical education counts as research.

One of the courses I loved was chemistry 110. Chemistry 110 is the course people take who are afraid of science. One of my goals to teaching that course is to neutralize that fear, to make the students want to come to class, to want to learn chemistry, etc. You use all kinds of methods to do that.... I put a great deal of effort into that course. In fact I've written a textbook for that course and I've written a lab manual. Since I'm the person primarily responsible for it, I determine the curriculum. Another course I like to teach is inorganic chemistry. I try to do the same things in each of those courses. I teach a sophomore inorganic course and I teach a senior inorganic course and I teach a graduate course. I approach those the same way. I want to make them enjoy it.

I go to meetings on chemical education. One of my areas of expertise is demonstrations that can be used in lectures to make the lectures more alive, to make the students more involved etc., and I've published a lot of those in journals and I've talked about those in meetings. I've done a lot of work in developing new methods of presenting old ideas.... By the way, do you know why they call it the periodic table? The reason we call it that is because the students look at that periodically during the course.... I go and visit maybe thirty or forty elementary schools each year. [I visit] some middle schools and occasionally a high school, but most of the work I do is in elementary schools.... When I tell the students we're going to have fun with gas, immediately they start laughing. I also do these presentations for service clubs, for non-science meetings. The National Retired Federal Employees Convention is going to be held here in Las Cruces. I do the same things I do in schools, except I do it at a different level. It's the same kind of ideas. I've had people come up to me after one of those presentations and say they learned more chemistry watching that than they did in the time they took chemistry. I don't like to do a demonstration unless they teach. All of these are always entertaining, but then the people end up learning. I hate chemistry demonstrations that are exciting and don't teach anything.... When I write papers or get a grant to do this kind of stuff, it's considered in the same way as a person who is doing basic research. The university also recognizes these kinds of activities in their awards. The university has many more awards for teaching than it does for research. [There are] only a few awards for research and there's many for teaching. I've gotten all the major ones, the Westtape, the Rouse Award twice, and the Burlington Northern Foundation award. Several people in our department have gotten those awards. We do emphasize teaching as an excellent job. I do have a good time! All of a sudden they're [other faculty] saying, "Oh we'd love to do that, but it's not valued. The university does not recognize it. They only recognize advancement in our
field, in non-education components.” Can I read you what the vice-president said when he approved my retirement program? They probably don’t have interest in this area. They’re probably interested in the basics of science. It was when I first came here. I gradually lost my interest in the basic research and started doing more and more in chemical education. I was like them when I first started. I still put a lot of effort into my teaching, but I put easily as much into my research when I first started. It’s one thing just to talk about putting effort into your teaching, another thing to try to advance education in general. None of our faculty here really do very much in advancing chemical education. We have a lot of good teachers put a great deal of effort into their own personal teaching, but have very little to do with other teachings. I’ve gotten to the point where I put as much effort into my outreach type programs as I do my own personal teaching. I don’t think there’s too many people in the university doing that. [Our reformed course coordinator] was hired as a chemical educator. He will be granted tenure on the basis of that. He has to demonstrate productivity and he has to demonstrate creativity. He’s got to publish, but you can publish in the educational area. It still counts, at least in our department it does. And the university recognizes it. The dean recognizes these activities. I think it probably has to do with the individuals. Those individuals probably feel that it’s more prestigious for them to do basic research than it is for them to do research in the educational areas.... It might be that some departments are prejudiced against the education aspects. I know the administration is not because ... when I do things that benefit public schools that makes the university look good. The legislators are the one’s that allocate the money to universities. What kinds of things do they see? They know about people going and doing things out in these programs. They probably know more about that than they do the basic research. The only thing they see in the basic research is the grant dollars, the funding dollars.

I think [chemistry working with education] is the exception.... I’ve been involved in the selection committees for new faculty in the College of Education ... and I’ve been on oral committees in education. We need to do more of that obviously. In our department, we have several people that have talked about forming a bridge through the College of Education. I’ve probably done more than most people, but several people talk about it.... [Our reformed course coordinator] works in the college of education too. There are some other things I do for the university in terms of education. We have alumni honors nights for the top juniors in high school.... I’m the entertainment for [surrounding cities].... And I was the director of the Regents Summer Program. That was a program for high school students where the students came and actually got a taste of college life. They took short courses in all the different kinds of areas. We had science courses, humanities, arts and engineering courses, agricultural courses, etc.

Presently, I teach a graduate inorganic chemistry and two sections of 110.... I make it inquiry-based lecture. I do a lot of demonstrations that illustrate ... The students really ... appreciate seeing the chemistry actually happening. I
rely on homework and problem sets for the grade. I don’t have them write papers in the graduate course. In the freshmen course, I use exams and multiple choice exams. I do give quizzes, which are not multiple choice, and they’re pop quizzes. I give ten pop quizzes during the course of the semester. I tell them the reason I make them unannounced is to encourage them to come to class … [If] you miss this one particular lecture, you might be lost in the next lecture. Another one is I want them to study everyday rather than to wait until the exam is scheduled. It doesn’t seem to bother them too much. I also teach an honors class where the grades are based a little more on other things as well. For example, we do a lab as if we’re doing research. I’m the research director and we have a TA who is my chief assistant. They are my other assistants. We’ll pretend we just read the literature and we just saw that Levasier has just stated such and such. If you do this, this should happen and we test it. We try to see if we can get the same result as he did. We try to duplicate the experiment. Sometimes the students will suggest things to do. They take notebooks, just like a research person would do. Somebody should be able to reproduce exactly what you’ve done by just reading the notebook. At the end they have to write a paper over some research that we get, just as if it were a true research paper. They actually end up going back to that period of time. Let’s see if I have some. [Reads a selection]. Isn’t that neat? Let me find another one....

Once a semester gets going, they’ll be people in [my office] everyday ... When I teach the honors class, there might be thirteen people in the class and I bet half of them come to see me on a one-on-one basis. The graduate students do also. I get students coming in here that aren’t taking my class. I like to help students. They sense that I enjoy helping them. That’s part of our job. A lot of people feel that they’re put upon if their students come in to waste their time. I mean I had students tell me that. They don’t like to go and get help because the teacher or the professor acts as if they are wasting their time. I probably spend maybe an hour a week talking to people within my own department. With administration, I probably maybe spend an hour a month, but if I need to I feel free to visit....

[Science education reform] is in a very disorganized state. Don’t you agree? You could see it in when we tried to develop this special course. Everybody had a different idea as to what they wanted to do. When we started teaching, everybody taught it the way they thought it should be taught. How extensive are these kinds of things we’re doing? We’re going to affect few students, but how extensive is it throughout the state? We’re not hitting very many. Most of the schools I go to in the [adjacent] district, you can see that the students have the ability. Nearly all the schools I go to down there are elementary schools. I can’t see any difference between those students and any others. I go to University Hills. I go to San Miguel. Do I see any difference? No. They have the same innate desire to understand. They get just as excited down there as they do up at University Hills. You can tell when kids understand things. They get this look in their eyes like, yes, they understand,
they love it. Children haven’t lost that [wonderment] and many teachers don’t help in that regard I’m sure. That’s one of the things we’re trying to address right? Once they get out of elementary school the people in middle school have to pick up the ball. I think if you’re going to explain something at the proper level, you really have to understand it. I think that’s where we’re really lacking, teachers don’t [understand the content].... [The last science educator] and I came up with a proposal to change the curriculum for elementary education majors. [Shuffles through papers] Here it is.... This is the survey ... Students are taking this [science] methods course ... What they had in content courses prior to taking this class. Forty-five students had biology 110. Twenty-two had astronomy. Six had chemistry 101. Three had chemistry 102. Twenty-four had had chemistry 110. Thirty-nine had geology. And look at physics. How many people had physics? Fourteen out of the sixty had any physics. Twenty-four had chemistry. Most everybody had [a] biology background. Some of the people, their only courses had been biology.

The best situation would be to eliminate all these straight lecture classes. What would that do to the cost of higher education? Instead of having one class of one hundred and fifty, you would have ten classes of fifteen. You have got to have ten people teaching rather than one. That leads to inefficiency ... [and] inflation.... If you want to reverse that, then the costs are really going to go up. We need to advertise [the honors class]. That’d be a perfect course for elementary education majors. As you know, I really do believe in the interdisciplinary thing, but I still like to call them the traditional needs. When I’m talking about kinetic molecular theory of gasses, I’m related it to the physics behind it.... So they really do, one does tie in to the other. I just wrote a paper on a demonstration that was published in chemical education. Let me show it to you. [Pause] This relates to physics, chemistry, and it’s all about thermodynamics. There’s a perfect example of a chemistry demonstration that ties in the important aspects of physics, heat.... I invented a demonstration called the [ammonia fountain]. This one is really inquiry-based. I have people try and figure out what is happening in this one.... The best way to do that in an inquiry-based method is to let them look at it then have people write a paragraph or two as to why they think that happened.... We put a great deal of effort into trying to continue the interests of the students. One of the major ways of doing this is to have our students work in laboratories doing research. We get involved in the co-op program where they can actually work off campus too. Most of our undergraduates just work in the laboratories with the faculty members or post-docs or graduate students.

We grant between five and fifteen Ph.D.s each year. We have about fifty graduate students. Most of those students are working towards their Ph.D.s. Some of the students take a master’s degree on the way to PhDs. It depends on what they want to do. If they want to work in laboratories as bench chemists, quite often, it’s easier to find a job with a master’s degree of that type. Ph.D.s are usually overqualified to do that type of stuff. Right now,
it's probably easier for a student with a bachelors degree to get a good job than a masters or a Ph.D. A bench chemist actually works in the research group. They get together and decide what kind of experiments they want to run and then these technicians go and do it. Some of the bench chemists have higher degrees. We don't see too many [secondary science teachers getting a masters chemistry degree]. I wish we saw more. They get educated in our department. They get a secondary education degree with chemistry as their main subject, they have essentially the same amount of chemistry as a BA chemistry major.... Do they get their masters in education?....

I've traced how I've become involved in chemical education primarily rather than sticking to research.... How are we going to teach a general chemistry course with 150 students in the class? Well that's what I've been trying to address, obviously, over the last few years. What I do in an hour and fifteen-minute class is to break it up into segments so it's not an hour and fifteen minute lecture .... What kind of things will break up a lecture so that the students can restart the thought processes? You can use demonstrations.... I tell anecdotes. Most often, the anecdotes are related to the subject matter. Sometimes they're not. I mean, sometimes I just tell jokes. Sometimes the jokes are related, sometimes they're not. But you can see you're starting to lose the students, they are getting bored and their attention span has now been surpassed.... Sometimes they're tricked into thinking. Sometimes they're trying to figure out how I am doing something.... But that's an inquiry-based approach where they're actually generating the concept by thinking about it. I try to do as much as that kind of thing as possible.... You can't teach somebody to do what is part of my personality, but you can teach people about using inquiry-based methods. You could teach people about those little tricks that I use and kind of try and engage the students. I use other methods too. Yesterday I was talking about stoichiometry ... Students don't really understand why they are learning something like that. I decided to take a chemical reaction involved in the discussion of a metal, which is of great economic importance to [our state], the production of copper. It allows me to introduce a little bit about economics and how natural resource can involve economics. I've visited all kinds of mines and smelters and places and facilities involved in the copper industry. I have a slide presentation and I introduce the slides in the middle of the lecture. We got involved in the chemistry and then we work on a problem where we determined how much copper you can get out of a certain amount of ore ... they see that there is a practical use of that type of calculation. They see how a metal they've used all their lives is made. They find out you have a sulfur dioxide by-product which is an environmental hazard.... They convert it into sulfuric acid, which has great practical importance. All the sulfuric acid they make is shipped to the ... oil refinery in ... to be used as a catalyst in making unleaded gasoline. When it is no longer useful as a catalyst, they give the sulfuric acid away to farmers. Farmers then can use it to put in their irrigation waters or on their soil directly to neutralize their soil....
The way [the reformed course] was taught is the traditional way of teaching a team-taught course. Each person goes in there and teaches it the way they want to teach it. There was very little interaction ... This person taught for two weeks and then another person or persons came in and taught for two weeks. That honors course I was telling you about, the idea was that it was going to be a team-taught course. I was going to organize the course. I got all these different kinds of people to talk about different things. I organized it so it did fit, but when a person came in and talked for a period or two they were unaware of what kind of things we stated in the period before that. I could see how they could have tied in better, but they didn’t know. The only way to know is to go to all the classes and nobody ever does that. So, after a year or two, I learned all the kinds of things that they were going to teach the students. I then taught all of them myself. I was able to weave it together to coordinate things.... When you get somebody like me who really does have strong background in physics and math and astronomy and chemistry and that one person can put it together real nicely.... Maybe you have two people doing that rather than how many people do we have working on that? Six was too many.

We have all these foreign graduate students teaching our labs. Many of them have very strong accents and they can’t teach unless they have mastered English. If you’re Chinese, it’s very difficult not to have a very strong accent. So there’s another aspect of that. The students just say, “Why don’t you get Americans?” Well, because there aren’t enough.... We do need more scientists, but we don’t need very many more scientists. That is what we try to do. This 110 class is not taught as if I were teaching majors....

Well, I guess what I’m going to have to do as far as chemical education is concerned, is when I go to these meetings, I’ll have to expound on those techniques that I use that seem to be used, ones that do not involve my personality, just the technique.... How do you engage the people that don’t want to learn? We don’t want to [make anyone feel foolish]. When I go to those elementary schools, the whole class becomes engaged. You know what I mean? You can see, I mean it’s not two percent. They all think it’s neat and it’s all scientific. I say, “How many of you think you might want to go to college?” Well, they all raise their hands, right? “How many think you might like to become a scientist?” Well, they all raise their hands. They think it’s neat. If you’re going to be an educated person and you’re going to be an artist, you should still understand science. I mean scientists understand art. Why shouldn’t artists understand science? I don’t mean the details of it, but you understand when you see a formula you ought to know what it means. I wrote the formula of water on the blackboard. By the way, do you like jokes? You like scientific jokes? I’ll go up the board and say, “What’s this?” They all say that it’s water. By golly! That’s not water. If you were dying of thirst that’s the last thing you’d want. That’s the formula of water. That is calcium carbonate. That’s the only one you can do that with. So anyway I think people ought to know what those formulas mean. Don’t you think? They all
know the formula of water. Why not know what it means? I mean, everybody should catch on to that. In fact, everybody in my class knows what that means. Even all the students in those elementary schools know what that means. I get the letters back from them and they draw pictures of water molecules. They put H₂Os on them and all that stuff.

Survey/Questionnaire Responses

The following section provides verbatim participant responses to the questionnaire administered early in this study. Only five of the six participants returned the survey. Although William did continue with the interviews and his profile was constructed, he did not submit his survey responses.

Question 1. When you are teaching, what decisions about what you actually do in your classroom do you believe others govern and what decisions do you feel free to make yourself? Please list.

[Adrienne] It depends. For instance, in the Science class for the fall, a group of us decided what should go into the class. I was to do Scientific Method. The method itself was dictated by the group to meet the science standards that the students would need to follow, but how I did it and presented it was entirely up to me. In my EE 111 class, I have an outline of topics I need to cover and skills the students need to know. How I present the information is in my control, how I test and work with the students is up to me. I do feel pressure to have students work homework problems and take tests, but the grading and weight of grades is determined by myself. It is important that I have guidance in the EE 111 class, since it is a prerequisite for other classes, and other classes depend on me teaching what is on my list. When I teach EE 572 (Information Theory), the content, method and grades are entirely up to me. I put in what I want the students to know and what I feel is important. In this case, I totally govern what I teach.

[Hobart] Others: (Large classes) general outline and order of topics, exams (committee effort). Myself: specific examples, demonstrations, in class activities and discussions, quizzes and homework.

[Patrick] Decisions governed by others:

a. classroom size (number of seats)
b. number of meetings per week
c. class meeting time
d. class decor, tables versus fixed chairs, wall decorations etc.
e. number of students
f. TA assigned to the class

g. lab assignments (department standard)

Decisions made by the instructor
a. textbook to be used
b. examination format and exam weights
c. auxiliary aids (slides, transparencies, movies) employed in class
d. number of in class activities
e. topics covered and amount of time spent on each
f. quantity of homework

[David] I believe that there really is very little others govern as far as how I teach. The content of a course is very flexible as far as the senior and graduate courses. For the lower division course there are more outside influences because others also teach the course and thus there is a need for agreement on content and approach. There really are not too many constraints placed on me as to how or what approach I take in conveying material for courses.

Decisions I make (depends on course)

a) Choice of text
b) Content of course
c) Teaching style
d) How grades are determined

Decision others govern (depends on course)

a) Choice of text
b) Content
c) Grades must be established. Tests given.

[Sophia] Decisions governed by others: framework of time and space (location of class weight of different elements of assessment and evaluation (participation, writing, 'objective' tests, independent exercises, etc.).

Question 2. Where do your ideas for how you teach come from?

[Adrienne] I try to use methods that I have seen work. I pull a lot from my experience with previous classes, and I listen to what colleagues tell me has worked for them. I try to think how I would want things presented and what makes sense to me, and use that.

[Hobart] Observing and talking with others. American Chemical Society Meetings.

[Patrick] Ideas for how to teach come from student evaluations, peers, and seminars. The seminars were given by the English Department (WAC) and the Center for Learning Assistance. The final decision to use a particular format depends on how successful I feel it will be in aiding student learning. The discussions with peers takes place within the department and at

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professional meetings. Occasionally a national news segment reports on a "different" approach that has been successfully employed at other locations.

[David] Much of the concepts of my teaching approach comes from my experience as an undergraduate and graduate student, educational experiences leading to college and in other learning environments that one goes during a lifetime. Observations on what "worked" from those that were not effective.

[Sophia] Ideas for teaching: from education section of my professional society (Ecological Society of America, Botanical Society of America), from professional journals, from my own mind, from my experiences with excellent teachers or with unusual scientific phenomena, from my colleagues at [this university] and elsewhere.

Question 3. How do you organize your ideas for teaching? How do time parameters influence your planning?

[Adrienne] Usually a first time course goes roughly and I always feel pressured for time to adequately prepare for the class, but after the first time with the class, I have a better feel for the pace of the class and don't feel as much pressure. There never is enough time to do all I want or prepare all I want to have. I organize my ideas in a basic outline, I list the topics I want to touch on, and write out any special notes or points that I want to make clear. Then when I teach, I have the flexibility to change emphasis depending on student's input.

[Hobart] Outlines - Time is a major limitation. Especially in planning labs.

[Patrick] The organization follows the topic sequence given in the book. Time limitations force me to ask what is really important for the student to know. I then focus my discussion on those topics and rely upon the student to read about the other material in his/her textbook. If the material is not used later in the class, it is given a low priority; if it comes up frequently, I make a point of discussing it in the context given in that particular chapter. The time limitation is actually a good thing otherwise I might begin to talk about numerous other facts that although interesting, are not vital to understanding the main point of the chapter.

[David] Teaching is still very much work in progress for me as I have not had any formal training. The approach is somewhat different for each class. I consider the background of the students and how the information would be used by the student. For example, my approach to Biol 219, microbiology for largely nursing students is different from virology (Biol 475) or immunology (Biol 475) which is largely composed of senior and graduate students. With
each I try to access what concepts are important and what concepts are likely to be needed by the students as they enter the work place or go on to graduate or medical school. I also try and make the material relate to the students.

Time parameters are a very important constraint in what approaches can be used. There is much material that I believe is important and needs to be covered within a course. Alternative teaching many times requires additional time.

[Sophia] Organization: Think carefully at the beginning of a term or a class about the overall organization and conceptual content of the semester - this goes into the syllabus. For individual classes or lectures: what I TRY to do - collect files of news items, ideas, examples of cool approaches, etc. under a course name or subjects within a course, then draw from those when planning a class or a block of class meetings. What I actually end up doing: turning a theme or central idea over in the back of my mind while I do lots of other things, then with not really enough time left I sit down to organize and often do something like free association while preparing for class. Time parameters - limited time for the class causes me to be less ambitious; limited time for preparation (relative to research, grad students, other courses, administrative duties) means less than optimal organization.

**Question 4:** How do you deal with diversity of students within your classroom?

[Adrienne] I try to present things in a variety of ways—hands-on, graphical, lecture—so that students who learn differently can understand it in the way they learn best. I try to use things they are familiar with to lead into a new area. If someone is ill prepared for the class, I encourage them to get prepared but will also help when they need some extra help.

[Hobart] Try to treat each student with respect and as an individual.

[Patrick] I have found that if you treat students preferentially in class it actually builds resistance among those students and annoys the other students. They see this type of treatment as insulting or in the context of a teacher's pet. It is better to handle individual student needs outside of the classroom. This lessens the pressure on the student and allows his/her particular needs to be addressed. Unfortunately many students who could benefit from this are hesitant about coming to office hours. I encourage them to talk to the TA if they feel more comfortable.

[David] Provide individual attention to the students through office hours, review sessions and questions during lecture. Although I have a course syllabus if additional time is needed I do not hesitate to alter the coverage and
speed of the material. If additional time is needed course plans are altered. Attempt to several approaches to key concepts.

[Sophia] Diversity of students: cultural diversity, I deal with by bringing in as many and as wide a range of real-life connections as possible. Gender and personality type and learning style differences, dealt with by deliberately using variety of styles of presentation or of activities, and structuring activities so that no one person repeatedly would be relegated to merely observing (for example). Diversity of background, very difficult to deal with in a science course, dealt with by offering basic or remedial material as extra reading options, offering enriched or advanced choices for reading or text material, having lots of student-formulated writing or activities, emphasizing improvement over term from student's starting place rather than arbitrary scores etc. in advanced division (non-lecture) classes.

**Question 5.** Describe any differences that you see between an activity and an experience.

[Adrienne] An activity is where you do something active, performing, participating; this can help to get ones whole self involved. An experience is something that you can internalize and gives a deeper understanding into something.

[Hobart] Activity: individual chunks, a lab, a quiz, discussion of a topic, demonstration. Experience: sum of several activities geared to a particular goal.

[Patrick] I will define an "experience" as a visual event as opposed to an "activity" which I will define as a work that requires student verbal or written participation. I much prefer that latter because I believe that students learn by being actively engaged. In my opinion, demonstrations can be interesting but their educational benefit is limited. Unless the student is mentally involved, the result is more entertaining than educational.

[David] Every activity does not necessary result in an experience. Where as an experience is the result of an activity. Experience has a longer-term impact compared to an activity.

[Sophia] Hmmm . . . activity is planned? Experience could be more open-ended or could be something student brings with them, as opposed to something I plan and provide for class?
Question 6. What are your sources for the curriculum you use to develop a course that you teach?

[Adrienne] It depends. For the Science class for the Ed. Majors, I looked in the science curriculum. I used science books geared for children (for use with Elem. School students), science books, and the other instructors working on the class, and my own experiences. For my EE III class, I [used] several texts on circuit theory, the web, input from colleagues, applied circuits books, technical manuals, and my experience. For my graduate classes I use several different text books, journal articles, the web, and experience.

[Hobart] Texts, Journal of Chemical Educ., ACS Meetings, publishers, other faculty

[Patrick] Sources included the Web, textbooks, and other books that deal with the subject. Some of these books can be at a much higher level than the class, others give me a different perspective on the material. I often use specialized films, mainly PBS type films, to visually illustrate some concepts that are discussed in class. The bad side of this is that not all of a film is equally relevant and the current situation at [this university] and copyright laws do not allow film segments to be easily viewed. I do not use pre-programmed disks and most computer labs that I have seen are pretty bad.

[David] If the course has a text then that can be a major source. Research experience that has relevance to the course, other texts, knowledge from other experiences.

[Sophia] Sources: see above for ideas. Professional materials (research literature, recent review literature, review journals) the major source of content. "Curriculum" in the sense of my selection and organization of concepts to be covered - largely independent other than in introductory classes where department has agreed on general content to be covered.

Question 7. What does “order” in your class mean? How do you maintain order? How important is this for you?

[Adrienne] It depends on the class, and how large it is. The larger the class, the more discipline I expect - quiet when someone else it talking, people listening when someone is talking, etc. I do expect some sense of direction to what is going on. Noise should be kept to an appropriate level. If I feel things are getting too far out of hand, I ask the people to refrain from what they are doing, and get control back. It is important for me to feel that we are

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accomplishing something - order does matter to me. If things are totally unorganized, I'm not comfortable.


[Patrick] "Order" means that we are discussing course material. This discussion is often conducted by student groups. I do not mind if the students are talking and the classroom is noisy if they are dealing with the course subject matter. I have found that students are rarely disruptive to a class. If they are bored they simply do not come. They seldom speak out of turn.

[David] Order is maintained by having an environment conducive to learning. Order has never been a problem in my experience. One way to maintain order is to generate a stimulating learning environment.

[Sophia] Order: means respect for speech and thought and work of others. Behavior that betrays lack of respect will disrupt order. Very important to have quiet behavior in large lectures where noise and disruption really interfere with others. Noise and exuberance (even) not really the issue in a lab or field class or even upper division discussion type class, as long as everyone respects others’ rights to speak and to participate. That respect is VERY important to me.

**Question 8.** What is your approach to grading and evaluation? Please be specific.

[Adrienne] Ideally: Each student would be evaluated on a one on one basis, and would be allowed to demonstrate their knowledge to me. If they can explain the material, and do the work required, they would get an A. Students would continue to learn the material until they have succeeded - no matter how long that takes. Practically: I don't have the time. So, I believe it is important to provide sufficient feedback to the students so that they can see their mistakes and understand what they should have done differently. I don't think tests always show what a student knows. It is important to find other ways the student can show that they have learned. I would much rather have a system of pass/fail rather than assigning letter grades.

[Patrick] Normally I will give two exams per semester and a comprehensive final. These exams normally include short essay type questions. In addition I give frequent unannounced quizzes. The combined weight of the quizzes is approximately equal to that of an exam. Each successive exam is worth about 10% more than the prior exam in the computation of the semester grade. In the more advanced classes (Junior level), a research paper, worth about 20% of the grade is assigned. Homework is also given the same weight as one exam.

[David] Through the traditional means of exams, problem sets, and presentations. I try to maintain a certain portion of the evaluation to focus on the student’s ability to synthesize, interpret and they formulate an answer rather than memorization. Measure of critical thinking.

[Sophia] Grading and evaluation: Where possible I minimize importance of letter or numerical grades, emphasize particular skills or qualities sought in work or product. I teach a Viewing a Wider World course that is S/U only (my ideal!). I attempt to give specific feedback on what could be improved or alternative approaches a student might try.

**Question 9.** How do you accommodate student interests and needs? Please give examples.

[Adrienne] I will point out to students how what we are covering can be used in or for what they are interested in. I will spend extra time for office hours to accommodate questions. I will hold study sessions, when the students indicate they need help. I will arrange outside help for them if necessary.

[Hobart] Try to give interesting examples: Bonding - Instead of going through rules of bonding and applying them to one molecule after another, I try to add in something about why molecule is important or useful. Kinetics - talk about rates of reaction in regard to the ozone hole.

[Patrick] I ask if any students have special needs at the beginning of the semester. Once alerted to this need I always accommodate it. One example would be a student who has trouble taking notes and asks to tape record the lectures. This is allowed. Another example is a student having trouble seeing the transparencies used for the quizzes. In this case I provide a hard copy to that person. Special seating arrangements can be made. In the case of a student athlete, all missed quizzes and homework can be made up.

[David] Try to determine areas of interest and presentation of information in a way that is relevant to students. Provide applications to the topic at hand. For example, relate the inflammatory response to allergies that many students
have experienced and then discussing the immunological mechanisms that explain the symptoms. Or use examples that are of mainstream interest such as the discussion of HIV and its effects on the immune system. Or for pre-nursing students the importance of proper safety precautions in handling specimens and the microbiological basis for these concerns.

[Sophia] In most courses I attempt to build in time for student-selected topics. Discussion and participation, with flexibility to follow new lines of argument, promoted in most classes. Needs: I look critically at student performance in certain tasks or areas, if they are doing poorly then I often interpret that as a "need" for more explicit instruction or modeling or practice.

**Question 10.** In what ways do you create a challenging curriculum?

[Adrienne] I'm not sure I do. I try to present material at a level the students can understand, and assign problems that stretch what we've learned in class. I try to have work span several levels: from very simple, to something complex. Through design problems, students learn to apply what they've learned, and to adapt what they've learned. I want to make them think, but not get too frustrated.

[Hobart] Projects that require creative approaches. Complicated problems that must be broken down into simpler ones.

[Patrick] I strive to give a variety of activities at different levels to the class. Some of these can be difficult but most are within the current ability of the class. I do not avoid math or challenging concepts but realize that the general instruction should be at a class appropriate level. Some students are challenged by elementary math so one must be careful not to dummy down the class to the lowest performing student.

[David] By advocating the use of concept understanding rather than memorization. By asking questions that require the student to synthesize the concepts to come up with a solution. Test their understanding and ability to process information.

[Sophia] Open ended questions, take home exams etc., that are synthetic and that have no one RIGHT answer, that allow students to challenge themselves if they with. In sense of organization of topics: I strive to include topics/skills/experiences that would be expected of professionals in whatever topic is being covered, let students know the importance of professional, high-quality skills in real (post-college) world. Also strive to maintain current, contemporary topics (easily related to student's world, current events, etc.).
Question 11. Teaching linked to real-life experiences can have an open-ended quality because there is no one correct answer. How can teachers teach this way without feeling a loss of control over students and what they need to learn?

[Adrienne] They can let the discussion flow, but direct it. If things start getting too far off the teacher can direct the discussion or work back to what the topic is. A teacher can use flexibility, and perhaps the experience will lend itself to something that you'd cover in a couple of weeks - then re-arrange the schedule.

[Hobart] Teacher must be facilitator. Provide some guidance and direction to limit scope somewhat and prevent student frustration. Students want structure and to be told exactly what to do. Some structure must be supplied for the student while also encouraging independent thinking.

[Patrick] Open-ended questions are, in my opinion superior questions. They promote a wide variety of comments and can be debated by the students without feeling that they are "wrong." This process helps them value evidence and develop logical argumentation skills based on the incorporation of factual material. It also enables students [to] see the limitations of factual material, i.e. sometimes the same material can be used to support different positions. This type of questioning should not be viewed as a loss of control of the class but as a worthwhile educational experience.

[David] Many of the things I discuss in immunology and virology are not well ... offer the opportunities to use what has been discussed and explore the possibilities. Learning through the process even if the outcome is not completely controllable can offer a positive learning experience. Sometimes though it may be difficult cover in a lecture setting. However, problem sets can also [be] effective in encouraging this type of learning. In exams I have made questions that are hypothetical and have asked the students to provide justification for their answers. Downside can be however that the students think there is more subjectivity in assigning grades.

[Sophia] Focus on level of critical thinking or of other specific skills (graphing, quantitative analysis, writing, observations, hypothesis formulation, experimental design, etc.) you want student to be able to demonstrate - these can be evaluated no matter what approach or topic student chooses.
Question 12. What assumptions do you bring to your science class about non-science majors?

[Adrienne] I try not to bring any. But I suppose that I assume that they are not as interested in science as I am, since if they were as interested in science as I am, they'd be science majors. My experience has shown me that most teachers are afraid of science and sometimes math, so it is possible that I would think that the non-science majors may also have a fear of science - but I do know that that is not a fair generalization to all non-science majors, and probably not a fair assessment for Ed majors either.

[Hobart] Not interested in science. They need to be shown the relevance of science to everyday lives.

[Patrick] I really do not bring many assumptions to class since each semester they can be so different. The basic assumptions would be that many of the students are science anxious and have poor math skills. In my department we do not have an undergraduate major so all of our undergraduate classes are essentially service classes. In these classes we have freshmen to seniors from most of the colleges at [this university]. The upper classmen have generally put off taking their science class because of the above anxieties. The freshman seem less fearful. In the final analysis there is little difference in the semester grades between these students.

[David] They are not as well prepared and not as strong in their science background. May need more examples and review. May be less interested so more effort on presentation may be needed.

[Sophia] That all of them can (with enthusiasm and opportunities provided by instructor) learn of the relevance of scientific literacy to their own (and future) world. That all of them can gain enough insight into the scientific method to contrast it with other human approaches to the world. That most of them can come to appreciate many scientific principles, many biological processes, and to understand them at some level despite lack of related coursework or analytical thinking.

Question 13. What are your beliefs about abilities of students going into elementary education?

[Adrienne] I believe that anybody can do anything, and learn anything that they want to. I believe that basic math and science is within the grasp of everyone. I believe that students going into Elem. Ed. possess a spectrum of
capabilities. I think they need to be encouraged to experience math and science.

[Hobart] They probably are more afraid of math and science than many other students. They may have avoided math and science and are not as comfortable with math.

[Patrick] My beliefs are:
  a. they are poorly prepared in their academic fields and they spend too much time taking education classes that have little value
  b. they generally have poorer skill levels than non-education majors
  c. they do not have an appreciation for the vital role that they will be playing in society
  d. they graduate with inadequate skills to learn new and challenging material
  e. they are factually oriented and do not have a very deep understanding on the material they will be teaching.

[David] These students have to be more generalists in their knowledge and may have some apprehensions about learning and teaching science.

[Sophia] Not so much abilities, as interests that I fear are turned away from science and from quantitative thinking. I would love to assume that elementary ed majors are very people oriented, very interested in and sensitive to children, but I know this is not necessarily the case!!
CHAPTER 4

ANALYSIS: UNDERSTANDING AND MEANING-MAKING

Upon reviewing the professors' responses, I found it difficult to actually use the information to "categorize" them into one of three Caine and Caine perceptual orientations (1997a). This study was originally based on the Caines' study, but it was revised in the process to reflect the emerging factors identified by the participants and analyzed using Glaser and Strauss' inductive constant comparative method (as cited in Maykut & Morehouse, 1994). Their responses help determine some of their espoused theories. Observing their behavior in the classroom helped me compare what they said to what they actually did. Again, what they did is indicative of their mental model and this study tried to shed light on the congruence between what they said and what they actually did with respect to the belief system components described below. There is evidence that sometimes their espoused theories and mental models were in contradiction while at other times they were congruent. It is the latter that may support why it is so difficult to change behaviors and move toward pedagogical transformation. It seems easier to move from a transactional state (PO1) when we identify our contradictions between what we say and what we do, but when what we say and what we do support outdated, traditional and potentially damaging practice, it becomes more clear why there is so much resistance to educational reform.

Components of Belief System

Assessment.

*Living on the edge of possibility means that we have an organized and authentic philosophy of learning and teaching that allows us to use, invent,
and create approaches that apply what we know about learning. (Crowell et al., 1998)

Professors recognized the need for alternative forms of assessment, but cited constraints to implementing them in the courses with the most diverse student populations. They thought of the CETP reformed course as an opportunity to try something new, yet could not apply it to their regular courses due to perceived and actual constraints. They talked about using alternatives in the honors and upper division major’s courses because of the reduction in class size. Students in these classes are not necessarily those students who need diverse pedagogical methods since they are the ones that persisted in a traditional system and in a way weathered and even excelled in the self-selection process.

A question of honesty appeared on several occasions. The professors seem to be caught in a paradox. They either stay with traditional assessment methods that they know produce an environment in which cheating is inherent and that they know does not reflect conceptual knowledge attainment or move to try an alternative where the element of control may be lost. According to Crowell et al., “When we change our perceptions of the world, our approaches to living in the world also change” (1998, p. 102). This suggests that even though there is a lack of knowing what to do, the fact that the problem is obvious gives hope that the search for these new methods will be pursued.

[Adrienne] I’m not convinced tests give an accurate view of what the student knows. I think homework gives them much more of a chance to delve into things. I can give them much more complicated problems, much more thought type problems to see where they can take it. The only problem with that is cheating. I don’t know whether or not students are working on their own or working as a group and sharing the information....
I am still convinced that tests are not always a good way to see what students know. I just finished ninety finals and some of the things which happen because they’re under pressure because they’re on time and they make stupid mistakes and I guess I don’t know what tests are supposed to simulate in the work environment where you are under some sort of pressure to produce ... I don’t necessarily see the good in tests except for me ... the test doesn’t show me really anything of what they can do. Yet, I still feel like I need to catch the students who want work, the ones who aren’t cheating on me and not doing the work and not really understanding it. I’m hoping that [from] the tests I will get a better view of what the individual knows. Anytime I give them homework I am not convinced that it tells me what the individual can do. It may tell me what a group of them can do or it may tell me what they’re copying from a friend. In some cases it can tell me what the individual is doing. The whole idea of assessment totally messes me up because it drives me nuts. I want to be fair. I want to reward the student who is working hard and trying to understand everything and does everything....

This professor’s view of the purpose of assessment includes preparing students for stressful times in the work place. Encountering this revelation through reflective analysis might cause her perception to be altered toward a more productive understanding of assessment. She alludes to this more productive approach to assessment in that she believes it should show what the student understands. The focus of the search for an ideal should include the brain-based principles (see Appendix G), in particular, student choice.

An issue with honesty emerged with this participant. We must move beyond allowing a perception that a small percentage of students that “cheat” drive our pedagogical model and prevent us from growing as educators.

[Adrienne] The underlying belief is that if you can show me that you understand this stuff you should be able to get a passing grade on it. The assessment tools are, I’m not satisfied with, I’m not happy with them, but I don’t know good alternatives that will show me the same thing with the number of students that I have. When I was doing graduate-level classes, if they did poorly on the tests I’d say, “Okay, you can come and you can demonstrate to me that you really know this stuff. Make an appointment with me, you’ll come into my office. Don’t bring any books or notes with you and
we will talk about what you've done and we'll see if you can explain the stuff to me, like a mini oral exam. And if you can do that, fine, you've convinced me that you understand, then I'll raise your grade.”

Adrienne admits she is not satisfied with assessment tools as she knows them. Not knowing about nor fully understanding how to use alternative methods seems to be part of the problem (see Pape & Tittle, 1998). Teachers, like students, must have experiences in order for meaning-making to occur. She has tried some methods that are in her view not valued by her department. She has found herself being marginalized due to attempts at more equitable assessment methods in her graduate classes.

[Hobart] They do a mind-dump after every exam. I know if you talk to anybody in any science department about what they want the students to be able to do when [they], get out of the course, [they will probably state that they] want them thinking critically, using data, using scientific observations to come to a conclusion, evaluating complex problems... and things that can involve higher order levels of thinking. But we test them on burping back definitions and algorithmic problem solving.... I still use exams, but the nature of the exams changes a lot and in this course that was small enough I could get problems and essay questions that were much more conceptual than the algorithmic problem solving ones.... where the assessment becomes a problem is going to be in the bigger courses. Where they have to involve the TAs in grading the final reports, which are probably much more difficult to grade than a lab report and getting consistency of grading.... pulling that off in big courses is, going to be the trick because in a big course, to make it manageable, the evaluation has to be done say at the lab section level. Training inexperienced teaching assistants as to what they need to look for and consistency is going to be a very big issue, particularly in things like chemistry and probably in biology and physics courses and maybe math courses to an extent. But, scores and exams are still going to be a component and how to adjust those to what you are doing is a major effort. In the arts and sciences course we haven’t had to concern ourselves with exams or scores because we’ve been able to do evaluations based on written responses, discretion, reports, papers, and oral presentations because we’ve had the manpower and the small number of students.

[Patrick] I’m really not in favor of the multiple-choice kind of exams because I don’t think it shows a particular depth of the student understanding
and it lends itself to the memorization of facts. I don’t feel [they] demonstrate a particular depth of understanding, perhaps just a good memory. The exams are a useful tool, but they’re generally given so infrequently. You might have two exams in the course of the semester and the final. That’s pretty much the norm for introductory classes. That’s terrible! What are you going to do if you find out your students aren’t with you and you’re a third or even if it’s the second exam you’re two thirds of the way through your class? I’m much more in favor of giving lots of in-class activities. Even if I don’t know where the students are, the students know where the students are.... It’s then up to them to take the initiative. I’m not laying it entirely on them because you can walk around the class, look at their activities and if it’s blank it’s pretty clear that there’s a problem. Then one-on-one you can ask the student where it is that they have a problem. The instructor can still do some individual help in the activities by just glancing at it, not picking it up and grading it, just glancing at it there on the table.... I find that that’s a very useful tool, but it’s not the formal exam and they don’t get a grade.... I think the best kind of exam to give is a written exam. We have short answer questions where the students have to express in writing what their thoughts are about a question because it’s a lot easier for an instructor to judge where the level of a student’s understanding is.... On a written exam you cannot guess the answer. I think it’s a superior way of letting the instructor see where the students are. It’s a dual evaluation. The students evaluated on the depth of their knowledge and the instructor can evaluate his own teaching.... The oral exam is comparable to the written exam, maybe even a step above. Maybe it’s the top-level exam. The reason it’s the top-level exam is it allows you to probe.... Their workbook of in-class activities is another way of doing that. Now you can collect them at the end of the semester. That’s what I do. It’s not like I read every answer there and say that it’s not quite right here. What I do is look at the portfolio in an overview sort of way....

This seems to devalue what students put into their workbook. It is not looked at in the same detail as tests and calls into question issues of consistency and equity (see Sokolove, 1998). It has the potential to become a valid tool for assessment, but because this is not part of the mental model there will be no meaningful change in the assessment practices.

[Patrick] I assign more weight at the end of the semester than the beginning of the semester because the students are unfamiliar with the exam format. Sometimes the students know the material, they’re just not used to your exam format.... My solution would be to make sure that before you give a student an exam you give them some sort of pre-exam that is not actually graded. You
might hand it out in class so they think it’s going to be graded. After they do it, you go over what your expectations were and then just say this was a practice [and] that you are not going to grade this....

Patrick speaks of allowing the assessments to give students necessary feedback. Immediate feedback is a key element (see Appendix H) in maintaining a brain-compatible environment (Kovalik & Olsen, 1994). This professor also is questioning the extant assessment practices and applies new methods that were picked up after participating with the English department in Writing Across The Curriculum. He seems to be addressing the anomaly that caused him to review his practice of assessment, albeit based on one experience from outside his department.

[Patrick] Examinations are inexact processes.... It is sort of what they know must be relative to what they knew before they came into class. They know more, maybe not at the level that I wanted them to be at, but they are at a level that they’re satisfied with.... If I were to give a question that a lot of the students had done poorly on, I have a number of options. I could throw the question out for being an invalid question. Basically it’s invalid because I did a lousy job of instructing. I could just take that into account at the end of the semester. When I look at the individual student grades, if they’re consistent except for that one exam where I knew there was a problem, I [could] just give that exam less weight in the final evaluation of the students’ progress.... They have two examinations to show that they understand the material during a three to four month period. I don’t think that’s adequate.

He also has a deep-seated belief that quantitative proof is needed to show that a new method will work better than an existing one. There is evidence that he is willing to incorporate qualitative input in order to diminish the weight of a test that students do poorly on because they may not be familiar with the format. He also reserves the right to drop a question that seemed “unfair.” This type of action increases the possibility that he will incorporate a broader spectrum of alternatives once they become available to him.
Brain-based educators see that traditional assessment methods may be producing a threat that causes “downshifting,” a term used to describe how the brain moves to a survival mode where learning does not occur (Caine & Caine, 1994). His desire to find an alternative gives hope of possible change, but the change must incorporate a more general view of teaching as a practice. Paradoxically, these professors embrace notions of reform and yet cannot act on their desires to improve without the experiences and knowledge that comes from research in education.

Selecting essay writing as the method has the potential to preclude students that do not have equal command of the language even though they understand the science being assessed. How diverse is this viewpoint or does it also perpetuate self-selection?

[Patrick] The only thing I can say about the evaluation process is that generally speaking, you find that there’s very little movement that students will do. They do excellent on the first exam, do excellent on the second exam and excellent on the final. Students who do mediocre on the first exam, do mediocre on the second exam and mediocre on the final. Students who do poor in one do poor on all three. I wish that weren’t true. I wish that generally one would see a radical improvement in students’ scores. My experience is that you could almost give the students their semester grade based upon their first grade.... It will enable the scientists to more accurately judge the level of knowledge of our students. Essays are the way to go if the essay is understandable.

This passage seems to reflect a sad commentary on the impact of instruction. If no change is seen during the course of instruction, then the possibility for personal growth is truncated and the standard adhered to when using one mode of assessment continues to divide and separate members until only those who do well by the method in question are selected out for further studies.
[David] Their grades come from exams and problem sets.... The graduate students aren't being evaluated on the ability to go to presentations. It's more for their benefit than it is for us. It's a way for them to acquire tools that I think they need when they get out. I almost see that as a secondary objective. My primary objective is to give them opportunity to put themselves in a learning situation.... [Presentations] are not necessarily a tool for me to evaluate their progress. That's where the problem sets come in. I can't do that on a test.... With the problem sets, I have the luxury of not having them be done in that period of an hour. They can take it home and talk to me or talk to others.... In the reformed 121 class I gave out projects.... We catch students cheating on exams, even in the lecture hall they cheat. You have to have documentation. You have to go through prescribed procedures. And then you have to be prepared to be sued....

Interestingly, this professor uses a metaphor of consumerism. His language is indicative of a practice of defensive education. Education is characterized as expensive, less interactive, more bureaucratic and less humanistic. These tend to reduce the chance of being sued by students identified as clientele. It is built on a relationship of mistrust. The professor assumes that students have a predisposition towards cheating, yet alternatives to assessment are still not valued. His confidence to consider and to implement alternatives increases with the course level towards those students who have done well and remained throughout the self-selection process.

[Sophia] Then we have these writing assignments that we give. This serves two purposes. One is that we recognize that not everybody performs well on multiple choice exams. [Writing as an alternative method] has been the best way of assessing the understanding of concepts. On the other hand, when you have five hundred plus people, you do have certain constraints on assessment or evaluation. You know you couldn't offer private oral exams to every one of those people. Our repertoire is not nearly as wide as I wish it were, but what we do have is a so-called mini essay or micro-theme that I have used in a variety of classes before.... The exams are primarily multiple choice, but then there are two mini essays included on each exam. The lecture TAs grade those mini essays or sometimes, like final exam week, when we have a lot to do and we have to turn it around very quickly, all four of us, the two lecture TAs, and the two professors will sit down together and grade them very
quickly. Although these mini essays don’t constitute a huge percentage of the points on an exam, they are appreciated by a number of the students as an alternate to the multiple-choice questions.... Points are given, not for a correct answer versus an incorrect answer, but points are given just for being there and turning in one of these.... So there are six exams during the semester and the mini essay points are an additional exam’s worth of points. So you’re missing one seventh of the points. They can still pass. They can’t get an A and they’d have trouble getting a B unless they were absolutely perfect on the exams.

The passage above shows the effect of class size as well as the use of assessment for controlling student attendance. She adheres to a “best” method and the possibility for alternatives are restricted by the constraints identified. During the CETP reformed course, this professor did not use tests and exams, but allowed for students to engage inquiry-based interactive activities.

[William] The sad story about [assessment] is that I used to not give multiple choice tests. It’s so much better not to. I’d give some essay questions, problems where you actually work out problems. When you teach 250 students and have exams like that, it takes all week to grade the exams. I just succumbed to laziness and went to multiple choice. I try to design the questions to make the students think.... I rely on homework and problem sets for the grade. I don’t have them write papers in the graduate course. In the freshmen course, I use exams and multiple choice exams. I do give quizzes, which are not multiple choice, and they’re pop quizzes. I give ten pop quizzes during the course of the semester. I tell them the reason I make them unannounced is to encourage them to come to class because if you miss class, it builds on itself. [If] you miss this one particular lecture, you might be lost in the next lecture.... I also teach an honors class where the grades are based a little more on other things as well.... as well as exams and the exams are essay exams. They’re not multiple choice, obviously.

More evidence is provided for the use of traditional assessment as well as for control of attendance. There is also mention of class size as a mitigating factor. The professor’s repertoire is expanded, but only under conditions of the honors class.

Assessment remains an important issue in education and we must move beyond the notion of incremental change if we are to embrace science education.
reform for all. Through reflective practice belief systems can come to be more fully understood and practitioners can then compare what they say to what they do. When these two perspectives do not coincide the opportunity to select alternative methods that accommodate a broader base of learners is made possible. As Kuhn (1996) has identified in the discourse of scientific revolution, anomalies must be seen before we can act to understand them.

The participants' response to question eight on the survey dealing with grading and evaluation supports the idea that there is variety in assessment as well as a belief that existing traditional methods must change. William suggests that it is important to have a one-on-one relationship with students. Oral expression, among others, are part of his ideal. Hobart suggests more written assignments and projects to enhance assessment while David desires to "maintain a certain portion of the evaluation to focus on the student's ability to synthesize, interpret ... rather than memorization." Sophia has an idea that courses should have the S/U designation rather than letter grades. All of these ideas suggest an acknowledgment of this important issue as problematic and offers hope for the possibility of transformation through reform. As educators, we must act when conflict arises between our espoused models and our mental models as well as when these two systems are in congruence if the model being adhered to does not address issues of diversity and equity.

Constraints.

Orientation Three thinking ... happens through a deliberate response to what we know and a willingness to look at ourselves, our schools, and our world with new eyes. (Crowell et al., 1998)
Constraints analyzed below are those that were explicitly articulated by the professors. It is interesting to note that professors most frequently addressed the social aspects of reform as having constraints. They did not seem as prepared to consider the cognitive or mental model constraints. In fact, they looked to others as constraining reform efforts and goals without deeply considering that which may be constraining them from more meaningfully embracing reform efforts. Reform oriented thinking must embrace a broader view within the cognitive domain as well as in the social realm. In this way, educators might better understand the relationships between the cognitive and the social and how the two together have the potential to impede or advance reform efforts. These identified constraints are external to the people involved and make it easier to draw conclusions that preclude broad-based reform. Believing that not much can be done about these external conditions causes these goals of reform to be considered unattainable. The perception of the constraints seem to give them a legitimized reality. Inherent constraints were evident, but they were not articulated by the professors.

[Adrienne] I like the idea of getting away from lecture. I'm not quite sure exactly how to do it when class sizes are thirty to a hundred students in size. I tried to have them do little projects in class and the fifty minutes was not long enough to really get in to any of the little projects I wanted them to do. Just about the time they start getting to the point where they can do something, ah, time's up and they have to go. So we've got this thing called time constraint and it does present a little bit of a problem. If I was an elementary school teacher and I had all day with the students I could arrange the time a little bit more flexibly.... When you've got a hundred students, that adds up to an awful lot of time. It adds up to delaying getting those back to students.

Adrienne is identifying time and class size explicitly while implying that lecture is not a good method and indicating that her pedagogical repertoire is lacking
alternatives that might address the problem. The final sentence above gives insight into the contradiction of the perceived constraint giving rise to a very real constraint imposed on the learner.

[Adrienne] I certainly could [ask them to actually construct something], but ... are they going to do it themselves? That's the hard part. It's because I can't trust the students to be completely honest. I feel I have to impose something that I don't want to impose. Unless I had them do a competition among themselves. Which is possible, but I still don't know they would work. If there is a weak student there, ideally the weak student would become stronger in working with some other learner. In the non-ideal situation we're going to have some students sitting back doing nothing and giving credit for it. I need to guarantee that I'm not going to be passing students with As and Bs or whatever grade I will arbitrarily assign.

Another constraint that Adrienne identifies is student honesty. Without the cognitive information that could emerge from a pedagogy of praxis, it may be difficult to develop a broader understanding of the underlying relationship of cheating to the existing schooling system. In essence, she is left with having to impose methods that she does not support. What she does not say here may be more important than what she does say. The possibilities of reform emerge from self-reflection and meaningful interpretation of language deconstruction.

[Hobart] In the big classes which have more than one instructor, we use common exams. There will be more than 500 students taking the exam at one time. It's still a Scantron multiple choice kind of thing .... to try and get a conceptual understanding I think is an area worth investigating, particularly if you can test conceptual understanding with a multiple choice instrument which is still the method of choice in the large service courses .... pulling that off in big courses is, going to be the trick because in a big course, to make it manageable, the evaluation has to be done say at the lab section level.
Training inexperienced teaching assistants as to what they need to look for and consistency is going to be a very big issue, particularly in things like chemistry and probably in biology and physics courses and maybe math courses to an extent. But, scores and exams are still going to be a component and how to adjust those to what you are doing is a major effort. In the arts and sciences course we haven't had to concern ourselves with exams or scores
because we’ve been able to do evaluations based on written responses, discretion, reports, papers, and oral presentations because we’ve had the manpower and the small number of students.

Hobart mirrors Adrienne’s concern for class size and uses expense to justify maintenance of the status quo. He uses language dealing with conceptual understanding which shows he is aware of the goals of reform. Another contradiction emerges when the only alternative seems to be to continue the use of multiple choice exams as the “method of choice.” It is suggested for the larger classes, which are the most diverse ones. These are the ones that need methods aligned with the goal of reform. It is the smaller upper level courses that get alternative methods applied (due to their smaller size) and these are the classes that have narrowed student diversity through the self-selecting process. Hobart does point out that the reformed course, which is intended for non-science majors and has a more diverse student population than the general science courses available to the masses, did allow for innovative assessment methods. Education practitioners must look through new eyes in order visualize the possibilities that are driven by a different mental model. If we espouse that we want to change, but convince ourselves that the constraints are the reasons that we cannot, then little will be done towards true transformation of students and educators together.

[Patrick] One of the things that you find out [when] you become involved with the university is that there’s lots of uses for your time. The university will find ways of taking up all of your time.... There are just far too many students to do a good job than there are faculty.... In the last couple of years I’ve been involved in writing books. Those just have been absorbing huge clumps of my time.... I’m going to get this book done, which means that actually what I’ve done in the past I’ve let go. I hope to get back to them, but if I’m going to get these books done, I’ve just got to develop the time to do it.
Patrick identifies time and class size, yet he has the option of letting go of what he has done in the past. This means that he has made time for doing other things. Writing textbooks that are not based within the reform arena will only serve to perpetuate the status quo. Reifying existing conditions will serve to convert hope into hopelessness (see Freire, 1994). It is for this reason that professors must be supported to participate in meaningful professional development that will provide the experiences necessary to forge new mental models, not just espoused ones. It is the latter that are embedded in the rhetoric of contradiction that sustains resistance to reform.

[Patrick] I think these instructors have a fundamental misunderstanding of what interactive means. It doesn’t necessarily mean interacting with you one-on-one. That would be clearly impossible with a class that size. By interaction I mean they can interact with the material, the activity that you’ve given them. [They are] interacting with the subject matter and maybe not with me, but with one of their own, the person sitting next to them.... when you have large classes, you can’t give individual exams and probe their depth of knowledge. One is forced in moderate-sized classes to use a different examination format.

Patrick speaks of reform oriented concepts much like Hobart does. Patrick has had two very compelling experiences that have allowed him to consider pedagogical alternatives. Increasing the number and type of experiences can only serve to support the necessary mental model reform needed to teach for transformation. His use of writing as the single tool has greater potential for becoming one of many used by his students. Students having choices is another of the elements of brain-compatible environments (Kovalik & Olsen, 1994).

[David] In the CTEP format, what happens if your class is now one hundred and fifty? Can this format work realistically looking at resources? Can you do this now ... for everybody in the program? I think you’re now looking at a
huge number ... we need to break the class down, so it won't work, I don't think. What happens when we have some team taught by a number of professors? Instead of one section, what if you had ten sections? How does that work? Impossible. It's not possible.... When you get into these creative methods, there is the tendency that you go down in class size. Instructor to student ratio also drops. It's going to cost more money. It's going to take more resources to get this.... If you added up the man hours that the professors put into making this course, and then add that up the man hours of a single individual generating the one semester of biology, I'm going to bet that the professors poured into this class a lot more in total hours.... All of us are really working long hours and we hesitate to get involved in something that requires more time.

David compares the reformed course to the larger traditional entry-level biology courses. Larger classes serve more students and when these classes are broken down the "man hours" increase. His mental model is exposed regarding, for example, issues of what a scientist looks like (a gender issue) as well as his espoused theory that sounds reform oriented if only the classes could be broken down in size (and if money was available). But when I observed his methods in the small reformed class, they were fundamentally based in tradition. His class presentations were primarily lecture-based, using the overhead projector. As with the other participants, he stated in the interviews that he does this with his upper-level courses which have an even smaller number of students than the reformed science course. David was open during the interviews and shared that he did not have any background in teaching—other than what he had observed along the way of his education (see Brooks & Brooks, 1993; Bruckerhoff & Bruckerhoff, 1996; McGinnis & Watanabe, 1996). These conditions are part of the problem, but taking risks and participating in reform initiatives can begin to alter the deep belief system that informs mental models.
[Sophia] Last semester, in addition to the integrated natural sciences course, I was teaching our largest general education survey course, Biology 111, which basically had five hundred plus students enrolled in it. My real teaching responsibility last semester was Biology 111, two lectures, three times a week. Two lecture sessions back to back with two hundred seventy in a class.....the contact outside of class with students is very time consuming, very time consuming.....I’m no longer necessarily involved with the fieldwork one hundred percent of the time because I just don’t have time. Because of teaching obligations and now that I’m department chair, I mean, that’s definitely what I’m saying good bye to, at least temporarily, active involvement in the data collection, in maintenance of experiments, long-term experimental set-ups in the field, and so forth.

Sophia supports the other professors’ perception that time is a major constraint. It is interesting to note that this is such a powerful perception. The constraints of that time are also affecting her passion to do field work.

[Sophia] I think that selfishness ... prejudices of different kinds. Prejudice may be a strong word, but pre-conceptions definitely get in the way. And limited time and resources. The limited energy that each of us has as researchers because you just heard what some of the other obligations are. I didn’t even get into service, which is supposedly five percent of your time. If you’re on an editorial board for a journal, that can be hundreds of hours of work in a year’s time. And then we have all the service work on campus. You know, go to faculty meetings, go to committees, go to the advising center. Then [there is] outreach, some of us do try to do various kinds of outreach. You’d be kind of foolish to spend scores of hours doing that when the only possible category you can report that under on your annual report would be the service five percent. You know, so what’s the difference between being ranked number one in service and being ranked number five in service. It’s a vanishingly small impact on your overall evaluation because service is such a small part of your job.

The passage above further identifies the need for reform. There is evidence that the old and the new are competing to the extent that we are at a point of scientific revolution. As Kuhn (1996) points out, when anomalies can no longer be understood by the present paradigm, a new and accommodating paradigm emerges. "Most societies ... resist challenge by new ideas that would destabilize the structure. Yet,
history tells us that societies do swiftly make sweeping change” (Milbrath, 1989, p. 365).

[Sophia] I see the major barriers as being structural or organizational more than personal. All of us as individual faculty members are liable to go out there, get inspired to try something new. We certainly have a great deal of flexibility and freedom in designing our own courses, our own curriculum, our own course content and presentation methods. [There is] basically resistance in terms of inertia of the institution, in some cases, limited resources. Time and money prevent people from trying these innovations more frequently. There’s resistance on the part of the students as well to being exposed to some radically different presentation technique or expectation. Whether it’s resistance or it’s just lack of perceived moral and financial support, all of these act to reduce the energy that faculty members are liable to put into reform activities or innovations…. I think resources and lack of a clear message from above have led to a pretty fatalistic resignation to the status quo for a majority of people.

In the beginning sentence of the previous passage Sophia captures the essence of a theme that runs throughout the professors’ narratives; “major barriers as being structural or organizational more than personal.” This distancing of the self from the problem or issue exacerbates the resistance by not fully addressing the cognitive implications. She further bases the motivation for change in a hierarchical structure and continues to remove the practitioner from the change process. Her assumption is that students resist innovative attempts by faculty (see Bailey & Chambers, 1996). Hilty and Gitlin (1995) point out that one of the real constraints is that teachers have bought into the notion of top-down reform, which keeps their voice marginalized. Bybbee (1997) suggests that we move from purpose to practice from the bottom up and that practitioners must assume responsibility for their respective roles.

[William] When you teach 250 students and have exams like that, it takes all week to grade the exams. I just succumbed to laziness and went to multiple-choice. I try to design the questions to make the students think…. What would that do to the cost of higher education? Instead of having one class of
one hundred and fifty, you would have ten classes of fifteen. You have got to have ten people teaching rather than one. That leads to inefficiency. That leads to inflation. See, that’s how we’re able to keep down the cost of higher education, by making the classes bigger and bigger, to make it more efficient. If you want to reverse that, then the costs are really going to go up.... How are we going to teach a general chemistry course with 150 students in the class?

William speaks of the inefficiency of reducing class size (see reference to Coleman Report in Oakes & Lipton, 1999). He is concerned that doing so could potentially lead to inflation. Reform-oriented professors must reflect on alternatives. Could improved pedagogy change this professors resigned view? His question “How are we going to teach a general chemistry course with 150 in the class?” is itself indicative of the need for reform. The perception that classes with large numbers of students are a constraint to reform is in opposition to the low number of students that persist in the sciences (Seymour & Hewitt, 1997). It isn’t that there is not a pool of potential science persistent students, it is what we do with them as educators of science that makes the numbers dwindle. If science educators stay with the notion that nothing can be done until the number of students in a class is reduced, then they will never be able to envision the possibilities and support them with doable initiatives. There seems to be an issue of ignorance of the tools of reform. The question of one’s own privileged status must be addressed in order for us, as science educators, to identify ourselves as part of the problem similar to what the community college professors did in a study done by Fedock et al. (1996). A good starting point might be to ask, “What do I bring to the classroom that inhibits participation in science?”
Culture.

Another aspect of the science reform culture is that recommended changes are often out of context, both in terms of institutional limitations and the needs and abilities of students and faculty they are supposed to serve. This indifference to context may also reflect the habits of doing science, for it appears to rest on the unexamined belief that, once articulated, the "right way" will be self-evident, teacher-proof, and appropriate for a wide variety of institutions. (Tobias, 1992a, p. 16)

[Adrienne] I didn’t realize that as you get more advanced degrees you keep narrowing down your area of expertise until you know a lot about very little. I sort of thought it went the other way when I was in junior high. [Sigh] so many delusions.... I’m not allowed to teach graduate classes anymore [pause] - now that is part of it. They don’t think I’m competent to teach graduate students. Since I’m not in a tenured track slot, they’ve barred me against doing graduate work. I see their position to a point, I mean, I’m not published. That’s part of the problem too. That’s part of why they don’t think I’m competent, because in my research I don’t have any main publication. I have tech reports, but I don’t have any publications in journals and so I have not been through the peer review process and they don’t really think I am qualified to be teaching. It really bothers me, but there’s not much I can do about that. I’m trying to continue to work on my research and I’m going to try to get more things published, but it’s hard to do when I’m teaching freshmen because they’re so time consuming. I’m sort of caught in a no win situation.... Tenure and promotion is based on how much research dollars you bring in and how much you publish. There’s starting to be some change there, but it’s slow. Our department head has said he does not want promotion and tenure to be based solely on research. He wants to incorporate the teaching component as well.

Adrienne reveals the specialized nature of a department full of Ph.D.s and characterizes it interestingly—as narrow. That would lend itself to addressing the in depth nature of reform oriented teaching, but limits one in the area of interconnectedness. She also shows how the system can be rigid and limiting to those who do not “comply.” It is possible Adrienne is experiencing marginalization similar to that of non-science major students. Her competence is questioned due to her lack
of research. Moreover, she appears to get plenty of the routinized work for the
department. Tenure and promotion is commonly tied to research and publication.

[Adrienne] [Academic "inbreeding"] is another reason why I have not sought
tenure here. It is because I don't want to put them in that position. However,
our department has hired several of its own graduates. My husband is one of
them and [a professor] next door is one of them. Our department head is one
of them. We like our own graduates, but we do need to get other points of
view in here.

Although academic inbreeding is espoused as undesirable, it apparently occurs
quite often. Several of the professors have not only attended but also have only
taught at this university. The reasons against inbreeding is to keep the diversity of
thinking high so that a department does not stagnate or get too narrowly defined.
This contradiction seems to work against diversity and more solidly positions existing
practice to perpetuate self-selection.

[Adrienne] When I did finish I wasn't happy with the product and so I never
published. I think [that] was the biggest mistake. I should have been made to
publish the results because now I feel like anything I write is not going to be
publishable. I have never gotten a publication. I haven't tried that often.

Adrienne is relegated to teach lower level courses now. This practice must be
questioned, not only because of the apparent injustice done to a professor by
devaluing teaching in such a manner, but also because of the message to students
regarding who advances, who publishes, and what role women play in engineering.

[Adrienne] ... we have found out that faculty don't always know what's going
on in their lab.... I only get work done on it when I have to get a report done
or during breaks which is Thanksgiving and Christmas break and summer.
That's when I have to do most of my work for research.

The lab is where hands-on activities help students understand the concepts.
This is accomplished with the help of TAs that probably have even less pedagogical
training than professors. Adrienne admits that faculty are dealing mostly with the transmission portion of the course. Opportunities to do something besides lecture as well as to get to know the students within a dynamic and less certain process are consequently missed. This cultural practice is highly suspect in developing negative attitudes towards the discipline and fails to build positive ones. Adrienne’s position is further constrained when she has to do her research on her “own” time because her on-campus load keeps her from moving beyond the mundane.

[Adrienne] Getting faculty to buy off on that, spending much more of their time teaching would be less much less time for research because if you broke the classes down into tens or twenties out of a hundred you’re talking five to ten more classes instead of one class. You’d have to have a faculty member doing all that, so realistically I don’t think that’s going to happen... then you could actually do it right.... We had a department head organize a seminar for us to improve teaching and retention of students. He wanted us to look at that. Only maybe ten of our faculty showed up for the first meeting and seven somewhere between six and eight finished [out of forty or fifty faculty]. I don’t know what to think.

In the preceding passage, Adrienne shares the hope that her colleagues could have smaller classes and spend more time teaching rather than research, but even when the department offers professional development, it is not well attended.

[Adrienne] I think the university is going to be the same [in five to ten years] because they’re cast almost in stone and we’re almost immovable. I will hope that there will be change, but unless there is some reason for them to change, they’re not going to. Now what drives universities? Money and tenure are the two things that will motivate a faculty member.... [Sigh] Territories and tenure. Yes. Politics and from what I’ve heard lately, politics on campus is a whole lot worse than politics in D.C. and that is bad because at a university, it shouldn’t be politics it should be academics.... I am not tenure track. I have, according to the college, no power. I can’t make decisions on the same level that tenured do.

Adrienne’s perception is underscored by the lack of a critical component to the transformative process; namely power.
[Hobart] When they hired me ... course development is considered my area of scholarly activity. The classroom is my laboratory [where I do] both my teaching and my research. When we do our goal statements and you apportion how much is teaching and research and service, the dean and department head know that it is teaching or research.... In a research university that's often the situation. They value the time spent on teaching a little bit more ... At Illinois you can be a horrible teacher and if you have the grants and the publications you're going to get tenure or you're going to get promoted early if they thought you might ... or leave somewhere.

The National Science Foundation has called for administrative buy-in as well as cross-disciplinary collaboration. Hobart gives evidence that the dean is supporting the CTEP reform initiative. It is with this type of support that reform will take hold, but these practitioners cannot wait for a trickle-down effect. Each and every participant must begin the journey of transformation through a process of dialectical self-analysis and reflection.

[Hobart] I think the main reason and that people resist change.... as we went through our careers, always saw lectures, bad lectures, and so it's the way we were taught. It's what we've seen the most examples of. I think it's probably the case particularly with high school teachers. I think a lot of high school courses are taught a lot from the lecture format. Even though those teachers had the methods courses where they talk about effective methods usually from cognitive research and what works. They have had a couple of methods courses and maybe a hundred hours of instruction that way and thousands of hours in the classroom where it was different. It's hard to break a habit. There are people with a good teaching in the lecture format. I've spent a lot of time working on lectures, lecture notes, demonstrations, visual aids that you know, very often it's a pretty good show.

Hobart shares the power of indoctrination. Teaching is the only career where the context is defined and perpetuated from early childhood (see Hart, 1998). He even challenges the pedagogical effect that a couple of methods courses have on K-12 teachers. A better understanding arises when we extrapolate the effects to university professors that have not even had those courses. The underlying problem cannot be
“fixed” with a couple of exposures even though these professors saw value and incorporated change after limited reform oriented experiences. The drawback is that their perceived constraints are keeping them from continuing their journey of transformation.

[Hobart] The bottom line is the easiest thing to judge people for promotion and tenure is how many papers they’ve published. So the time you devote to reforming a course that you teach means that you publish one or two papers fewer by the time you’re up for tenure and that you might get lower teacher evaluations. There’s not much in it for a beginning professor to spend that kind of time. I think it’s not as bad here as it is in some schools. In my position, you know, I was hired so that my scholarly work is in course development or curriculum development in teaching reform. I mean that’s one out of a department, one out of a college.... Reform comes in many respects from below. There can be some encouragement and incentives that come from up high, but it takes the faculty to do it and then only if you have that strong leadership and encouragement and reward system put in that [ensures] you’ll get credit towards tenure for being involved in these kinds of activities ... If you publish a paper on a reformed course, that counts just as much as a research paper. And so, work has to be done from below. The rewards and the leadership have to come from the deans and the colleges, vice presidents and chancellors and so on. And that’s one of the things NSF is trying to do … Our dean does buy into it. I know that I’m going to get credit for what I’ve done getting involved in this.... It’s not going to happen if you don’t have the faculty doing the stuff in the trenches. But it’s not going to become systemic unless there’s the leadership of the deans and higher level and getting credit for those kinds of things. From the faculty standpoint ... is to spread the word, whether it’s the publication or the presentation of papers. But, it’s also working with your colleagues.

When the existing faculty culture is challenged in meaningful ways, the roots of reform may begin to spread from within and the long anticipated top down reform can be abandoned. Energy can then be used to continue growth in a collaborative way. Hobart’s position sends a clear message that values are changing, but will it be heeded or resisted due to the status quo’s dominant position?

[Hobart] You can’t cover everything. I see it sometimes in new faculty members ... not so much, but sometimes with graduate students and TAs.
And it's the idea of, "Well, you've had my course and you should understand all the nuances of chemistry that I have," even though you've taken just one semester of general chemistry in college. I majored in chemistry for four years, spent another four years in graduate school doing nothing but chemistry and three years getting a Ph.D. So, there's eleven years of studying compared to one semester and you can't expect the student to have those nuances and understanding.

Hobart hits on a subtle point that may have widespread application. Reform oriented teaching allows for teachers to become involved with their students as co-learners rather than transmitters of text-based knowledge (see Gardner, 1998; Tobias, 1992a). The modeling that takes place in this new relationship can enhance the development of those nuances and understanding.

[Hobart] I think there was this gap between the science departments and the education schools. There's this animosity.... Research and teaching aren't that much different. You have to make a point with research faculty ... What is the university's role in conducting a graduate program and research? They say, "To increase their knowledge and understanding." And the reason it's going to get you support from the state at a state university is this part in the educational role. You're educating people now to take leadership positions in your discipline. Whether it's a leadership position in an industrial laboratory, industrial setting, or it's a leadership position as an educator or faculty member. But, it's education and I think the faculty members that see the graduate role as an education role are going to understand that and see applications for the courses. The ones that are in it for the ego and the long list of publications and getting the reward or recognition may not cut it in class. I see it in our department.

It is evident that Hobart has begun to reflect on the issues. He speaks from a position where espoused changes can be implemented from within the ranks – or as he puts it, "from below" (see Hurd, 1997).

[Patrick] I think this is one of the reasons why new faculty have a hard time adapting to different methodologies because they haven't proved to themselves yet that the methodology that they're using is going to be ineffective. So it's very difficult to talk to new instructors, new faculty and say, "You know, you really ought to try this," because that's a model that they're unfamiliar with. That's a model that they didn't even grow up with
and they just don’t feel comfortable with it.... The anxiety that the instructors have is I think of trying something new. They’re afraid of failure. Even though they’ll admit that what they’re doing is wrong, they’re more content to continue to do what they know is wrong rather than to try an alternative. There’s anxiety of the part of the instructor to try a new approach.... I think that what might be going on here is that it’s so far divorced from their research area. They’re seeing a trained astronomer so when they think of research they think of astronomical research. It’s not that they would necessarily argue that trying something like this in the classroom is research. It is just so foreign to their concept of research that I don’t think they get to that point where they can see it as just another research project that they could do. I’m a researcher, I know how to construct tests to see whether something’s effective or correct or not. Why don’t I apply it in my classroom? I think that they compartmentalize things such that their research in astronomy is one thing and their teaching is something else.... You hear that today on university campuses where the phrase that new faculty members seem to be indoctrinated with is, “Publish or perish.” It’s not, “Do a good job in the classroom or perish.” It’s publish or perish. The university sends a signal to its faculty, as does the department itself, that although education isn’t to be dismissed it’s not to be one’s primary concern. Now after you’ve been in the classroom teaching for a number of years it becomes naturally an increasing concern of yours for the reasons which I mentioned last time. As a scientist you just cannot be happy with working with a model that produces less than satisfactory results. Your scientific training, in other words, will begin to overwhelm the considerations that the others tell you about. You shouldn’t give it a high priority. If I think you’re a good scientist, then you look at things beyond your immediate discipline in the context of the way you work in science. That’s going to point the direction of science education reform, point you in the direction of that. I think this is something that naturally evolves in faculty members, perhaps not at a conscience level that they’re thinking in terms of this, but it eats away at you. It eats away at their resistance. That is both within you in trying something new and is institutionalized in the context of the university’s promotion and tenure system.

Patrick is alluding to the indoctrination effect resulting in teachers teaching like they were taught (see Bruckerhoff & Bruckerhoff, 1996). It calls into question the knowledge of alternative pedagogies and the process by which professors can experience them in a meaningful way that will support reform. In other words, if we know this is part of the problem, then it can now be addressed. “Rather than relying
on convention or tradition or what seems to work, it is more effective to look to
research for improving teaching” (Nieto, 1999, p. 4). Patrick is identifying the
frustration that scientists develop because of the constricted scientific model that is
used to guide their development as scientists. We, as science educators, must remind
ourselves that reform is not a scientific enterprise (Tobias, 1992a). Values within a
discipline and department drive the mental models of the collective group of
scientists, but the educator must form a personal mental model based on what is
known about learning and teaching and this cannot be imposed, it must be learned
through experience. Historically, many of the professors that get involved in reform
initiatives are full tenured professors. This should distance them from the notion of
“publish or perish” and allow them to model “do a good job in the classroom or
perish.”

[Patrick] We say that sometimes there’s this difficulty of scientists talking to
people in the humanities. It’s really true at some level, much to my surprise.

There seems to be difficulty because we compartmentalize our disciplines.
Education or an understanding of learning and teaching, however, are important
components across disciplines and within all university departments (Brucknerhoff &
Brucknerhoff, 1996). During the interviews, Patrick came to realize that maybe
students have a problem with communication. The next step might be to act on it in a
personal manner that will bring his mental model in contact with what he espouses.

[Patrick] At the last astronomical society meeting just held in Austin this
January there were at least two sessions that dealt with science education.
Both of those sessions were very well attended…. They report what they’re
doing now. Generally that is not a straight lecture.
Most of the professors mentioned similar observations to what Patrick has reported. Contextual change is part of the reform process and this should be used to support the notion of personal transformation.

[Patrick] I think it’s something that should be done. But it’s not something that the university itself seems to value in terms of promotion and tenure raises. That doesn’t seem to be something that they ask you a lot. I’ve been here over twenty years. I don’t know that I’ve ever been asked, “Have you ever reflected on the direction that your classes are taking?”... If you were to [ask us to reflect] during the last week or the first week of every semester, there’d be no instruction. I think that probably the vast majority of the professors would actually spend it catching up on their research. If they did reflect about it, they might come to the sad conclusion, “My students aren’t learning as well as I’d like them to do. I haven’t a clue as to how to do anything better than what I’ve been doing.” I think that would be true for the newer faculty.

Patrick feels that reflection is a worthy endeavor. There may be a disparity in understanding reflection as it applies to praxis. Professors would be well served to find literature and professional development is this area (see Knapp, 1992). The Method of Currere is a powerful source for anyone wanting to understand their academic experiences through reflection. Pinar (1995a) describes a method that is regressive, progressive, analytical, and synthetical.

[Patrick] There’s politics involved here.... [There are] turf struggles. The problem is not all with our students, is it? The problem is institutionalized. I think universities move perhaps at a glacial rate of reform. Although we claim that this is a hotbed of reform at the universities.

Like others in this study, Patrick sees the deeply embedded nature of the status quo. The respondents identify the culture and allude to its power and immobility. Its very nature is overwhelming and intimidating if reform is seen as a top down problem rather than a process we live with. This is why the journey of transformation must become a personal one with collaborative intentions.
David] The researchers that come in and are new hires think as scientists.

David’s comment can be deconstructed in such a way that his view of a professor at a university is one of being a scientist as opposed to a teacher. It has emerged that the university science culture values one over the other (Jennings, 1997; Mattson, 1997). This is why most seem to support the scramble to get research and publications while affording little effort to their re-education to improve instruction. Seymour and Hewitt (1997) provide evidence that students leave the sciences (and many that persist feel similarly) because of poor teaching as the number one reason. Since most students will not become scientists, it seems prudent to address a broader base of students with the intention of guiding them towards science literacy.

[David] I saw the sort of a mass production factory mediated way of undergraduate education where I came from. For some students it was fine, for others you really need that individual attention. You never got to see the professor, you just got to see the graduate assistant. It was really an impersonal approach to teaching and [since] it was a research institution, the professors did not focus on teaching.... When I first arrived, I was told that there’s a certain segment of the population in a class that is going to get an A, even if you stand up in front of the board and inspire gibberish. Then there’s some segment of the population ... that is going to struggle.... they’re gong to get Ds and Fs. I think that’s right.... There is always going to be nine or ten percent of the population....

This passage illustrates the indoctrination effect self-evidently. If this is what you have been accustomed to seeing, it seems rather difficult to form much different mental models. Even while identifying the issues that plague the existing teaching model, David appears unable to embrace a reflexive stance in order to question it. Instead, he “complies” with the expectations; all part of indoctrination. It has been reported in these interviews that 10% of the students persist in science and a professor can expect 10% to get Ds and Fs. This can be interpreted as scientists teach to 10%
of the population. A question of democracy in education arises when 90% of the
students do not have their needs met. If those 90% of students were to become
science literate, it is possible that would demystify the discipline and tumble the
pillars of this hegemonic process?

[David] Grant writing is an instrumental part of training the graduate
students. Without the grants, they don’t have the supplies, I can’t get them on
RA-ships.... Another part of it is has nothing to do with teaching is
management, results of our research, sometimes through article writing....
That’s the ultimate thing. In a research discipline like we are in, when they
write their CVs [curriculum vitae], one of the things they’re going to be
looking for is whether they have any publications coming out of their graduate
training.... My goal is to have every student that comes through here give
presentations at scientific meetings, at least have the opportunity get
themselves in publications.... I’ve only had one masters student go through
and now she’s in the Ph.D. program. So I don’t have a big track record
here.... I’ve thought about integrating.... If I were just teaching, and my
evaluations were based on teaching [then] that’s a different environment so I
may be more likely to make some changes.

David has been teaching at this university for three years and has mentored
one student. It brings contradiction to the notion of expense of reform as considered
in the context of lowering class size. Consider that this department is supporting a
professor over a span of three years teaching upper division classes in order to get one
student through the program. The ideas that have been incorporated into this mental
model serve to resist the notion of science for all and also protect his position by
aligning closely with the cultural values of the discipline (see Jennings, 1997; Lasley,
Matczynski, & Benz, 1998; Springer, Stanne, & Donovan, 1997).

[Sophia] ... our own graduate students who are thrust into teaching, maybe
never thought about the teaching process, have no idea of education research,
or what the issues are in science education reform. That would be very good
for us, very helpful. Attitude is everything. [Chuckle]
Sophia identifies a reform issue dealing with the use of non-educationally prepared graduate students as teachers (see McGinnis & Watanabe, 1996; Thoresen, 1994). This parallels the same issue within the ranks of the teaching professorate. This research is showing that there are many components to the mental model that must be addressed. The fact that science professors/teachers continue to prepare more for their role as scientists than science educators is one that must be addressed with any meaningful strategy for reform.

[Sophia] We restructured those introductory courses to be a two-semester sequence rather than a one semester overview for majors so that they’d have time to master some of the more difficult concepts. Then you get to their sophomore year and you have to repeat it over and over and over again because they didn’t really get it the first time.

This passage shows more evidence that the traditional system is indeed in trouble since material does not seem to be learned. Until professors see that they are part of the process that is causing this to occur, they cannot get to the point of improvement (Fedock et al., 1996). The question must be asked, adequately analyzed, and answered, “Why didn’t they get it the first time?”

[Sophia] I don’t think he was ever involved in any professional teaching improvement activities before he participated in that. I know that he found a number of the concepts much more novel and much more foreign to the way he had been taught and the way he thought about teaching. And he thought it was great. He thought it was fun to be able to try things out in a smaller setting. When some of my colleagues, who’ve not thought about teaching as a professional activity, have been exposed to some of these innovative teaching techniques, their initial reaction has almost always [been], “Sounds great, can’t do it when we’ve got three hundred people in Biology 111.” I think they might be appreciative of it. They might be enthusiastic about the possibility of breaking out of the mold and yet they might still fall back on thinking it can’t possibly be applied at the scale we’re talking about with regard to large course enrollments.... At an institution level there just doesn’t seem to be a big investment in improvement of instruction.
Many of the comments made by the respondents seem to indicate that they separate themselves from others when critiquing the status quo. It is crucial to include ourselves when we review that which has operated to maintain the status quo. If we engage this in a personal manner, we have some sense of control. This is precisely the reason I am calling for self reflection as a necessary first step towards the process of transformation and reform (Crowell et al., 1998; Freire, 1994; Giroux, 1988; Knapp, 1992; McLaren & Leonard, 1993; Pinar, 1995a).

Sophia Even though [this university] says that research and teaching are each important parts of our job, we all know who gets the salary increases and who gets summer salary; people who have grants. The reward system is definitely skewed toward research. And my primary professional society has recognized that. One of the big projects that education section is running is aimed at the reward system within colleges and universities. They're finding deans and vice-presidents and provosts to participate in these workshops, to talk about how can you build rewards for improvement of instruction, teaching innovation, teaching effectiveness. How can you supplement the reward system that is currently very much skewed toward the science itself? Because science itself is what gets you grants that can generate your salaries. It's what gets you a publication record that generates recognition. The grant directly pays summer salary. What most of us have experienced is that research grants are very comfortable paying summer salary for nine month faculty, but when I apply for a grant that has to do with undergraduate research experiences or undergraduate mentoring, usually PI salary is explicitly excluded. You cannot ask for that. They assume that the institution supports its educational efforts. If it has anything to do with education, you can't ask for salary. Why should it be that the College of Arts and Sciences provides seed money for research activities, but not for improvement of instruction? I'll tell you why. It's because the dollars they use for that come from research grants' indirect costs. Often when you apply for an education-related grant, indirect costs are very sharply limited whereas in a science-based research grant, they're aware that there are many costs to research and that's the basis behind indirect costs. It's that the institution is allowed to try to recover some of those costs of supporting research, the costs of building the research laboratories, the costs of maintaining research equipment, the costs of maintaining a research library. If money is coming into the university, money comes into the college every time an arts and science faculty member gets one of those grants. Then what do they do with that? They turn that around and use it for seed money for junior faculty who come in to help them build their
ability to compete for grants. When I write to NSF's education directorate for example, usually you can ask for only a very limited amount of indirect costs as administrative fee only. Or you can't ask for any at all. So, where's the university going to get the money to improve instruction? From its state legislative allocation which has been shrinking every year for three years and which wasn't really adequate to begin with. I mean, they don't have the dollars is what it amounts to. The other thing is that where do we all do our Ph.D.s? We all got our degrees in Ph.D. granting research institutions. By definition, who do you want to be like? You want to be like your mentors, big, successful, big name scientists. Not big name educators, big name scientists. So the culture is definitely oriented toward scientific research publication, toward grant-getting as a measure of your success. And then the internal institutional culture doesn't do a lot to counteract those pressures. The other thing is that people who are quite successful as research scientists, to the point that they attract substantial outside funding, they publish regularly, they have a national or international reputation. Those people are heavily recruited for jobs at other institutions. Therefore, the university often coughs up extra salary dollars to keep them here. It's extremely unusual in my experience for someone whose, it's not unheard of, but it's much less common, for someone whose focus is science education to be recruited out of one basic science department into another. [The] citation analysis is very competitive, citations and grant dollars. That's what it's all about.

This descriptive account of the university culture shows how aware practitioners are of the current state of science in higher education. Sophia points to the administrative prestige assigned to research within disciplines while the teaching of science is relegated to a secondary status. The gap between the espoused and mental model needs to move from awareness to praxis in order to narrow the incongruence that is evident (see McLaren & Leonard, 1993). There exists a resulting tension between reform and science. The culture is in need of review and deconstruction. Only then can the dominant view that supports the status quo in valuing scientists over science educators be effectively challenged (see McLaren, 1994). When scientists return to academia they are guided by their specialized discipline more than their ability to educate.
[Sophia] I had very little time to go out in the field and actually collect data. I was moderately successful on Tuesdays and Thursdays at spending the mornings writing, analysis and writing. So that was my research, my scholarly activity. That's something that has evolved over time. When I first came as an assistant professor, definitely, my mode of operation was to work as an individual. That's the way people in my field work. Ecologists, field biologists tend to work as individuals rather than as part of big laboratory teams, which is more typical in the bench or the laboratory side of biology. We tend to come up with ideas on our own, go out in the field and collect the data on our own...Teaching is what I thought I was interested in doing. Later, I became seduced by the idea of doing science and it's really only since I got tenure that I've become more confident about myself as a research scientist. I'm very, very much more interested in maintaining my scholarly activity than I used to be. None of that had any room for becoming an administrator at all. The longer I was here in this department, the more interested I realized I was in the dynamics in groups, the interactions of us all as colleagues within the department, the welfare of the group as a whole, the department and the department's programs as a whole. I came to realize that I was much more interested in those things than many of my colleagues were. I began to suspect that at some point I would be interested in taking on more group responsibilities, which is to say, administration of some kind. I did not anticipate doing it this early in my career. For various reasons that I'd rather not go into, our department needed somebody with a very positive mindset to step in. Hence, that was me last year. I decided that I would rather put the energy into doing it and dealing with the issues head on than have my energy frittered away by watching a lot of the negative things continue and spiral downwards, possibly eating up a lot of the energy that I'd rather devote to my research or my teaching. You know, I think the place has so much potential and it's been very good for me and I just found it less frustrating to step in and take responsibility than to watch it fall apart and not take on the responsibility.

Sophia identifies working alone as a characteristic of research. That does little to give voice to individuals so that they may collectively challenge the cultural life she mentions. Scientists are hesitant to call themselves educators, yet she maintains a large part of her identity as an educator. She lives in a culture that devalues her professional identity as a professor to the point of "seducing" her away from her initial ambition to teach. She is not permitted to enact that part of her identity.
The majority of our faculty will choose students who are aimed at research experiences, at research degrees aimed at either academia or some other research or technical position after graduation. The majority of our faculty, if given a choice, would probably not choose to admit and to train a student whose stated aim is to go into K-12 teaching. That’s just the reality.

Sophia identifies another significant reality that has become a major obstacle for furthering the science education of educators through a self-selecting process.

This constrains the university’s ability to produce science literate K-12 educators.

This important contradiction keeps us in a “catch-22” situation. Pre-college educators are blamed for not preparing the students for college, yet the people responsible for the teachers’ education practice a pedagogy of selection and separation.

People that I’m very seriously interested in, I encourage [them] to come to campus if they can. But again, if you’re attracting applications from the east coast and we don’t have the money to fly them out here, that’s asking a lot to expect them to pay their way out here before we admit them. In those cases, if it’s somebody who looks great on paper, I’ll often go ahead and sign. They’re admitted. I encourage them to come and visit. We make arrangements to put them up here with the graduate students or in my own guest room, show them around, make sure they meet as many faculty and graduate students as they can, give them a good feeling about the place.... As a regional school, we get a lot of applications from people who have no better formed idea of what they’d like to do than simply they’d like to take more biology courses and they already have a bachelors degree in something. It therefore makes sense to them that they should get into the masters program. If you can’t tell that they have the science background to be successful in graduate level courses, if they have not demonstrated that they have the ability to succeed with the research project and carry out a masters thesis project, if they don’t seem to even realize that that’s part of the expectation, that level of drive and initiative and persistence and success outside the classroom that it takes to succeed in research, then that may not be a very safe bet for a person to take into the graduate program. I can’t recall ever seeing an application from someone who was an active teacher or who planned to be an active teacher who said, “I want to get my masters in biology so that I can be a better biology educator.” I don’t think they’re applying. Maybe they are and I just don’t happen to see them. I actually think among our twenty faculty I’m probably as receptive as anybody to K-12 educators and I don’t recall ever being approached by somebody for entry to our masters program. The majority of the applicants either have no idea what they want to do (that’s not
a good bet) [Chuckle] or they know what they want to do and they want to do research…. At least some of us would be open to a person who came in and said, "I need to have a masters because I’m a high school science teacher and this will make me a better science teacher. I want to do a research degree because having some first hand experience with research will make me a better science teacher." At least some of us would be receptive to that. I’m not sure that everybody in this department would.

The self-selection machine is evidently secure. It will effectively impede reform efforts, lest an emancipatory dialogue pervades to produce an active discourse of reform. Problematizing this component of resistance to reform holds much promise to moving from a language and practice of indoctrination towards one of possibility (see Freire, 1993; McLaren & Leonard, 1993). Plato directs us to a dialectical approach, “Opposites cannot be understood without opposites” (in McCarthy, 1996, p. 26).

[Sophia] We all have our own cultures. I’m thinking some more about why is it that some of my colleagues would take a research oriented student over say an educator. It’s because what makes us successful is publication and grants and if I train you as a high school science teacher and then you go back to your high school, realistically, how many publications are you and I going to co-author in the future?… I think our introductory labs actually do an excellent job of that. The lectures, you know, that stinks. That is a downside of the either the laboratories or the general course, that the Ph.D. professor is the one who’s up there on that remote stage with the microphone and it’s graduate students who teach the laboratories. So [students] have a less direct sense of this person who’s already functioning as a professional researcher. On the other hand, graduate students are often more approachable and they are embarking on their own scientific professional careers. In some ways it’s a more appropriate role model, mentor for an undergraduate student at an early stage. It doesn’t seem so much like some activity that only distant, impossibly capable people carry out. No, it’s a real live person, not that different from yourself in age and dress and manners and talents.

Sophia continues to share her awareness to the issues. She admits the cultural constraints exist but seems to feel incapable of addressing them since she views them from an external locus of control. Placing value on personal reflection and
collaboration open to issues beyond science and into education might allow for a more meaningful engagement with the issues that she is actually an integral part of.

[William] Alan Van Heuvelen inspired me to do that kind of stuff. They hired him away with a big salary in physics education. He's a professor in the physics department, but his area of expertise is education now. He said that some of the members of the faculty didn't really accept him. I mean they're pure physicists. Their program really got a boost when one of their faculty, who was a Nobel Laureate in physics, decided to devote his efforts to physics education. Then the other ones said, "I guess he must be all right." [Laughs]

William supports Sophia's observations about not valuing good teaching by adding this story of a physics professor that was "hired away." It took this "powerful force" (a Nobel Laureate noted in Tobias [1992a] on exemplary programs) to counter the notion of pure physicists in order to legitimize an elevated and equalized educational perspective. It was however accomplished. This type of transformation should be duplicated often and in many places. This example sheds more light on the contradiction between recognizing issues while looking at teaching as secondary to the more valued identified position in science. William seems not aware of how his learning is resistant to possibilities. The actual practice eludes him due to the gap between theory and practice. William noted earlier that teaching is the fun stuff, but the real stuff is chemistry content.

[William] Does the university support me in this environment? Yes. They support me. When I write papers or get a grant to do this kind of stuff, it's considered in the same way as a person who is doing basic research. The university also recognizes these kinds of activities in their awards. The university has many more awards for teaching than it does for research. [There are] only a few awards for research and there's many for teaching. I've gotten all the major ones.... Several people in our department have gotten those awards. We do emphasize teaching as an excellent job. I do have a good time! All of a sudden they're [other faculty] saying, "Oh we'd love to do that, but it's not valued. The university does not recognize it. They only recognize advancement in our field, in non-education components.... You can
publish in the educational area. It still counts, at least in our department it does. And the university recognizes it. The dean recognizes these activities. I think it probably has to do with the individuals. Those individuals probably feel that it's more prestigious for them to do basic research than it is for them to do research in the educational areas.

Many of these innovative ways appear to be reform oriented. However, the pedagogy remains grounded in a traditional context. Science educators need to be prepared to redefine the essence of science (Hurd, 1997). How might these science professors be received if they were doing innovations of a more radical nature? It is within this department that a broader-based science education process might take hold since it is espoused by the administrators and many of the professors. I observed these professors attempting to move away from straight lecture and traditional testing, but the move did not begin to approach the possibilities that exist within the realm of reform. Lectures were shortened and demonstrations were incorporated and even some group type activities were used, but they were still lectures, disengaging demonstrations and generally unrelated group work (i.e., not related to a larger theme – similar to traditional laboratory work). There is much to be learned from recent literature on teaching and learning (Brooks & Brooks, 1993; Caine & Caine, 1994; Diamond & Hopson, 1998; Duckworth, 1987; Gardner, 1991; Hart, 1998; Johnson, Johnson & Holubec, 1990; Knapp, 1996; Nieto, 1999). The extant mental models can begin to be examined by searching out recent works from teacher/researchers that have proliferated during the 1990s. During the Decade of the Brain, the neurosciences added much to our understanding of how humans learn. Technological advances have allowed researchers to uncover much about how the body and brain

[William] A lot of people feel that they’re put on if their students come in to waste their time. I mean I had students tell me that. They don’t like to go and get help because the teacher or the professor acts as if they are wasting their time.

William gives further insight into the arrogant attitude of some professors that further alienates and perpetuates elitism. This supports Hudson’s findings that students cited availability of faculty advice and support as critical in their decision to persist or leave the sciences (as cited in Seymour & Hewitt, 1997).

Curriculum and Instruction.

In science and mathematics education, traditional curriculum development still occurs, as these privileged areas still receive significant amounts of federal and private grant monies.... However, the general field of curriculum.... is no longer preoccupied with development ... the field today is preoccupied with understanding. (Pinar, 1995b, p. 6)

[Adrienne] I’m part of the curriculum committee and one of our charges is to try to update our curriculum and work on that to make it better. I think they thought my experience would be helpful since I know the loopholes.... all the faculty gave their input as to what they felt should be in each of these level classes. And so they’ve taken a whole list of things that now has become my curriculum. That is what I have to teach.... We do have a textbook that doesn’t necessarily follow along page-by-page, step-by-step.... I use other [supplementary] textbooks. So I’ve got a whole plethora of textbooks that I go back and look at for ideas of how to present different things. For some of the lab inputs I use some of my own ideas and then talk to students who have been through the program and they gave some input.

The constraints articulated by the respondent inhibit the understanding of curriculum as it applies to the relationships among school subjects and the relationship between curriculum and the world (Hurd, 1997; Pinar, 1995b). These
same constraints serve to perpetuate the ordered and highly organized developmental curriculum common in the first half of this century.

[Adrienne] I do hands-on, I really do. I have to admit [that] I enjoy it even though it’s frustrating and doesn’t always work. Because if you try something hands-on, there always the chance that it’s going to go wrong, and that things aren’t going to work exactly the way they theoretically should. That’s why I like theory. Nothing goes wrong in theory.... I’ve seen a regular lecture, and I have to admit that is one of the easiest ways to “teach” something. I would like that teach to be in quotes because I’m not always convinced that teaches anything.... If they ask me a question and I don’t know the answer we can figure it out together as a class, or we can go look it up, or we can go find the answer some other way. Even if I do know the answer I don’t have to answer it. I can make them come up with the answer themselves, but that comes with experience.... It’s still easier just to stand up there and give a lecture than it is to try to involve the students.

Adrienne, like most other participants, teaches the way she was taught and has little confidence that constraints will be removed in order to allow her to change. She deviated from tradition when participating in the reformed science course. Her section dealt with using the scientific method. It was basically presented in the traditional delivery style, however, there was increased student involvement. The problems that she worked on with the class were generated from students in a class discussion. Adrienne stayed mostly in the front of the class during the lectures and demonstrations. Students engaged in group-work where they had to move from station to station in order to test their hypotheses about what causes water waves. Videos were used to support the presentations and many handouts were made available for students to use when they become teachers. She also used worksheets with activities for students to work on as she made her way through the first module of the reformed course. Although there were no tests, mentioning grades often served to motivate the students into working on assigned tasks. According to Caine and
Caine (1997b), the PO1 teacher uses Instructional Approach One while a PO3 teacher uses a combination of IA1, IA2, and IA3 (1997b). A PO3 teacher knows when it is appropriate to use direct instruction and when to allow students to engage in meaningful complex experiences that build dynamical knowledge which is far beyond the surface knowledge associated with rote learning.

[Adrienne] [Speaking of the reformed science course] I would change what I did. I liked the way I started it [with the scientific method] and I liked the way we went into it. I liked the way we gave experiments for it, but they really missed one big section of it. That was the research part of the scientific method. I think most of them came away with the idea that what we did in class was research. We didn’t do any research in class because we didn’t have any materials to go out and look and see what had been done previously, and so they got a false idea of what research means by research; searching the literature, that kind of research, as opposed to experimentation. So I think we would have to have them actually go out and go to the library, use the web, go to other sources, and actually do some research. I’ll have to incorporate that in next time.

Adrienne is reflecting back on the reformed course and thereby reshaping her vision of curriculum and instruction. This is considered an attribute of the “Possible Human;” a more complex and integrated teacher for today (Caine & Caine, 1997a, p. 97). This needs to be valued and supported so that the learning that occurs from processing this experience can be transferred across all of her classes, whether they have engineering majors or not. This is one of those increments of change that ultimately lead to reform. Pedagogy is an important component in a teacher’s belief system and an issue of reform. It exemplifies those practices that have exclusionary effects and highlights the fact that these professors are not pedagogically prepared as educators which speaks to the very culture of their own disciplines – privileging select people as scientists.
Now you have these freshman chemistry courses that are encyclopedic in nature and ... they have gotten so big that applications are being left out. I think the trend I see emerging now is trying to cut back on things ... at least in the curriculum materials I've seen that appeal to me the most.

Hobart uses everyday experiences and phenomena that are closely related to students' lives (see Hurd, 1997). In the reformed course he engaged the students with current issues that applied chemistry. His topics and activities revolved around the theme of *Life in the Universe*. Students did activities where they actually created acid rain.

I'd say [that with] many of the approaches [I used in teaching], I was emulating what [I] had seen other people do and so it was probably a fairly traditional lecture format which worked to varying degrees.... Chemists caught on to the hands-on part and it had a pretty big effect on laboratory instruction. But, they sort of neglected the minds on [aspect]. A year ago I read in the paper that described the learning cycle using the 4-Mat method. It looked at the learning style of students and what struck me was that the students would pick their learning styles and have a different question that they wanted answered about something. In order to understand some body of knowledge you've got to answer these questions: Why is this important? What are the fundamental principles or concepts? How do we use it? What happens if you do something different so that you can extend something that you learned from one situation to another.... That's the way you do research too. If you identify a problem and if you don't know enough to solve the problem, you go to the library or you go to the laboratory to learn more.... I hope some of things we're discovering in the [reformed] natural science course will provide a trickle down that gives me evidence and reasons to convince my colleagues to try and change teaching techniques in larger courses.... building consensus and exposing some of the other faculty members who may be more resistant to change to some of the things that we know from cognitive research about how students learn which is something that I'm learning new myself.... I think that I made a pretty drastic change through my career.... But, I decided to take the plunge and more or less try and do everything hands-on. I [began] to start everything with a question, doing some sort of experiment that actively involved the students, followed by a discussion and prodding the students to come up with much of the information.... There's some things that you may want to present in terms of a straight lecture, but in smaller chunks at a time.
Hobart’s exposure to alternatives and actual pedagogical models has afforded him a more innovative and effective approach. This has led to a greater commitment and dedication to reform. Even though he has an expanded repertoire of pedagogical approaches, he demonstrates an inability to break with lecture. This exemplifies the power of the belief system informing his mental model.

[Patrick] I realize that that model is more effective than a straight lecture. In some of my other classes, it’s still more lecture than I’d like. I haven’t had time to develop the writing material and they don’t exist in the form that I can simply buy off the shelf.... I think when instructors are sent textbooks that it can dictate the class.... They are now subconsciously slaves to this book and they have got to teach what’s in the book.... You lose sight of what the goal is.... I don’t think we ask if this book is particularly student friendly or what is the global aim of this book? Is it aiming at teaching a process or is it aiming to teach a bunch of facts? Most textbooks in the sciences teach facts.... The way in which a teacher presents the material is [influenced by] the textbook, not some higher vision of science education. I think I do [look at alternatives], but you know, maybe I don’t ... I do use a textbook so maybe I’m just as guilty as the next person and I’m just criticizing them where I should be criticizing myself.... I think that [I developed] alternative strategies based upon, to a certain extent, teaching techniques that I’ve seen others employ that looked like they were being successful.... from the PBS news program that deals with education that shows different ways in which instruction is being conducted.... My lecture notes were already done so it’s easy for me as an instructor to go in and use basically the same lecture notes semester after semester.... You start out teaching the way you were taught. The way we were taught was through a traditional lecture format... I was unaware really that there was any other technique out there.... I can’t recall [any non-traditional instructors in my education].... All graduate classes, when you have a small number of students, are highly interactive.... I try to incorporate into the class as many interactive activities as I can.... The process that I would use for that would be to introduce the subject before they’d be given the activity. I then would go over the activity without saying I’m going over the activity.... The students felt that they understood it, I felt I had adequately explained it on the blackboard and had discussed it at an adequate level in my mini-lecture, and the TA thought the material was clear and understandable. When they tried to do the exercise, which consisted of three questions, I found that the majority of the classes got it wrong. It wasn’t like the material was difficult. It’s just they hadn’t ever worked with it.... It wasn’t at a deep, deep level and the surprising thing is that the majority of the class can’t answer those questions that are on that sheet. Even though they’re
designed to be rather simple. As an instructor, I find that very helpful because it tells where the students need more work. If I had left the class without having given them that in-class assignment, I would have assumed that they had known the material. I am convinced the students would have thought they knew the material as well. We both would have found out otherwise during the exam, which is too late in the process to really be helpful. I give them a few minutes to respond to say question number one. They usually work in teams so they can ask their fellow student for help. They work for something like three to four minutes on the question and I’ll interrupt them and say, “Okay, let’s look at this question. Who would like to volunteer an answer?” If nobody does, I’ll call on people and it’s evident very quickly that few people are actually able to do this problem. I then demonstrate what the solution is and everybody sees how it goes. After the first half of an hour, we are pretty much talking to ourselves because the students have sort of drifted off. They’re still trying to take notes, but I’m not sure how much real exchange of information is taking place after a half of an hour. After a half of an hour or so you might stop, hand out this activity and after fifteen minutes it’s done. You then go give another, move on to additional material if the students are ready to do so. Give the same type of mini-lecture that you had before and then after 20 minutes you enter into another activity. This breaks up the monotony of the class and keeps the students more alert especially since you’re asking them to do something. You could wake up the class in many different ways. Show them a filmstrip ... or have a demonstration. That’s not directed at student learning as much as asking them to actually perform the activities. That’s really the main difference in the instruction that compares to say ten years ago ... I’m devoting a lot more class time to the students to be working in class.... It is astronomical. I’m not at the point where I’m going to say that this is every day kind of stuff. There’s nothing like a little bit of peer pressure to let a student know where they stand relative to their colleagues. That type of process begins to become more effective as the semester goes on because they don’t want to be embarrassed by telling their colleagues that they don’t know how to do the material. What I mean by that is that at least they’re going to try and come to class prepared for an activity that they know we’re going to do. If they come to class prepared, even if they don’t know how to do it, the preparation was identifying what they didn’t know.... My solution would be to make sure that before you give a student an exam you give them some sort of pre-exam that is not actually graded. You might hand it out in class so they think it’s going to be graded. After they do it, you go over what your expectations were and then just say this was a practice, that you are not going to grade this.

Patrick realizes the inadequacy of straight lecture, but relies on it nonetheless.

He sees the facts versus process issue and he is asking the right questions, yet he is
unable to apply them. He acknowledges that he was and remains unaware of alternative approaches. The fact that he has to rely on T.V. for input highlights the degree of lack of support for reform-oriented teachers. Patrick, like all other participants is under the impression that innovation can only be attempted within the context of smaller classes after the process of self-selection has taken place. The previous passage shows where intimidation is employed in order to get students to comply. This is brain-antagonistic and brain-based theory warns against using threat, whether it be real or perceived, since it produces a physiological state where learning is reduced and a "fight or flight" response is activated. This is known as downshifting (Caine & Caine, 1994).

[David] you can't cover as much material in the innovative program than you can in a more traditional lecture format.... There are not a lot of things one can do when you're sitting in a lecture hall that looks like a movie theatre where you have tiers and you might be on the second balcony looking down at the lecturer. [Maybe] hire more professors or hire instructors to give the class.... I give handouts for every lecture that I give. There's a synopsis of the lecture as a way of giving the students a greater opportunity to listen rather than to listen and write at the same time.... I give them a little bit more support than what's available rather than strictly lecture and having them listen to what I have to say. I have actually summarized some of that important information so that it really points to some of the concepts that I think that are important. It helps give them a roadmap so then they can ask questions.... basically you're on your own [to improve pedagogically]. You can talk to colleagues about this such and such, sitting on a lecture and have them evaluate your teaching style. . . . I haven't used peer evaluation....

David too identifies large classrooms as places where innovative practices cannot be implemented. He takes away much of the challenge by providing handouts so that his lectures do not overwhelm the students. He stated in the interview that he does not employ this pedagogy in upper division classes. Students in those classes use more research and hands-on techniques due to their small numbers. These
students may benefit from innovative practice, but they are the ones that actually "made it" up to this point with traditional methods of instruction. It may be that we as professors of first and second year students need to consider using those methods that are known, but reserved for upper-class students when the class load has been diminished/selected.

[Sophia] The problem with majors going into an integrated course such as the 121 is that there's no way that they'd be exposed to enough vocabulary or concepts to move on to any other biology course.... We've been willing to reduce the number of different topics that we expose them to, preferring them to have more time to better understand each topic and to be able to do some of these inquiry-based things in laboratory, which do definitely take more time. There's a point beyond which you can't reduce too much further because they do need to move to the upper division courses.... it is a textbook supported course and we try and lecture in such a way that our lecture notes are closely tied to and supported by material in the textbook. What we test on is based on our lecture.... One reason I'm very excited about [the reformed course is because] I have worked with some of these elementary teachers. They have that bad taste in their mouths about science and they haven't grasped that doing science is asking questions rather than being a whiz at memorizing and taking very difficult exams.... I'm hoping that that changes the whole mind-set that small children are exposed to. We turn around some of those attitudes in this very large freshman course that does have a lot of people take it because biology sounds better than physics.... Yet, if you wanted to learn how to design an inquiry-based activity and how to hobble together the equipment or the supplies you need to carry out an investigation, those are the courses that give people the flavor of what it is to do science inquiry, but we never get education students, you know, I send flyers over there all the time.... With conveying information, it's easy to maybe come up with ways of hands-on or first-hand or manipulative kinds of experiences that will make up for or reach out to a broader range of people than those who are comfortable learning out of a textbook and learning from lectures.... Every single lecture we put up on the overhead and then we post on the web and we post on the bulletin board a list of key terms and concepts relevant to that day's topic. There is also a mini essay question from that day's lecture material. A mini essay question is one that could be answered satisfactorily in three sentences, but it does expect something more than just memorizing a single definition or spitting back a single word or phrase as an answer. Sometimes it expects you to do a little reasoning, something of a higher cognitive level than just memorization and regurgitation. Sometimes it's being able to explain in words, a complex process, recreate in your own words some description of a process or a
sequence of some biological events in an organism or in an ecosystem.... I had already been doing things like pausing at a certain point in a lecture and asking groups of two or three students to put their heads together and think through some little problem or do some little calculation or do a little mini debate of some ethical point related to environmental issues or genetic testing issues or some other biological social applications that come up in the course of this semester. This semester, I made a concerted attempt to do those much more frequently. I tried to formalize the way in which I asked students to provide feedback or to have a chance to share their outcomes or their results with other groups in the lecture. I'm interested in pursuing more of those.

Again there is evidence that large classes are seen as the reason that non-lecture methods are not able to be used. I must reiterate that professors cannot afford to apply methods that are known to be brain-compatible and more conducive to learning only after the selection of students has occurred. It is obvious that professors need help and support in order to make this transition and the signals seem clear that they are eager to improve their practice. Fedock et al. (1996) can provide leadership and guidance toward collaborative efforts to teach and re-educate our teachers and professors on these matters.

[William] You still have to learn the basic concepts.... I think you should teach the basic concepts. Even if the people never really use those concepts.... teach physics first then chemistry and then biology in that order and then go in the fringe areas [of] astronomy [and] earth science.... I observed my instructors and I knew which one's were good teachers.... And I aspired to teach like they do. So I learned by example how to teach.... I like to use lecture demonstrations.... I go to these conferences to do that kind of thing too.... We talk about inquiry-based instruction. You can do that in lecturing too. You have to engage the students. Things I used to do in the past, I now changed the way I do them. I say [to my audience], "After years of experience I have memorized how many electrons, protons and neutrons are in each of the atoms of each of the elements. You just give me the symbol or the name of an element and I'll tell you how many electrons, protons and neutrons are in it." When the students say uranium or something like that, I look over my shoulder [and say], "There are 92 protons, 92 electrons and 146 neutrons." And they're kind of impressed, right.... Every time they ask me, I look over my shoulder. [They say], "We know what you're doing." [Laugh]. See we're engaging, they're thinking right? They're thinking, "What in the
world is he doing?" I’ve engaged the class. They’re not sitting there [with me telling them].... In that honors class, one of the things that we do is we learn how Fisher determined the structure of glucose or the scientific reasoning and experimentation that went into it. He used optical activity and reactions and so forth. We learned how Fisher determined the structure of a complicated molecule and [he] won the Nobel Prize in 1891. We go through all the experiments he used, the logical reasoning he used, and then we work problems with different sugars and I give them hypothetical results and they determine what the structures of those sugars are. Then on the tests, I will give them something they haven’t seen before, but I will give them all the different experimental data. They then have to take those experimental data and determine the structure of that sugar. They’re using the logical reasoning, experimental results that Fisher used. They have to construct it so it’s one where you can’t memorize a method. You have to understand and then you can, so it’s a thinking type thing. I like to use all kinds of thinking type problems. We’ll have maybe 10 or maybe 15 students in that class. You’ll have every undergraduate college represented. And very rarely do we have chemistry major. We try to develop the concepts of chemistry by analyzing experiments that were performed over the last 300 years or so. They’re only allowed to use the information that was known at that time in analyzing the experiment, we see how these concepts were developed and so we see theories.... They have a laboratory where they actually do these kinds of experiment and that we don’t cover a lot of chemistry, but what we learn is where all these ideas came from.... One of my areas of expertise is demonstrations that can be used in lectures to make the lectures more alive, to make the students more involved etc., and I’ve published a lot of those in journals and I’ve talked about those in meetings. I’ve done a lot of work in developing new methods of presenting old ideas.... I don’t like to do a demonstration unless they teach. All of these are always entertaining, but then the people end up learning. I hate chemistry demonstrations that are exciting and don’t teach anything. In fact, I never do one of those unless it has all kinds of educational value to it.... So I make it inquiry-based lecture.... What kind of things will break up a lecture so that the students can restart the thought processes.... Demonstrations illustrate things, but it also allows students to restart. I tell anecdotes. Most often, the anecdotes are related to the subject matter. Sometimes they’re not. I mean, sometimes I just tell jokes.... Sometimes they’re tricked into thinking.... [This pedagogical approach] has to be natural. You can’t teach somebody to do [what is part of my personality], but you can teach people about using inquiry-based methods. You could teach people about those little tricks that I use and kind of try and engage the students.

It is important to note that often professors appear to have adopted the language of reform without really incorporating needed changes to make reform a
meaningful reality in their classrooms. The poor results that are occurring are tied to poor and inadequate techniques that remain unchanged even when they are questioned. The fact that these professors acknowledge flawed methods and still rely on them is an alarming signal that beckons resources and support to provide opportunities for re-education in order for reform to have lasting systemic ramifications.

Diversity.

*Multicultural education ... becomes a central and essential element in any consideration of educational reform.* (Cummings in Nieto, 1996, p. xvi)

[Adrienne] I have taught a very wide range of students.... They [students] are different, of course. I've got one vantage point. [A learning style inventory test was given here at the university] The people who were engineers all were the same type of learner, every single one. Now, does that mean all engineers are inherently that type of learner? And if they are that type of learner, is it the kind that likes things presented in a nice formal way. They are more prone to lecture. They learn a lot from lecture. Hands-on is still fine, but they're more adept to learning from lecture.

Adrienne is presenting evidence of the self-selection that appears to be widespread in SMET courses. She seems fairly confident that those students who persist have some learning commonalities, especially if there is only one general pedagogical perspective that they are exposed to. The question that emerges is do these students end up in the upper level courses with students similar to them because they have been selected by having only their needs met over those of others or are they at this point due to common interests?

[Adrienne] I'm not sure [if it could be cultural]. [The elementary where I help out] has a very high Hispanic-kind of an interesting mix [of students]. I hate to say that the boys tend to prefer the kind of cut-em-up part and the girls prefer not to. That's an over generalization. That's not always true. We have some girls who do dissecting too, but the tendency is that the girls are
squeamish and tend not to do the actual touching. I don’t see very many girls at all [in engineering].... I don’t necessarily see much difference in the grades between women and men in the class. Some women do real well and some women don’t do quite so well. Of course, I shouldn’t say of course, unfortunately, there’s still a lot more men in the class. There are about 50 people in both classes. Maybe ten of the students are women.

The two contradictions found in the passage above indicate that Adrienne is attempting to reconcile observed disparities between students and the underlying gender issues with regard to equal educational opportunity. It has to be okay to question existing educational structures and practices. What part is she playing and how does it fit into the larger university picture? The tension and confusion that is evident in Adrienne’s experience is due, at least in part, to the professional culture. Values and expectations develop and support a belief system that not only separates students by learning style, but also by gender. Of the few females that Adrienne sees in her classes, some do very well. Deprivation and selection have already had their effects on those that did not make it to her classes. Professors may espouse equity, but it is their mental models as well as the system of which they are a part that produce behavior that divides and separates students. Perpetuation of gender stereotypes is a major force towards limiting access in the sciences (Seymour & Hewitt, 1997; Tobias, 1992a, 1992b). Examination of both the espoused and the deep-seated belief systems is essential to transforming the system that is currently in place for the few. An equal opportunity for each student can and should be provided. The present reform initiative is attempting to effect changes in the early university exposure of students attending SMET courses. Many of these students will be education majors and they will in turn effect changes in the K-12 student populations.
[Adrienne] In college you get students in your class because they want to be there. If they don’t want to be there, then why are they paying the money to be there? I don’t want this to sound prejudicial, so I was going to say some students as opposed to identifying some particular students, if that’s okay. There are some students who come to the university, not because they want to learn, in fact they want to do everything they can to minimize the learning. They just want the degree with their name on it and that’s all they want. Whether they know the information or not is immaterial. Evidently where they go next doesn’t seem to matter that much either. Whereas, if you go out and get a job at some places and you’ve got this degree, you go there and you don’t know anything, it’s really going to matter and you’re going to be out on your can. [The former group] includes some of my international students. When they go back to their country, it doesn’t seem to matter whether they know anything or not. They get hired because they’re somebody’s brother or somebody’s nephew. It’s a whole different ... I cannot perceive of such a culture where if you don’t know anything, you still get the job.... We don’t need to [import engineers]. It’s just those countries look over here and they know that we’ve got some good colleges and universities to teach their students. Now they’re sending them over here with the idea that they’ll learn and go back home. They don’t go back home. [Chuckle]. They stay. Once they get here they try and get jobs. I can’t blame them. I think we’ve got a very good life here. I can’t blame them for wanting to earn more money and stay here rather than to go back to whatever it was that they had because I don’t think that whatever they had was nearly as good as what we have here. Even when they come here, if they even live in married student housing. This is not the best housing in the world, nor is it the most comfortable. It’s still a lot better than what some of them had before. They don’t mind putting up with that kind of stuff. I still think the US students have had it too good. They don’t want to work as hard. These guys come over here, they’re willing to work, to study hard, to work hard at it and learn it. There are American students who are great students and who enjoy learning and are willing to work. I certainly don’t mean to say that there aren’t. There are probably a lot of them. I don’t always see them. I’m sure there are. They just don’t all come [here].

Adrienne has openly stated what many would hold back and not open up to examination. She has revealed even more evidence of her belief system that, if left unexamined, could prevent the transformation towards the educator she clearly wants to be. As she continues introspection of her mental model perhaps she will be able to further her transformation towards a pedagogy of emancipation and break the cycle of
separation and indoctrination. It is important to try to uncover the underlying assumptions within the stereotypical statements made above and understand the implications towards discriminatory practice. Adrienne says that she does not “always see them.” This summons the questions: What do they look like? Who then who does she see, and why? Difference exists without being visible.

[Adrienne] Trying to get the faculty to move on it is a cumbersome path. I guess it just has to be done. That still doesn’t mean we’re going to change our way of teaching or necessarily re-evaluate our way of teaching. What they’re going to do is try to get assessments from students. I have a feeling that most of the students are going to say, “I learned what I needed to learn.” They’re the ones who graduated and went on into their fields. They aren’t the ones who dropped out and changed to a different major…. [Assessment methods that could capture what the student learned is] what I want. That’s ideally what I want to do, but I haven’t found satisfactory ways to do that, given the range of students that I have. I do find that they can be very creative about getting around things. [They] look it up somewhere and finding someone else who’s done it as opposed to just doing it themselves. Granted, I would say ninety to ninety nine percent of the students will do it on their own. I don’t know, is it worth that extra aggravation to prevent that other percent from taking advantage of the university?

Adrienne speaks of the students who were selected by the system, yet she attributes negative motives for them to stay in school. She previously said she was a good candidate for her position because she knows “the loopholes” and now it seems that she gives her “successful” students negative credit for “getting around things.” This is why modeling is important and it must depend on a consciously constructed belief system that informs a mental model based on convictions not unquestioned experiences. Adrienne seems to survive in a culture she is in contradiction with and one which does not value her teaching aspirations. She is participating in a system that teaches to the few in more than one way. This is partly due to the culture within which she practices. She, like others, is also preoccupied with the “one percent” that
take advantage of the university and bases much of her pedagogy on them. Maybe most of the faculty do recognize the need for reform, yet they do not change to become more inclusive lest they might remove the power and prestige of the few. The professors that participated in the reformed course did not use tests to assess student learning. Most of them relied on a single alternative that may not have “fit” all of the students. This indicates that professors must broaden their repertoire of alternatives. This would require the professors to make liberal changes in the way they perceive students who are different – those that do not “look and act like” scientists and engineers. The perception of diversity must also broaden so that the process of education is more inclusive of difference. The system is not set up to be democratic when it bases its methods of assessment on competition and knowing facts rather than on democratic processes where students can form learning communities and have choices on how they will demonstrate knowledge understanding.

    [Adrienne] I don’t know which is better. I guess it depends on the individual. This gets us back to when you teach; are you teaching the subject or are you teaching the individual? If you’re teaching the individual the subject is somewhat immaterial. I need to teach the students. I don’t need to teach the system, a different emphasis.

    Adrienne seems to be clarifying her convictions as she reflects during the interviewing process. This hints at the significance of meaningful dialogue for educators to begin identifying important positions that may facilitate the transformative process. A method that has been used in this study is to discover the (in)congruence regarding what one says and what one does. A meaningful analysis of
the results may provide for the construction of new mental models that are reflective of the values of reform.

[Hobart] Illinois pretty much gets the elite students and I think just about anything will work with them. Illinois, Berkeley, an Ivy League school is probably the way to try [reform innovations] and make them work. Students [from these schools] will make anything work. Here [at my present university] the preparation and background of the students is much less. Pretty much everybody that I taught at Illinois was taking calculus [during] their first semester that they were taking freshman chemistry. They’ve probably had at least four years of science, if not more, in high school. It was kind of like teaching honors classes I mean you could do just about anything and it would work. Here we have huge dropout and failure rates. If only 30 percent Ds, Fs and Ws are happening in the course of a semester we think it was a pretty good semester. Not all of that is the fault of the students not having the background. Some of it has to do with the way we deliver the course…. Here, probably most of our science classes reflect the population in the state much more. I think the way I’ve dealt with it is you can treat the students with respect. They’re individuals. You’re there to try and help them. I try to go in there, I don’t have a preconceived notion that just because you’re black or a woman or Hispanic you aren’t going to do well in science. Anybody can do it if they are willing to spend the time with it. There’s nothing that I’ve seen that’s the reason one ethnic group over another is smarter, dumber or better in science or worse in science. One of the best students this department turned out was a black kid who graduated last year. Some of the Hispanic students I’ve had have been some of the best students in my classes. [There] doesn’t seem to be any ethnic preference for it.

Hobart’s obviously good intentions do little to advance students who are different from the ones that will “make anything work.” It is difficult for someone who has enjoyed the position of power and privilege of a scientist to “see with new eyes.” In other words, “It means being acutely aware of our new perceptions and how they are an integral part of everything we do and everything we are” (Crowell et al., 1998, p. 17). It is essential to move beyond good intentions to create new learning environments with renewed purpose and clarity that a pedagogy of praxis can instill (see McLaren & Leonard, 1993). We must reconnect with our humanity
and personalize the learning for our students by engaging their individual stories and perspectives. "Learning becomes personal when we allow it to have meaning for individual students and when we relate that meaning to a sense of purpose and connectedness" (Crowell et al., p. 51).

Hobart speaks of the high rate of Ds, Fs and Ws at this institution. These are grades of those few that have made it to the university in order to take chemistry. There seems to be further selection of those who were already selected! This is intolerable and if part of the "fault" is poor background, then we must do all we can to ameliorate this by producing science literate and able teachers for those students who will follow. Hobart acknowledges that "some of it has to do with the way we deliver the course." This can be addressed, but we must move beyond the rhetoric of reform. Students must be taught with respect, but this too is not enough. It takes more than this and more than believing that "anyone can do it." I agree that there is no ethnic preference for learning when it occurs in a context of equity, but therein lies a point of contention. Oakes and Lipton (1999) address who can do science:

"Nothing about age, skills, or language fluency need prevent students from working and making sense together. In fact ... diversity among students enriches the learning opportunities" (p. 179).

[Patrick] We produce excellent science majors, but the reason I think for that is eventually those students are going to be doing the science. In our freshman level classes we generally don't ask our students to do science except for maybe in lab. In the lecture, they're just there to listen. They're not there to become a participant to demonstrate their knowledge. They're there sort of as a sponge. We hope they absorb information. But our science majors are actually asked in subsequent courses to demonstrate that knowledge by solving problems by getting directly involved with the subject matter. I think we produce great science majors because they work with the
material. I think we produce lousy general science products because we don’t ask them to work with the subject matter.... We just don’t teach our general science students, our non-science majors that process. We do though with our majors, but not until later years because then the classes are smaller and the subject is narrowed down.... If science majors stopped at freshman year, they would do terrible too. [Laughs] They don’t because they go on and they take several other classes.... Some students, of course, are just interested in it before they ever came to college. Their dad maybe was a scientist or an engineer and they’re going to become a scientist or an engineer. It’s also possible that in introductory classes the better students find it interesting.

Patrick’s observation and suggested reasoning is quite interesting. He recognizes that the freshman level science courses, which have majors and non-majors in them, do a “terrible job.” He points to the fact that the science majors are able to recover later in the schooling process. It is not known how many actually “recover,” but studies by Seymour and Hewitt (1997) and Tobias (1992a) indicate that even the majors don’t recover and in fact leave the sciences. Patrick’s characterization of what occurs in the general science courses is self evident and true. There is a lack of diversity in pedagogical terms as well as lack of understanding of diversity itself so the self-selection process is reified. The improved conditions for students in the more advanced classes result from pedagogical enhancements that makes their experiences more meaningful due to smaller student-teacher ratios, more connectedness in the curriculum, and the fact that these students get directly involved with the material. This is similar to the tracking that occurs in K-12 classrooms outside of the university where the “gifted” get the innovative and engaging experiences. Patrick’s language divulges important assumptions about his belief that scientists and engineers look like “their dad” and that “better students” find introductory classes interesting. He just described these classes in quite a negative
light yet it is from these classrooms that science majors are selected because their learning style is accommodated by the dominant narrow pedagogy.

[Patrick] We don't have an undergraduate program for astronomy so I don't have any experience with the undergraduate product. At the graduate level, I can't say that I've seen any difference minority, non-minority, be it male, female. I think they perform equally well. I have seen a change in the discipline in the sense that there are now more females in astronomy than certainly when I started. I can't say there are more minorities. They're such a scarce commodity. I've seen a few, but the number of minorities seems, in my field, maybe on a few percent kind of level. We [now] have two minority students in our program at the graduate level. And that's very good, two out of about twenty, ten percent. If that's true and they both graduate, we're going to see a gradual increase in our field, but I don't see many minorities interested in applying to our program.... It's clear what the ground rules in this class are, that it will be interactive. It will be asking [them] to work with [their] neighbor. They will be working on projects that I give in class. I also point out that if they don't like that they can always transfer to a different section. I don't teach every section of astronomy. One thing you don't want to do is have a number of disgruntled students. They'll poison the atmosphere of the class. They'll fight you the entire semester. They'll bring down the morale of other students. You want to weed those students out as quickly as possible. And as quickly as possible is the first day. I try to be very clear that there are no hard feelings. [They are] not insulting me. I don't feel badly about this. If this isn't for them that's okay with me and I won't hold it against them, but it's time to get out of my section and get into another section. Out of a class of fifty, I might have two students who are willing to admit that they have that attitude. I probably have a like number of students who have that attitude, but don't admit it. You just have to deal with [them] during the rest of the semester.... I don't have students actively resisting that method. They tell me at the end of the semester on their student evaluations that this is unusual.

This passage is illustrative of a skewed perspective of minority students.

Patrick's reality assumes these students look different. The students in these classes do not come close to representing the demographic make-up of the community in this part of the state. He "does not see many minorities interested in applying" because of his expectations in their outward appearance as well as in their attitude. This practice of intolerance is self-selection at its most effective point.
[David] The first year you go in totally blind. You have no idea what the student’s backgrounds are. People don’t know what to expect and I had never taught this class before…. somewhere along the way that gets derailed because there wasn’t enough support or the teaching style wasn’t correct … Maybe they ought to be doing something else that they would actually be better at. Some of that sort of people that have sort of fallen through the cracks maybe simply due to a mismatch of their expertise…. If innovations are done early, I will have students that are better prepared for course work. Instead of twenty students, I may have fifty students. Instead of having ten minority students in my class, I may have thirty minority students. We might see a greater representation of students in what we want to call hard core science classes…. It didn’t change the way I perceived [non-majors] at all. I think it reinforced what I thought, that the student population is made up of a broad spectrum of individuals and when we teach at a given level we are only seeing a minority of the population. When we start to look at the rest of the population, then your teaching skills have to change. The breadth of knowledge of just basic skills can be pretty low for non-majors or even majors…. I don’t disagree that for a certain segment of the population, this approach is preferable. If we target the drop out rate as the clientele that we really want to get them to drop the drop out rate, we’ve really targeted a population. Whereas if we say we’re going to take the entire population and we’re going to now change the curriculum for the whole population, then I think that’s asking a different question at this point. You have to be more careful than taking the population that right now are not doing the job. This is not working and taking what we think would work for that segment of the population and altering it to make that group better…. I think it goes back to that every student is different. I don’t know of any one process that can hold the attention or drive the learning for everybody.

David admits not being prepared to teach in anyway other than the way he was taught. Even though he has only been teaching at the university for three years, he has already volunteered to participate in the reformed science course.

Interestingly, this is usually undertaken by faculty who have reached tenure positions. The exclusionary language revealed in this statement must be examined in order construct a pedagogy that does not damage students in their ability to carve out a meaningful life. Science is for everybody, not just a few. If the suggestion that students “ought to be doing something else that they would be better at” were applied
on a broader basis, it would have devastating effects. Pedagogues must have an understanding of how learning occurs in order to avoid relying on notion that can further marginalize students. David suggests that early innovations might better prepare students. Diamond and Hopson (1998) have done much to advance our understanding of how enriched environments enhance learning. The problem is that teachers are not having meaningful science experiences during the years they are studying to be teachers and yet the university professors would like for them to provide an enriched pedagogy of innovations. The early years are critical and David might be suggesting that these innovations are necessary in order to increase science participation by more students. University science educators must move beyond only being scientists and pursue teaching along with advancement in their disciplines. This will require that their belief systems change along with their knowledge base regarding learning and teaching.

David speaks of students as clientele and has, possibly unwittingly, used a metaphor of business and consumerism. This implies a commodified education that can be accessed only by those who can "afford it." This further refines the tools of exclusion and his protectionist view that resists addressing educational change for the "entire population" risks the welfare of many. Teachers can change the perspective that values preparing students for school over one where schools are prepared for the student (see Nieto, 1999). David’s contradiction between knowing that every student is different and practicing a narrow pedagogy while admitting that he does not know of one process that drives the learning for everybody is a perfect place to begin reflection for transformation.
[Sophia] I've been happy to combine teaching to both science majors and non-majors with my research program. The nature of the students that we have encourages those of us who are interested in being effective teachers to explore alternative options — not just assume that we can teach biology the way we as professional biologists related to it. In teaching our non-majors courses and teaching our general education courses I've kind of been forced into looking at alternative methods of presentation.

Just like most of the science professors, Sophia has made a distinction between science majors and non-majors. Many students in the general science classes have not made up their minds as to their major area of interest. Current research suggests that the science experience itself will affect their decision to persist in science (Seymour & Hewitt, 1997). When she uses the term “nature” of students, does Sophia suggest a historical difference in terms of students experience or is there a hidden implication of difference? She definitely sees distinctions in learning style, which has an underlying assumption that each student is unique making it imperative to look at and consider alternative methods.

[Sophia] At the time, that made a huge impression on me. That there was almost no strategy you would come up with that would satisfy or placate these critics and therefore that neither one of those had anything whatsoever to do with would they be an effective teachers? Would they be effective scholars? None of those were issues of personal appearance or of friendliness or of collegiality. None of those issues came up for the men who were being interviewed for those positions. It was clear to me that women were being judged on the irrelevant issues and there was no way to really win or to optimize to satisfy those irrelevant concerns. It was a very frustrating experience.... There's also no guarantee that they would be [replaced with female professors]. In general, I have felt that this is a very open department, very supportive of women as well as men. There were certainly some individuals who were here when I first got here who were a little hard to deal with. But that's true in any group of twenty people. I mean, I certainly felt fine as a woman assistant professor coming in to this department. I was the first female assistant professor, and still the only assistant professor to have a child, to be pregnant and have a baby and have to deal with infancy and so forth while teaching as a faculty member here. I never had the least negative response or reaction from any of my colleagues about being female in general
or about being interested in gender issues, or about starting a family. None of that. I mean it's been an incredibly supportive environment to be in, which I appreciate very much. Compared with biology departments that some of my colleagues are in around the country. I collaborate a lot with folks in the college of agriculture, both in the departments of fishery and wildlife science and even more the department of animal and range science. There are no women in range science. There are a couple of women in animal science who frankly have, no I can't say that on tape, never mind. I'll just say that I interact with folks down there a lot. I've been on search committees in that college and so forth. Every time I come back here, I feel like kissing the ground…. I am incredibly grateful that I did not have to experience being an assistant professor down there.

It is apparent that Sophia has had to deal with the issue of gender during her schooling as well as in her professional career. A deconstruction of this issue may prove beneficial in gaining a deeper understanding of the effects of bias specifically towards greater diversity. The language of “appreciation” and “gratefulness” is not gender neutral. In fact, it may be reflective of the difference of experience in the sciences between genders. Should any woman feel grateful or appreciated for that which is simply expected and granted to men within the same discipline? This question must be asked (Nieto 1996; Oakes & Lipton, 1999). What do people of difference have to forego or give up in order to be accepted? As noted, there is power and privilege in being a scientist that is not equal to that of being a science educator. How are these inequalities seen and internalized by students?

[William] Every time you balance an equation, you have paid homage to the memory of John Dalton who came up with the atomic theory. You're not doing it for any other reason except to pay homage to that individual…. Most of the schools I go to in the [nearby] district, you can see that the students have the ability. Nearly all the schools I go to down there are elementary schools. I can't see any difference between those students and any others. I go to [a more affluent school]. I go to [a working class school]. Do I see any difference? No. They have the same innate desire to understand…. All our labs are taught by grad students. We have all these foreign graduate students teaching our labs. Many of them have very strong accents and they can't
teach unless they have mastered English. If you’re Chinese, it’s very difficult not to have a very strong accent. So there’s another aspect of that. The students just say, “Why don’t you get Americans?” Well, because there aren’t enough. Just plain aren’t enough.

William talks of paying homage to John Dalton and is possibly unaware of how science has been presented through the eyes of great white men. Upon reflection and through the use of dialectics, it is possible to incorporate a multicultural perspective by including people like Cesar Chávez who was responsible for making us cognizant of the harmful effects of pesticides on humans; a science issue, for example. Although William has grown up in this region of the United States, he has not needed to question his position of power and privilege and has possibly missed an opportunity to become a more inclusive educator. He has traveled to schools throughout the region and says that he cannot see any difference between students of more affluent schools and those of working class schools. William does recognize Chinese as different because of their strong accent. Upon closer examination, he would see a difference in language, technology, supplies and opportunity to participate and gain entry into science. These children did not all look or act the same nor did they have the same knowledge or experiences. We cannot be afraid to acknowledge difference. This type of color blindness is common when one has not had to deal with marginalizing experiences or taken an active role in the transformative process of reflection. So many educators want students to all be able to do what the standards suggest, but how can students have equal outcomes with unequal beginnings (García, 1995). William recognizes children’s innate desire to learn which is one of the brain-based learning principles (Caine & Caine, 1994).
Objectives of Instruction.

The critical shifts required to guarantee a healthy world for our children and our children's children will not be achieved by doing more of the same. "The world we have created is a product of our way of thinking," said Einstein. Nothing will change in the future without fundamentally new ways of thinking. (Senge, in Caine & Caine, 1997b, p. 14)

[Adrienne] They need enough science so that they understand what laws are being made now or the controversies that are going on now about assisted death or about abortions or nuclear generators for energy. I think they need to have enough education to make important decisions. I think that is what education is for. It can also be used in to help someone learn information so that they could go on and work in a particular field that they're interested in. My first definition is basically for public education and that everything else would be basically a private education that you could go on and do yourself, whether it was in college or trade school or other specialties.... Most of the students in our department are motivated because they want to graduate and get good paying jobs.

Reform is still thought of in terms of an exclusive population of students; namely those who are most likely to succeed under the current system. Are we just training students for the job market or are we participating in a learning environment where we move beyond surface knowledge towards acquisition of dynamical knowledge? Our mental models or theories-in-use are aspects of our perceptual or dynamical knowledge while our espoused theories are essentially surface and technical knowledge (Caine & Caine, 1997a, 1997b). Dynamical knowledge allows students to connect to the real world. Teachers must not get in the way of meaning-making and allow students to make connections between what they experience in school and the knowledge and experiences they bring with them. It seems clear that the purposes for schooling must cast the widest net possible and teachers must therefore move away from a narrow view of simply preparing students for the job market. Adrienne sees a distinction between public and private education, but this
can be used as a launching point to reflect and investigate the true intentions of instruction. We must bring into question our methods of motivating students so that all students can have the choice of participating rather than having the choice made for them without their participation.

[Hobart] All of our graduate courses are oriented towards a research career in chemistry. Essentially the pre-requisites to take a graduate course is that you have a chemistry degree which is not the case with most of the high school teachers around and it's geared toward a research career in chemistry... the value of knowing science, which means that you understand your world better... Is school for training or thinking? I think that's where you get in to sort of I think some of these back to basics movements. We want our students to be able to balance their checkbook or you know function. And that's part of it. There's a certain amount of education and learning that has to take place in order to function in society. But, I think there's something beyond that. I think [we should develop] the ability to think creatively and critically, to appreciate the things around you, to have appreciation for art or architecture or music. Sometimes it's at school where you get exposed to that. It has to be based on experience rather than just being told.

Hobart also demonstrates a wide range of objectives to instruction. It seems clear that as students work their way up in their coursework that the objective becomes narrower. He sees school as a place for students to learn basic knowledge and skills yet includes a broader view where school is a place for students to experience things. Too often the experiences are narrowly defined by instructors with limitations imposed by a university culture that survives within a narrow curriculum and pedagogy.

[Hobart] Research and teaching aren’t that much different. You have to make a point with research faculty ... What is the university's role in conducting a graduate program and research? They say, “To increase their knowledge and understanding.” And the reason it's going to get you support from the state at a state university is this part in the educational role. You’re educating people now to take leadership positions in your discipline. Whether it's a leadership position in an industrial laboratory, industrial setting, or it's a leadership position as an educator or faculty member. But, it's education and I think the
faculty members that see the graduate role as an education role are going to understand that and see applications for the courses. The ones that are in it for the ego and the long list of publications and getting the reward or recognition may not cut it in class. I see it in our department.... What you learned in graduate school was how to gather information, how to use it, and how to perform experiments.... if you learned how to learn and solve problems in your graduate program it doesn't matter if you go into another area. The goal has got to be learn how to learn. And then what you choose for content are some pillars. You probably ought to choose some of the more important topics than ones that are maybe just peripheral. But you don't have to do everything in every course if you have that focus on learning.

The last line of the passage above shows that Hobart has found some comfort with the reform notions that moves learning from breadth of coverage towards depth of understanding. He still identifies a need to move other faculty members from a traditional stance based on surface and technical knowledge towards one based on dynamical knowledge. This can be translated into more meaningful experiences for students. As the reform initiative evolves, so will the collective mental models of these professors as they collaborate in an effort to make sense of the issues involved.

[Patrick] [Students] haven't developed an appreciation for the sciences or even the scientific method. How it works. In our survey level classes we generally teach the facts of the discipline not the way in which the facts were arrived at or the method which science uses to uncover those facts.... I really wanted to see a concrete demonstratable outcome that was that my students would be literate in the field of science based on my field of science by the time that they completed the course.

Patrick identifies that which is pervasive in the survey courses. He questions students' ability to become literate after one course. Literacy comes as an accumulation of exposures and experiences and this lends itself towards providing students with an integrated and thematic approach to science (Cobb, 1998; The College Board, 1999; Knapp, 1996; Kovalik & Olsen, 1997; Stapp, Wals & Stankorb, 1996). We must move beyond seeing individuals, actions and events as separate and
isolated. Organizations are complex and interconnected yet we continue to fragment people and departments. "Schools are teaching students to prepare them for memorizing the parts in bureaucratically organized and controlled environments; schools are failing to produce self-motivated individuals who can think and live with complexity and ambiguity" (Caine & Caine, 1997b, p. 19).

[David] When I was going into grad school I was really running on the assumption that I would either work in the private sector or I would work in the government some place and I really wouldn't be involved in teaching and education so much. I took a lot of interest in terms of teaching on an individual basis. The researchers that come in and are new hires think as scientists.... I need to maintain a pretty heavy focus on writing, but I feel a responsibility towards my teaching too. Eventually one of the things that I would be interested in at some point is, but not for the next two years, I'd love to be involved in rather than writing ... the clientele that I'm really reaching for on a daily basis is really the science majors. I'm training graduate students ... training people to be interested in that respect.

David is again guided along the traditional path by expectations of the status quo. If scientists are going to teach, they should have the same background and expertise about learning and teaching as any other teacher. The self-selective process is applied widely to a student population that may not want to enter the research field; there are more non-majors than majors and of those majors, not all want to go into research. POI thinkers are narrowly focused on the acquisition of knowledge for reproduction rather than using knowledge and experience for the generation of new meaning and understanding. Learning science is too often oriented toward the objective of preparing students for the job market. The possible alternatives are not considered in light of the small proportion of students who ultimately persist in science towards a research end.
[David] I wouldn't approach the CTEP class the way I would approach the upper division courses. They're completely different objectives in terms of what I'm trying to do. With the CTEP course, there were really two things that I was looking for. One was just increasing their awareness and understanding of science ... and then also to begin to instill some notion of teaching.

David wants to learn how do deal with difference since he does see majors and non-majors in those terms, but keeping the distinction perpetuates a class or tracked system between the two groups. The science majors get "trained," which is limiting in the sense of becoming science literate. The resulting specialization perpetuates the exclusionary practice – especially when those scientists must teach in order to gain tenure. In this case, it seems that the espoused theories are congruent with the mental model. It just happens to be on the end of the continuum that does little to provide equal opportunity for all students for there is a sense of certainty that limits one's awareness towards the need for reform. Teachers with a strong sense of certainty about teaching also do not have much need to be involved in professional educational development that investigates issues of schooling (Hilty & Gitlin, 1995). Teachers who can function with ambiguity are continuously engaged in educative experiences. It is evident that most of these professors who participated in the reformed science course did so out of frustration derived from the ambiguities of not knowing rather than from certainties. One of the attributes of the Possible Human (the complex and integrated person or teacher of the future) is the capacity to flow and deal with paradox and uncertainty (Caine & Caine, 1997b). This should be accompanied by an understanding of process coupled with the ability to let go of many types of control.
[Sophia] They do need to master a certain amount before they can get into a pharmacy program or a medical school or before they can take the MCAT or the GRE or move on to a technician's job or many of the other things that biology majors do after they graduate.... Beyond recruiting potential biologists, I'm just as thrilled by the people who are going to be bankers or marketing executives, or whatever it is that people do, nurses, everybody. You get to the end [and they'll be science literate] and say, "I have some grasp of how scientists make observations and answer questions and I have some grasp of some of these major concepts that I never thought I'd be able to understand." That's incredibly rewarding.

Sophia shows a range of objectives for her instruction. Some will need her class as a stepping stone to some higher form of science while others will need it to get a "flavor" of what scientists do. There is still a notion of teaching to the test. To be science literate must not be constrained by basing the curriculum on tests or making it equivalent to what scientists do. Her views invite inquisition of the underlying assumptions about the inherent difficulty of science and the scientist's view as the only way to interpret science. These notions serve to perpetuate distancing of students who do not aspire to be scientists yet still want to develop science literacy. Kovalik and Olsen (1994) speak of science as the study of the natural world around us and as such demonstrate an understanding of the way the brain is constructed to think, perceive, and to construct meaning from our world. In contrast to other humanly constructed subjects in our curriculum such as mathematics, writing, reading etc., science is innate because it can be experienced firsthand through the senses, unlike the other "disciplines." It is only made to be like the others when it is presented in such a way that one must learn how to learn science by a culture based on humanly constructed disciplines such as biology, chemistry, physics etc. Humans are naturally curious and seek to understand and create meaning
out of experiences. This is the brain/mind learning principle number three (Caine & Caine, 1997a). In reviewing the passages above there is no mention of science for teachers (recall the discussion of teachers taking graduate classes in the culture section.)

[Sophia] We have had graduate students with [education] as their objective and we've turned out some very successful examples of people who've gone into high school teaching, people who've gone into community college teaching.... Some want to get a Ph.D. and teach at the college level or they want to work for an agency like the Fish and Wildlife Service, the BLM, the Forest Service or State Game and Fish. Or they want to work as a consultant and work independently and so they need the biology and field expertise to do that. [Others may] want to work for a non-profit like the Nature Conservancy or the Audubon Society. The majority of our applicants have something other than K through 12 teaching as their primary motivation for a masters degree.

Sophia has previously stated that her department does not get education students that want to receive a science degree yet here she admits there are both high school and community college teachers passing through this department. This needs further clarification. She must consider what her objectives of instruction are.

Reform challenges the notion that students should simply be prepared for the job market. Instead, reform-oriented professors look to the love and commitment to lifelong learning as the object of instruction. Sophia's desire to impart the love of learning with her students is met with resistance at times. Again, we must widen the perspective of what it means to be science literate.

[Sophia] Almost everyone who teaches in those courses views the general education component of them as being incredibly important and is making an earnest attempt to make the subject accessible and appealing and to reinforce its importance to everybody, not just for science majors or future scientists. It may be that dissatisfaction with the format leads to fatalism on the part of the instructors because we all know that what made science accessible and attractive to us were personal hands-on type experiences....It's supposed to be to impart a flavor of what it is to ask questions, to challenge, establish beliefs,
to act independently, intellectually and makes one’s own observations and
derive one’s own interpretations. I don’t necessarily think that that’s related
to people’s willingness to take measures to open up the accessibility of the
course to non-majors or that sort of thing.

Sophia is speaking to the very important issue of self-selection (see NSF,
1996d). It was her ability to learn from a conventional “uninspired lecture” format
that helped make science accessible to her. That format is still alive and well.
However, she speaks of what made science even more accessible and attractive to her
and her colleagues as personal hands-on type experiences.

[William] I’ve never really been into the methods except that I know what
kind of methods work for me. My primary concern is that the teachers don’t
have the background in these areas. If you don’t have the background in
chemistry and physics, you’re going to be afraid to teach. You’re not going to
want to teach any of those topics. You’re going to avoid them. You’re going
to, and then the students can sense it. They’ll also develop the same anxiety.

What William sees as a shortcoming in teachers is his strength – science
content. The converse may be true in the area of pedagogy. Although William has
eked out what is in his mind a successful strategy to alleviate the traditional lecture,
much of what he does to add excitement to the classroom is based on his “inquiry-
based lecture” and his energy and enthusiasm while he presents. This does not
address the needs of today’s students in a general sense. He knows what methods
work for him, which is the basic method that has “selected” most of the participating
professors – lecture. Part of his objective for instruction is solidly based on content of
science rather than life-long learning. His desire to make the science experience fun
still does not address true understanding nor does it create science literate citizens.
His idea that teachers are going to be afraid to teach is true when the model is based
on the accumulation of knowledge rather than on learning how to think.

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[William] One of the things we try to teach people is to think…. The vast majority of the students in Chemistry 110, not science students, actually come out with a positive attitude towards that course. That’s what we have to do in all of these general courses.

This is a wonderful statement that is aligned with reform. William states that students come out of the course with a positive attitude towards the course, but how about towards science? His intention of trying to teach students how to think is in line with the objectives of reform, but being passive receivers of information has been observed not to create thinkers. "Learning is not the preparation of a repertoire of knowledge and skills that might be useful in time to come; it is simply the future implications of current thought" (Smith, 1990, p. 43). Students learn that the knowledge exists and can be trusted along with the transmitters of the knowledge, but students must learn that knowledge can be challenged. Students can have feelings of betrayal, anger and rejection when they independently discover the transmitters of knowledge are not trustworthy (Smith, 1990).

[William] One of my goals to teaching that course is to neutralize that fear, to make the students want to come to class, to want to learn chemistry, etc. You use all kinds of methods to do that. One of the things I always do every time I teach that course [is] I try to come up with a new way of encompassing that course so the students will have appreciation for chemistry, will enjoy it, will see how important it is, and will practice a little bit about thinking. I put a great deal of effort into that course. In fact I’ve written a textbook for that course and I’ve written a lab manual. Since I’m the person primarily responsible for it, I determine the curriculum…. If you’re going to be an educated person and you’re going to be an artist, you should still understand science.

Understanding science is a noble goal aligned with reform. William could address student needs based on their lived experiences by sharing the curriculum with his students as well as other faculty since he alone has autonomy over it. He has
mentioned that education students mostly take biology for their general science requirement. It could be that they do not form any relationships with chemistry as they do in biology; the study of life. Reflection on the congruence between William's espoused theories and mental models may increase his pedagogical repertoire moving him and his students on a path towards transformation. How closely aligned are his ideals and his practice?

Experiences.

We began learning about age three that schools were "normal" and commenced attending them by age six or sooner.... We didn't question the existence of classrooms, fixed groups, grades, periods, subjects, courses, evaluations, or junior highs and high schools, any more than we questioned lamp posts, fences, green grass, or the warm sun of summer. These things were. Those opting for teaching or related careers come to college with a dozen years of things-as-they-are experience. Most return to the school milieu at around age 22—a time when real-world experience may be scant and contact with real children at the lowest point. After some 16 or more years of status quo exposure to education's structures and procedures, and the ideas that support them, what is is accepted as normal without much question. This is powerful indoctrination. (Hart, 1998, p. 29)

The participant professors recalled experiences from grade school, high school, college, and their professional development initiatives. Most showed evidence that they have developed and changed their pedagogical style and their underlying belief system due to these experiences. The effect of indoctrination is quite visible as I talked with them and observed their classes (see Bruckerhoff & Bruckerhoff, 1996; Hart, 1998; McGinnis & Watanabe, 1996). They identified that they teach the way they were taught and any change that has occurred was due to frustrations along the way as they taught their college courses. They also showed awareness of the need to reform the science education practice at the university.
There appears to remain little support for them to become involved in transformative experiences.

Most of the professors participate in outreach programs they have developed and said that it was not valued in their departments. The present culture in the departments expects professors to spend five percent of their efforts on service, fifty percent on teaching and forty-five percent on research. It is easy to see conflict arising from spending "valuable" time on an endeavor that collectively has less value. Some of their desire to help the teachers in the public schools also brings frustration since they have more "teacher preparation" than the university faculty and the efforts get reduced to trying to help out with content and occasionally with methods of experimentation.

Professional development experiences were limited in scope and number. All participants belong to their respective professional societies. Most find the time to attend their conferences and have noticed that workshops and breakout sessions are increasingly dealing with science education. Adrienne rarely attends because she feels that they are held at times that interfere with her teaching and does not have any research to present. Hobart attends and presents on topics dealing with science education. Patrick mentioned that he attends his society's conferences and has noticed increasing devotion of presentations dealing with education. David generally attends more specific presentations that deal with his area of specialization. Sophia presents content specific papers and has attended workshops by her professional society. William attends the society's annual conferences and even presents his innovative lecture/demonstration techniques. These are presentations done by the
scientists themselves that may be affected by cultural constraints that limit broad-based experience and knowledge about learning. This aspect of science and education must also become integrated so that those that have done the research on learning and teaching within as well as outside of the science arena can participate in the dialogue of reform.

Other experiences that inform their methods of teaching and learning are limited to one or two memorable ones. During the interviews it became apparent that they have not had exposure to meaningful professional development because of perceived constraints and departmental expectations dealing with research, tenure and promotion. Adrienne did not mention any workshops of this nature, but her involvement with public schools seems to occupy any free time that she has. Hobart has worked for the Educational Testing Service on AP exams. Patrick recalled two experiences of which one made a lasting impression. Writing Across the Curriculum has caused him to adopt a new aspect to his teaching and evaluation methods. Sophia recalled about a workshop that called her attention to innovative ways to deal with large classes. She is also participating in a collaborative research project sponsored by her professional society. Most of these professors mentioned that their college sponsors presentations and seminars that deal with topics of science education. These presentations are attended on a volunteer basis and some apparently did not sound appealing or were repeats of previous ones. The biology and chemistry professors mentioned that their departments have monthly seminars.

All of these professors had commentaries of their involvement with the CETP reformed science course. They viewed it as an opportunity to shed their
perceived constraints and try some of the innovations. They did meet several times prior to teaching the class and I was present for some of those meetings. I observed the participants as they developed the curriculum. Little was mentioned about pedagogy. They were allowed latitude to develop an innovative course that would develop science literacy to pre-service teachers using a thematic and integrated approach. They were constrained by their limited knowledge and experiences about teaching and learning. Below are some of their related comments about the course as it relates to their transformation as educators.

[Adrienne] [Speaking of the reformed science course] I would change what I did. I liked the way I started it [with the scientific method] and I liked the way we went into it. I liked the way we gave experiments for it, but they really missed one big section of it. That was the research part of the scientific method. I think most of them came away with the idea that what we did in class was research. We didn’t so any research in class because we didn’t have any materials to go out and look and see what had been done previously, and so they got a false idea of what was meant by research; searching the literature, that kind of research, as opposed to experimentation. So I think we would have to have them actually go out and go to the library, use the web, go to other sources, and actually do some research. I’ll have to incorporate that in next time.... I think this natural science class that we’ve worked on is an interesting way to help them see the different connections between the sciences.

[Hobart] I think things like CETP, where you get the colleges and the departments interactive more, you can see that everybody sort of is interested in the same thing.

[Patrick] We had some students who did that during our oral exams in the Natural Science class. You have the flexibility to ask follow-up questions in a probing kind of way.... We still need to get together and have a debriefing there. It just seems logical to me that at some point we’re going to have to sit down and say what is it that we did, otherwise I don’t know how we move beyond this.... The faculty in [the CETP] program are not new faculty. I’ve been around for a long time, [the earth science professor] has been around for a long time. I don’t think we will break the cycle because we’re a nut in a big machine. We are a cell in an animal. We’re just not big enough. We’ll effect our students, but our students are a dozen so that’s not going to change the
system. If we can develop a good model and show that that model is effective, then I think it will be adopted elsewhere. This is why I said that we really have to get together to make sure that what we’re doing is developing this good model. Not just something we feel warm and cuddly about because that’s not going to be transportable to other institutions.... The first semester was just really wrenching in terms of just trying to come up with a consensus on anything. It seemed like we were just perpetually going in a circle. We’d all agree on the catch-words even though we didn’t define the catchwords the same way. We had a hard time coming to some kind of consensus as to what we were going to do. In fact, it was a surprise to me that we even came to a consensus. At our last meeting, [the director] sort of announced what our consensus was. I didn’t see us evolve to that. I saw it more announced. I think that was mainly [the director realizing] this new semester’s only a month away and he felt he had to do something rather than [doing] a thoughtful thrashing out and building of a consensus.... Nobody was really able to commit to another scientist that they had data to support their viewpoint. They had qualitative statements and my qualitative statements were as good as your qualitative statements. It was extremely difficult to reach a consensus.... it’s a starting point. We all lived through it. In the future we will presumably get together and look at what we did. Then we’ll evolve it, which is great.

[David] CTEP is a two-way street. At least the way I look at it. I see it as an opportunity to educate students, but I also see it as an opportunity to educate professors. And with my background, with limited teaching and high skewedness towards upper division classes, I didn’t get the opportunity to teach or to interact with freshmen and sophomore students. What I see is that students have already been shaped by three years of undergraduate education.... Part of [my involvement with CTEP] was education on my part. I wanted to see if we could do some of the things that I’ve been wanting to do or I could have done with seniors... it was sort of an educational experiment ... and to get some experience with different kinds of students.... It’ll be a chance to interact with a totally different group of students and to actually talk to more experienced professors and see what they have to say about teaching.... Some of [the 121 projects] were very well put together....and so that might be an exercise that I could instill in my courses. Or some facet of that. [Long pause].... Now I’m very interested in continuing some involvement with CTEP. I have learned a lot more about what alternative teaching is really all about and actually being able to use some alternative methods and applying it to our teaching.... I will be keeping the ideas of CTEP and trying to be a little bit more innovative. And more pro-active in terms of getting the students to learn in multiple processes.... when opportunities like that pop up I will use what I learned and try to incorporate some of that into the presentations.
[Sophia] I was primed to think of it as an opportunity to try some different teaching methods, to try and reach students who aren’t very well served by the existing courses in biology and to do something cross-disciplinary because in my own scientific research that’s been very important. It’s very obvious to me that science is not compartmentalized. The natural world’s not compartmentalized. So it makes sense to me that an integrated approach works…. The bulk of my teaching of 121 [the reformed science course] came at the end of the semester. Both courses benefited from things I’ve done in the last few years to try and explore more ways of interaction in a classroom format…. One of the reasons I really liked the 121 class is because it’s so much smaller, it allowed me the opportunity to do certain things I would have a tough time doing in a lecture of three hundred. Like the role-playing games in the ecosystem dynamics, with the different trophic levels and various consumers going around consuming each other. That was very easy to do with a dozen students in the room. I’m going to use that in the course I’m teaching this semester, which has twenty students in the room. I could see doing it successfully with up to fifty or sixty students in the room. Frankly, I can’t see doing it … with this theater style seating where people can’t even walk around without stumbling over each other’s legs and books…. I feel as if I made some really valuable contacts with people who are overseeing the whole CTEP program, but I feel at a complete loss as far as the tangible future of the involvement of biology. It sounds as if we’re just continuing this divorce between science faculty who are simultaneously science researchers. Somehow this is in a different universe from actual science education aimed at non-science majors. The truth is that we do both.

[William] [Science education reform] is in a very disorganized state. Don’t you agree? You could see it in when we tried to develop this special course. Everybody had a different idea as to what they wanted to do. When we started teaching, everybody taught it the way they thought it should be taught…. The way [the reformed course] was taught is the traditional way of teaching a team-taught course. Each person goes in there and teaches it the way they want to teach it. There was very little interaction. You were there the whole time. This person taught for two weeks and then another person or persons came in and taught for two weeks.

It is difficult to predict how participation in one course will affect teacher transformation, but it did provide a forum for letting go of tradition and constraints in order to try innovations. The problem is that the repertoire of selections is limited by the lack of experiences and knowledge dealing with teaching and learning.

Professors and teachers in general are not provided with support in these areas and
when they are, practitioners do not fully embrace or participate in them because this aspect of education is less valued than pure science and research. This paradox exists and will limit the transformation of our educational system until the collective body of science recognizes this and changes the values that make up the culture of scientists/educators within our universities. Although initiatives such as CETP are addressing administrative support and institutional buy-in, there is a lack of institutional response to changing times and research on the brain and learning. Instead, reform efforts are largely being lead by individuals pursuing their personal visions (Hart, 1998).

**Issues.**

*We are now faced with the fact that tomorrow is today. We are confronted with the fierce urgency of now.* (Martin Luther King in Giroux, 1997)

The professors were aware of many of the issues that the present reform effort is attempting to address. Collectively, these issues emerged: alternatives to lecture, equity, student quality, teacher effectiveness, content vs. process, K-12 teaching and learning, assessment, university culture, tenure and promotion, education based on learning rather than high scores, animosity towards education department, compartmentalization of science disciplines, research valued over teaching, depth vs. breadth of science content, curriculum integration, tracking, high failure rate, diversity, indoctrination, and the decreasing number of “competitive” American students in the sciences. Each of these issues individually could spawn new research.

Even though the participants were aware of some of these issues, none seemed aware of all of them. The level of understanding of the issues seemed limited or
superficial since to do this at a deeper level takes time to read, research, and participate in discovery activities. The practice of action research could accelerate the reform process by internalizing a deeper understanding of issues related to teachers and students.

**Literature and Learning.**

*We need some new thinking about science education reform in general ... we need to find new ways to nurture departments and faculty who are committed to lasting change. New thinking begins with a critique of old thinking.* (Tobias, 1992a, p. 13)

Literature and learning were combined due to the limited references to them in the data. It seems appropriate to say that what is important here is not what was articulated during this study, but actually what was omitted. There was almost a total lack of relatedness to any sort of research on learning, teaching or other aspects of reform. It is obvious that the research literature most scientists spend time reviewing is within their areas of specialization. Three professors referred to *Revitalizing Undergraduate Science: Why Some Things Work and Most Don’t* (Tobias, 1992a).

Sophia addressed the issue like this:

It’s unusual to find a person who has read anything by someone like Sheila Tobias on student attitudes toward science and towards different kinds of science courses. Maybe we could do more just to make people aware of what information there is, what the reality is.

One of these professors is unusual if we use Sophia’s definition.

[Hobart] Dudley Hirschbach [from Purdue] published the first papers in chemistry literature on Piaget. Chemists caught on to the hands on part and it had a pretty big effect on laboratory instruction. But, they sort of neglected the minds on [aspect]. A year ago I read in the paper that described the learning cycle using the 4-Mat method.... the Tobias book shows that successful undergraduate programs have strong research components.... I tried the thing that, I guess Eric Mazur at Harvard is credited with. You pose
this question and in terms of a multiple-choice question.... That's where Kuhn's ideas of paradigm shift come in....

This is one area where personal initiative can bridge the gap between theory and practice. Part of the problem is this lack of knowing the theories that inform learning and teaching. Who better to interpret these theories than the practitioners? Although there are many references to learning in the interview data, most are based on notion and definitions developed from experience. Some professors have tried to incorporate what they encountered in their professional development, but such a limited exposure to new ideas will not provide enough understanding to sustain the development of knowledge and practice that addresses learning. Below, two professor's comments support my previous statement.

[Adrienne] Students can learn that way, and some of them do learn that way, but not all of them learn that way. There needs to be an interaction of some sort.... I don't think [science and engineering professors] think about [learning theory]. None of the professors that I know... except for maybe my husband and myself have had any education courses at all, courses dealing with learning or psychology or any of that.... Whether there is a real difference in the way they [college and elementary students] learn, I don't know.... I forget what it used to be called educationally.... I have heard this a couple of times.... I don't know where I picked it up or where I heard it form.... I [read] somewhere about the different levels to learning.

[Patrick] I know in education there are theories that say that you have other kinds of learners. Some learn well by doing one thing, others learn well by doing another thing. I wait to be convinced about that. I still feel that people learn best by doing.

Many times these professors are using what Freire (1994) calls the language of critique, but what is missing is the language of possibility.

**Possibilities.**

*The importance of developing a theory of science education is to provide a framework in which elements of reform may find meaning and viability.* It
provides a means for making consistent choices likely to improve the course of reform. In other ways it makes it possible to distinguish buzzword, slogans, postulates, and clichés from rational thought. It also provides for debates, deliberations, and reflection on problems in place of "instant philosophies and "off the top of the head" responses. (Hurd, 1997, p. 23)

Perceptual orientation has much to do with what one knows and where one has been. There is a powerful indoctrination working on teachers. We not only need to know what is wrong, but also know why. A pedagogy of praxis contains the reflective component necessary to do this.

Without intentional inquiry into new knowledge and participation in new experiences in order to sustain a new consciousness, reform cannot enjoy sustained and widespread acceptance. We cannot simply critique what we feel is not working and expect change without a recontextualization of the landscape in which the conflict emerged. We need to see the present with new eyes. It is not until the system dynamically reaches critical stages in reflective terms that transformation begins. We must not focus our attention on external relationships and ignore the internal changes and processes that occur as a system becomes different. We must initiate individual substantive changes in our lives through a combination of external conditions and deep personal reflection (Crowell et al., 1998). When we go through transformations of this nature we create a new personal history with new challenges and possibilities.

A new pedagogy will emerge from the clash of what we have been doing and our new understandings of learning and teaching. Responsive learning will be clarified as we confront our assumptions, our practice, and our learning environment.
Teachers have a sense that they can do much more than they are doing if there were more support, freedom, and time to work more collaboratively with colleagues. This is what current reform initiatives intend to do, yet the necessary transformation that must occur is caught in a contradiction. Teachers believe they cannot practice what they know intuitively is good for students due to perceived constraints. On the other hand, teachers say they experience great autonomy once they are in actual practice in their classrooms (Crowell et al., 1998).

The foundation for the present belief system is deteriorating. The needs of an increasingly diverse student population are not being met. We must learn to live in a new landscape. "But as new skills and perceptions are created, we may find that these changes represent a range of new possibilities for each of us and the institutions that make up our lives" (Crowell et al., 1998, p. 22).

[Adrienne] ... block scheduling. I think that's a good idea, but I'm not quite sure how we can do that here.... Our department head has said he does not want promotion and tenure to be based solely on research. He wants to incorporate the teaching component as well.... The way you make reforms, in my own teaching here in my department, if I want to do what I was just saying, we would have to completely change the way we do our labs.

[Hobart] But here, it's been quite a different situation. There are some pretty conservative faculty members that need convincing. So, I have kind of the freedom to try, but I have to convince people to do it too. Again, there are lots of people involved with any course and so my approach has been to try it in the smaller courses where I'm the only one involved and see how it works.... I hope some of things we're discovering in the [reformed] natural science course will provide a trickle down that gives me evidence and reasons to convince my colleagues to try and change teaching techniques in larger courses.... building consensus and exposing some of the other faculty members who may be more resistant to change to some of the things that we know from cognitive research about how students learn which is something that I'm learning myself.... I [spend my time] say much as a [regular] faculty member involved in research, it's reading the literature, going to meetings, reflecting back on what we've done in a course.... Keeping up with
education journals, talking to others about what they do. I think probably the most valuable thing I find [are] discussions that I had with colleagues at other schools on what they do and what kind of ideas they have. I try and bring in an educational oriented speaker at least once or twice a year. [I work on] laboratories that we do in 111 and 112, the small-scale labs that are based on some of these inquiry-based modules that are coming out of the National Science Foundation.... In the past I've looked [within the context of reform] at what I can do to improve my teaching.... Rather than looking at just doing my thing [I now try] to bring the rest of the folks along, whether it's kicking and screaming or willingly into trying some different things.... We need to find a way within the department structure to be worth it for the people willing to do that extra work.... To do the extra preparation, have them spend a couple of weeks in summer ahead of classes just like we have the TAs go through some training. I think the faculty will need to go through some workshops and training to do some of these things. The interest is there. I think the frustration is there that a lot of the faculty feel that no matter how much effort [they] put into improving [their] lectures or presentations [that] there's still the same huge percentage that do poorly in the course.... One time I made the point that probably the science method courses shouldn't be taught to the [education] students. There ought to be science method courses that the faculty [must] take. During the first semester in a teaching job as a new assistant professor you probably ought to take the science methods course over in the education college.... You've got the evidence now ... let's try it in all the other courses. And so what the NSF has done which maybe hasn't been done before is put it in a framework that at least I hope is going to be some institutional buy-in.... There can be some encouragement and incentives that come from up high, but it takes the faculty to do it and then only if you have that strong leadership and encouragement and reward system put in that [ensures] you'll get credit towards tenure for being involved in these kinds of activities ... that if you publish a paper on a reform course, that counts just as much as a research paper. And so, work has to be done from below.

[Patrick] In a perfect world, where there was nothing called time, I think that the oral exam would be a superior way of judging the overall competency of the student. That's what we use in higher education when we have our people take their masters and Ph.D. exams.

[David] What I'd like to see is that the base of science be elevated more so that the whole populace in general understands science better than it is now.... If we improved education from K-12, then when we get those students that come in to the college that maybe we can still use a fairly traditional approach because now the bottom has been raised.... One of the things you could do, if you got resources, is to hire instructors to teach the general education or science reform of primary and secondary science majors. It's going to be, resources permitting, easier because here you can ask those who are devoted
to that where that is one of the main functions and that person [can] be available all the time.

[Sophia] It’s hard for me to picture some of my colleagues going along with such a request [to participate in a non-text problem-based course]. That would be seen as requiring such an input of time and energy on their part, to make that a successful experience, that is would be perceived as a direct conflict with the other portions of their job responsibilities. The criteria on which we are all judged every year as well as those external standards that we talked about before; the standards of the profession and national reputation and research productivity and all of that. If you could remove all that, then I think that the majority of my colleagues would be at least interested, positively interested in such an experience. Some of them would undoubtedly feel uncomfortable being removed from the prop of a textbook and a standard list of topics that needs to be covered and vocabulary terms that need to be understood. But the majority of them are interested in teaching as a process and they would be interested in exploring different ways of handling it, frankly, because we’re all researchers, we’re all scholars, we all appreciate the opportunity to tackle one or a limited number of themes in depth and to become co-investigators with students in such a student directed learning experience. I think actually most of us do teach courses very much like that. But they are the courses that are directed to the upper division students and graduate seminars and so forth. We’re all very comfortable with that method. We’re just not accustomed to thinking of it in terms of lower division students for non-majors, non-specialists in the field. I think many of us might have some hesitance at how successful non-majors or non-specialists students would be in such a setting. We use this excuse because we feel like the students need more structure and top town direction and part of it is the external constraints. How can you possibly propose to teach this to sophomore non-majors when you have hundreds or thousands of them in a year that you need to deal with?... I’d like to see there be more flexibility in the reward and responsibilities allocated to faculty. The CETP course, great idea. Having people work together and try something innovative to serve what to us is really a new student population.

[William] [Without time constraints], I’d probably do it like they do it in the honors class. I’d give them thought-provoking problems.... I guess we give tests when we have to. Wouldn’t it be neat if people just came to school to learn and we didn’t have to test them... The best situation would be to eliminate all these straight lecture classes.... I decided to take a chemical reaction involved in the discussion of a metal, which is of great economic importance to [this state], the production of copper. It allows me to introduce a little bit about economics and how natural resource can involve economics. I’ve visited all kinds of mines and smelters and places and facilities involved in the copper industry.... They find out you have a sulfur dioxide by-product
which is an environmental hazard. They convert it into sulfuric acid, which has great practical importance. All the sulfuric acid they make is shipped to the Chevron oil refinery … to be used as a catalyst in making unleaded gasoline. When it is no longer useful as a catalyst, they give the sulfuric acid away to farmers. Farmers then can use it to put in their irrigation waters or on their soil directly to neutralize their soil.

It is obvious from the above excerpts that there is a wide range of ideas regarding the existing problems in our practice of education. It is still very difficult to see the range of possibilities however, from a position so close to the problem. Those who have moved their experiences away from the extant practices and constraints have the greatest chance for reform-based transformation.
CHAPTER 5

IMPLICATIONS: FUTURE PRACTICE AND RESEARCH

Considerations of the Need for Self-Reflective Practices

The components of the belief system as they were revealed in this study are part of an over-arching theme of resistance to meaningful science education reform. The implications of resistance as expressed through the incongruence between the espoused theories and mental models of each participant deserve our individual and collective attention. We as professors need to engage in a meaningful and personal effort of self-reflection. Only then can we begin to uncover and critically examine how we have been able to enjoy the prestige of a system of self-selection without the awareness that it was in fact and indeed unaccommodating to others.

The professors showed a desire to want to participate in reform. They remain however; unaware of their participation in the perpetuation of the process of self-selection that serves to maintain the status quo. Before they can engage meaningfully in reform, professors must go through the process of self-reflection and critical analysis of their own behaviors (see Freire, 1994; McLaren & Leonard, 1993). Professors on this self-critical path can more accurately assess and critique present exclusionary practices. They might then acknowledge how a move toward a pedagogy of possibility will not limit scientists. Instead, a pedagogy of possibility will serve to broaden the base of those who will call themselves scientists while educating all towards science literacy in a democratic and socially responsible way.

Each participant must question where he or she might place themselves on the continuum of perceptual orientations. They can each then proceed in a way that will
effectively challenge their respective mental models thereby closing the gap that exists between theory and practice or the rhetoric of reform and true transformation. I found elements of resistance in their espoused theories and mental models. Resistance was set up on an open-ended continuum. The maintenance of the status quo represents one end while the letting go of resistance represents the other end. Letting go in this context implies an opportunity for personal transformation that allows for reform efforts to be meaningfully undertaken and ultimately established. Each participant's comments were individually then collectively analyzed. Analysis of the emergent theme of resistance allowed for the identification and consideration of other underlying issues as well (see Bailey & Chambers, 1996; Crowell et al., 1998; Kincheloe & Steinberg, 1995; McLaren, 1994; McLaren & Leonard, 1993; Oakes & Lipton, 1999; Seymour & Hewitt, 1997).

Dealing with student diversity has presented a problem. Professors dichotomized students into majors and non-majors, lower-division and upper division, those that do and those that don't want to learn, poor students and the better ones, and education students versus the rest of the student population. These categories were apparently used to help explain why some students do not do well in these traditional courses, even if innovations have been implemented. Valuing one way of knowing marginalizes the majority. If professors are not teaching from a socio-cultural perspective, blame cannot be placed solely on the student when he or she does poorly (see Nieto, 1999; Rodríguez, 1998). Teaching for understanding is at the base of reform, yet present assessment methods are discriminatory in that students' ways of showing understanding are not valued and the bottom line is still

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grading and scores. Minorities will soon comprise 40 percent of the student population and as the student population becomes more diverse, the teacher population becomes less (Clark & O’Donnell, 1999; Hodgkinson, 1993; Weiss, 1993). Since this is the case, researchers in this venue are calling for professional attitudes to become more aligned with the reform goal that all children can learn (Schmieder, 1993).

Reform is in order, considering that current curriculum is a result of a “200 year-old goal prescribing that school science should be taught as an occupational subject, oriented towards the preparation of scientists” (Hurd, 1997, p. 34). This research found that professors could identify or espouse alternative objectives for instruction such as for becoming life-long learners, but their practice was limited to the objective of the above quote. Axtell suggests that we “speak and listen in a different way” if we are to uncover what we don’t know that we don’t know (1993). Others have suggested that we speak in terms of “seeing with new eyes” (Crowell et al., 1998). These and other brain-based educators mentioned in this work are calling for the inclusion of knowledge of the brain when considering efforts to understand learning and teaching. Crowell et al. (1998) have produced five guiding principles that educators can integrate into their new practice and school culture (p. 177):

1. Create a purposeful, self-reflective environment.

2. Enhance the possibilities of process and self-organization.

3. Establish an environment that fosters, promotes, and celebrates creativity.

4. Commit to a practice of integrity and authenticity.
5. Affirm a sense of connectedness and honor the diversity that exists everywhere in the world.

Science education professors must use reflexivity to gain an understanding of the harmful effects of practicing a pedagogy of contradiction. Educators can no longer hold onto practices that serve only the few. Lindquist (1978) called for challenging the existing reward system to be part of a strategy for change. Twenty years later the call remains unanswered yet still pertinent. He further suggests that educators adapt rather than adopt as they participate in change efforts and that “most people feel uncomfortable when they leave secure ground” (p. 240). Even though educators may feel uncomfortable, as change agents they must begin to look at the issues in new ways based on self-reference and self-efficacy (see Caine & Caine, 1997a).

Toward a Pedagogy of Possibilities

Marcus et al. (1996) produced a portrait of projects that receive funding from the Fund for the Improvement of Post-secondary Education (FIPSE). In her seminal book Tobias (1992a) says, “Trained in problem definition and problem solving, scientists inevitably bring the habits of doing science to the problem of reform” (p. 16). These scientists often frame complex issues in terms of problems and solutions. Reform is not a scientific enterprise. The FIPSE report contains over 30 essays that describe practices that have proven effective both through quantitative and qualitative as well as mixed methodologies. Professors in my study wanted proof of programs that exist that have been studied “scientifically.” Hart (1998) suggests that educators
must not only look towards innovation in our practice. They must also reflect on and retain effective existing practices and eliminate those practices that are not.

Aronowitz and Giroux (1991) speak toward making science accessible and available to all students, but only when scientific knowledge is removed from its "absolute pedestal" (p. 22). They present the progressive notion of making room for the excluded within the established culture as well as the postmodern stance that asserts no privileged place for science (see also Aronowitz, 1988). This takes us back to the language of continuums. A first step in transformation for a democratic education is the recognition of multiple perspectives. We as educators must come to know our position with regards to reform issues and identify those convictions that ultimately make up our mental models. This can only be done through praxis. Aronowitz and Giroux further suggest that schools become places where students discover a public voice without making many compromises. I think professors cannot be left out of this dialogue and analysis. Schools can no longer devalue diversity and serve an elite group that has bought into a self-serving curriculum. This serves to allow students to lose their cultural identity in order to be successful (Nieto, 1996).

This study shows professors hold a limited notion of diversity. It goes beyond ethnicity, gender, or socioeconomic status. We must question the position of power and privilege and hence the process of self-selection. "Learning to teach for diversity implies learning to implement more culturally inclusive and socially relevant pedagogical strategies. Learning to teach for understanding involves learning to
implement more critically engaging and intellectually meaningful pedagogical strategies" (Rodríguez, 1998, p. 590).

I also found professors willing to try to reform their classes because it has become obvious to them that something is not right. But good intentions do not make learning happen. Their efforts must be coupled with the knowledge of teaching and learning, new experiences and the resources to support and sustain new pedagogies. Most of the participant professors admitted that they teach the way they were taught. Aldridge (1993) suggests that the most serious thing wrong with science education today is the failure to teach science built on experience. This eludes many of the professors at the university and to a lesser degree the professors involved in reform because the call for constructivist pedagogies has been made. The problem seems to be the lack of understanding of constructivist and socio-cultural perspectives of learning (see Nieto, 1999; Rodríguez, 1998). Traditional science teaching has been undertaken whereby terms come first and not actual experience. The mystique is compounded by setting up relationships among things that aren’t understood in the first place and by attempting enormous coverage (Aldridge, 1993). Kovalik and Olsen (1994) attribute this to television and the video nature of our changing society, but they concur with Aldridge; begin with experience.

Barton and Osborn (1995) provide an important caveat that reform can be detrimental when it is located in the politics of assimilation even though it is intended to promote science for all Americans. Many teachers, including professors in this CETP study, say that students can all learn if they try or simply if they really want to.
Nieto warns that too many students must lose their cultural identity in order to “make it” through the present system (1996).

**Future Research**

Bybee (1997) calls for practitioners to internalize the idea that we are the reform. Reform is not out there. It is what we do in our daily work. Educators must move toward a collaborative practice within the teaching ranks as well as with student learning (see Beane, 1997; Johnson et al., 1990; Sawyer, 1993; Stepans, McClurg & Beiswenger, 1995). Fedock et al. (1996) studied professors who were willing to do what was necessary to move towards transformation. It was not until they realized that they were part of the problem that they were to make meaningful reform-oriented change in their mental models. It is possible that these professors were able to participate in reform more freely because they were at a community college where the cultural constraints are less when compared to university science professors who practice in a system that values research over teaching.

The community college professors had their focus on content and not on instructional practice (Fedock et al., 1996). I found it revealing that these researchers uncovered the significance of having a strong teaching mission, free of research demands. They also call on reflection to be incorporated in the design and redesign of units while collaborating with colleagues from other disciplines. The latter suggestion needs further review since the deep-seated beliefs that science professors harbor toward the colleges of education presently pose another great barrier. A possibility is for professors to see their work with these colleagues in new ways and move beyond denigrating perspectives. Prior to the academy that they participated in,
these professors believed that the problem in science education was based on teachers’ lack of content knowledge and that they could contribute to teacher development because of their expertise in science. As a result of the academy, they came to see their traditional approach to science education as inadequate. They went through relatively extreme measures when compared to other reform initiative participants. These professors visited school classrooms, consulted with a science educator, worked with exemplary teachers, and read widely in the literature of science education. Other CETP initiative studies had some commonalities, but the big difference was in the contextual setting.

NSF guidelines for the CETP collaborative initiatives require that there be collaboration between science methods professors, science content professors, and public school teachers that include exemplary educators. In the present study, science professors met a few times to plan the reformed course. There was no visitation of schools, no inclusion of outside teachers, no evidence of literature review, and no collaboration with science methods professors. Reading their profiles and curriculum and instruction belief system components contained within this study, it becomes clear that these professors have little to no experience with the self-reflective aspects of the academy in the Fedock et al. (1996) study.

Fedock et al. (1996) feel that the potential benefits of these collaborative efforts will not be fully realized unless science professors become more knowledgeable about children, teachers, and schools. Science professors must come to see the need for reform in their own science departments at colleges and universities, not only in elementary and secondary schools. These community college
professors were aroused to learn more about science education based on their
dissatisfaction with their own students’ content knowledge. This arousal only set the
stage for change. It did not come until they were introduced to important literature in
science education, met classroom teachers, and entered into serious dialogue about
effective classroom instruction. This is similar to what compelled the professors in
my study to move, but they lacked these important factors that seemed to precipitate a
new vision for science teaching. They must move from seeing themselves as part of
the solution to seeing themselves as part of the problem (along with teachers, schools,
and other educators). Teachers have much to learn from scientists and scientists
have much to learn from working with teachers. It is important they participate in
reform that must include changes at all levels, K-16.

NSF (1996d) has expanded our vision that science education should concern
itself with all or our students, not just those who historically have been represented in
science, mathematics, engineering, and technology. Additionally, the debate over
“teaching vs. research” in faculty workloads and in faculty rewards is being
considered by those controllers of educational purse strings. Some universities are
making significant changes in the internal culture dealing with the way faculty are
evaluated and rewarded. Promotion and tenure policies are beginning to be
scrutinized by initiatives from the American Association for Higher Education (see
also Jennings, 1997). These efforts are few and resistant forces are present to
counterbalance them, nonetheless, efforts are underway to recognize educational
achievements and validate faculty reward systems similarly to the publication of
research results.
The educational community must move towards addressing the needs and issues that have been identified in this research. This can be done on at least two fronts: individual and group efforts to improve practice and advancing the research on learning and teaching. The NSF report, *Shaping the Future* (1996d), calls for changes in SMET faculty, departments, businesses, schools, government, and foundations and agencies. Although broad in scope, it does not embrace the notions of reform from a total community perspective. This call for change is based within the existing culture. To move beyond how science is practiced today, Hurd (1997) calls for critical studies within contexts that serve to integrate contemporary science with human welfare and social progress. NSF’s proposal lacks the language that includes schooling and education from a more integrated perspective (see Beane, 1997). Lind (1993) suggests reform initiative should value and include teachers as part of the dialogue (see also Hilty & Gitlin, 1995), revisit professional development and in-service, and identify and support innovators and risk takers. I am suggesting that the changes in society and science have made it necessary to move education in a brain-compatible direction. Hurd (1997) support this notion:

> Before new science curricula can be developed, an expanded agenda of educational research will be needed and findings must be integrated with the cognitive sciences in ways that identify compatible styles of teaching and modes of learning. (p. 45)

> Science is an innate way for humans to come to know the world (Kovalik & Olsen, 1994). Science becomes distorted and undemocratic when it becomes categorized into disciplines producing borders that create conditions of inequality for
the general population. It is along these borders that future research on belief systems must reside.
APPENDICES
APPENDIX A

INTEGRATED NATURAL SCIENCES I SYLLABUS
AS 121   Integrated Natural Sciences I   Fall 1998

As future elementary school teachers you may be called upon to teach lessons in any of the sciences: astronomy, biology, chemistry, geology, and physics. This course and its sequel next semester are designed to give you a broad view of the natural sciences and the connections between them. You will also develop your skills for finding scientific information, how to use it, and how to think critically about scientific issues.

This semester the course will center on a theme of life in the universe and consists of an introduction and three modules.

8/19 - 8/24   Introduction:  What is science and how does it work?

8/26-9/23   Module I:   A Survey of the Universe: What are Likely Sites for Life?

9/25-10/26   Module II:   Why are carbon compounds and water necessary for life?

10/2 & 11/30   Module III:   What structures and functions do living organisms demonstrate, and why?

12/2 & 12/4 - open periods - catch up or final discussions

12/7 - Monday – Final class meeting 1-3 PM

TEXTBOOK:

*The Sciences: An Integrated Approach, second edition*, James Trefil & Robert M. Hazen, John Wiley & Sons. This text is available at the bookstore and will serve as a reference text for the course.

GRADING:

A separate grade will be given for each segment of the class

Class participation  5%
Introduction  5%
Modules  30% each

Each grade will be based on in-class activities and assignments and out of class assignments and papers. Each student will keep a portfolio of all of the work done during the semester. Attendance is mandatory, since many of the assignments that determine your grade will be done in class.
Participant Information Sheet

A Call For Self-Reflection as Professors Engage the Issues of Science Education Reform: An Ethnographic Study

Participant: ____________________________________________

Home Address: __________________________________________

School Address: __________________________________________

Home Phone: ___________ Office Phone: ___________

FAX: ___________ Email: ___________

Best time to call: ___________ Avoid: ___________

First Contact Date & Time: ___________ (Nature of study & survey)

Follow-up Meeting: ___________ 
Survey: ___________
(Determine dates/times/location for interviews. Pick up survey or extend to date of 1st interview)

First Interview Date: ___________ Time: ___________ Location: ___________

Comments:

Second Interview Date: ___________ Time: ___________ Location: ___________

Comments:

Third Interview Date: ___________ Time: ___________ Location: ___________

Comments:
APPENDIX C

INFORMED CONSENT FORM
INFORMED CONSENT FORM

PROJECT IDENTIFICATION: My name is Miguel Licona. I am a doctoral student at New Mexico State University in the Department of Curriculum and Instruction. I am presently working on my dissertation.

The purpose of this research is to gain insight and understanding of science education reform from professors that participate in reformed science courses such as the Arts and Science 121 course at New Mexico State University. I am asking you to participate in this project by being interviewed three times.

THE INTERVIEWS: The three interviews will be conducted at a convenient location that you have selected. Each interview will last approximately ninety minutes and they will be scheduled about three to seven days apart. The topic question for each interview is listed below.

Interview 1. How did you come to be a science educator in the context of reform? This question will allow you to reconstruct those experiences that led you to choose and become a science educator.

Interview 2. What do you actually do as a science educator? This will provide you with the opportunity to reconstruct details of your present experience in terms of curriculum and instruction. You may include information on relationships with students, colleagues, and others in the school as well as your perceived role in the reformed science course.

Interview 3. Given what you have said in the first two interviews, how do you understand your position now and where do you see yourself heading in terms of science education reform? This question is intended so that you may reflect on your past and present experiences in order to make meaningful predictions about your future in the reform of science education.

GUIDELINES: I will make every effort to keep your story confidential. For this reason, if you prefer, I will change your name to help keep you anonymous.

The interviews will be recorded on audio cassette tape and transcribed by me and/or a reputable and discrete transcriber. I will ultimately have the tapes and transcripts and be solely responsible for their safekeeping. I will code the data for emergent themes as well as construct a profile of the professor interviewed. Although the research is intended for the purpose of fulfilling the dissertation requirement, it may be used to support writings and research in the future, including instructional programs, presentations, and published articles.

At the completion of the interviewing process, you may request that something you said not be used in the profile. Please request this within two weeks of the final interview. You have the right to review the final profile and you may request a copy of the tape. You also have the right to withdraw from the interviews at anytime.

Thank you for your interest and cooperation.

_____________________________       ________________________
Participant signature               Date

_____________________________       ________________________
Interviewer signature              Date

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APPENDIX D

REFORMED SCIENCE COURSE PARTICIPANT SURVEY
Reformed Science Course Participant Survey

1. When you are teaching, what decisions about what you actually do in your classroom do you believe others govern and what decisions do you feel free to make yourself? Please List.

2. Where do your ideas for how you teach come from?

3. How do you organize your ideas for teaching? How do time parameters influence your planning?

4. How do you deal with diversity of students within your classroom?

5. Describe any differences that you see between an activity and an experience.

6. What are your sources for the curriculum you use to develop a course that you teach?

7. What does "order" in your class mean? How do you maintain order? How important is this for you?

8. What is your approach to grading and evaluation? Please be specific.

9. How do you accommodate student interests and needs? Please give examples.

10. In what ways do you create a challenging curriculum?

11. Teaching linked to real-life experiences can have an open-ended quality because there is no one correct answer. How can teachers teach this way without feeling a loss of control over students and what they need to learn?

12. What assumptions do you bring to your science class about non-science majors?

13. What are your beliefs about abilities of students going into elementary education?
APPENDIX E

THE PERCEPTUAL ORIENTATIONS CONTINUUM
### THE PERCEPTUAL ORIENTATIONS CONTINUUM

<table>
<thead>
<tr>
<th>The Perceptual Orientation 1 End of the Continuum</th>
<th>The Perceptual Orientation 3 End of the Continuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliance on the power of others.</td>
<td>Reliance on self-efficacy grounded in authenticity</td>
</tr>
<tr>
<td>Reliance on a narrow prescribed teaching focus</td>
<td>Reliance on one's own broad cognitive horizon.</td>
</tr>
<tr>
<td>Reliance on control as coercion.</td>
<td>Reliance on building relationships that facilitate self-organization.</td>
</tr>
<tr>
<td>Almost exclusive reliance on an external focus.</td>
<td>Reliance on an internalized sense of self-reference and process.</td>
</tr>
</tbody>
</table>

(Caine & Caine, 1997a)
APPENDIX F

CONSTANT COMPARATIVE METHOD OF DATA ANALYSIS
CONSTANT COMPARATIVE METHOD OF DATA ANALYSIS

Inductive category coding and simultaneous comparing of units of meaning across categories

Refinement of categories

Exploration of relationships and patterns across categories

Integration of data yielding an understanding of people and settings being studied
APPENDIX G

BRAIN-BASED PRINCIPLES
PRINCIPLES OF BRAIN-BASED LEARNING
(Caine & Caine, 1994)

1. The brain is a complex adaptive system.

2. The brain is a social brain.

3. The search for meaning is innate.

4. The search for meaning occurs through "pattering."

5. Emotions are critical to patterning.

6. Every brain simultaneously perceives and creates parts and wholes.

7. Learning involves both focused attention and peripheral perception.

8. Learning always involves conscious and unconscious processes.

9. We have at least two ways of organizing memory.

10. Learning is developmental.

11. Complex learning is enhanced by challenge and inhibited by threat.

12. Every brain is uniquely organized.
APPENDIX H

TEACHER COMPETENCIES NECESSARY
TEACHER COMPETENCIES
NECESSARY FOR IMPLEMENTING THE ITI MODEL

FOR STUDENTS
Key elements of a brain-compatible environment:
- absence of threat
- meaningful content
- choices
- adequate time
- enriched environment
- immediate feedback
- collaboration
- mastery/application

| NECESSARY COMPETENCIES OF TEACHERS |
|-----------------------------------|-----------------------------|
| Instructional Strategies           | Curriculum Development      |
| collaboration                      | see and understand connections among skills and content and their applications to the real world |
| effective structuring of discovery processes | develop curriculum based upon real world locations rather than from the typical paper and pencil tools of traditional curriculum |
| effective direct instruction balanced with ability to guide exploratory learning | create a yearlong theme with monthly components and weekly topics |
| questioning strategies that support acquisition of natural knowledge | identify key points |
| effective classroom leadership/management based upon consistent modelling of the Lifelong Guidelines, including LIFESKILLS | develop inquiries using seven intelligences, the scientific thinking processes, and Bloom's Taxonomy |
| consistent and daily use of daily agendas, procedures, and processing of collaborative work, including class meetings | create celebrations of learning using real world applications and provide opportunities for social/political action |
| lesson planning based upon physical locations | teach research skills and the application of new knowledge/skills |
| use of multiple resources          | model the skills and attitudes of lifelong learning |
| the encouragement of a passion for lifelong learning |                            |

(Kovalik & Olsen, 1994)
REFERENCES


physics course: The role of the graduate teaching assistant. Unpublished doctoral dissertation, Montana State University, Bozeman.


