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OUR LIVES ARE OUR THEORIES ARE OUR LIVES

**REFLECTIONS OF A TEACHER-RESEARCHER
ON BUILDING CONNECTIONS BETWEEN FEMINIST THEORY
AND LIBERATORY SCIENCE EDUCATION**

by

Angela Marie Barton

A DISSERTATION

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ABSTRACT

OUR LIVES ARE OUR THEORIES ARE OUR LIVES REFLECTIONS OF A TEACHER-RESEARCH ON BUILDING CONNECTIONS BETWEEN FEMINIST THEORY AND LIBERATORY SCIENCE EDUCATION

by

Angela Marie Barton

This dissertation tells the story of my struggles to teach a feminist liberatory chemistry to a group of urban community college learners so that students, who have traditionally been alienated from or oppressed by science can find ways to understand, critique, and revision the science in their lives.

This is a study of my teaching of two community college introductory chemistry classes. Personal reflections on positionality and conversations on the role of the "self in science" informed the teacher's and the students' efforts to understand and to critique the discourses and practices of western science. By creating a learning environment where it was "safe" to explore nontraditional interpretations of scientific events (in addition to accepted interpretations) we were able to build a critical understanding of western science as well as of the identities, beliefs, and values traditionally attached to the roles we are taught to play in science class, as

scientists, teachers, and students. Through our joint efforts to understand scientific concepts from the standpoints of our lives, we were able to uncover and unfold the ideological boundaries which structure how we think about science and ourselves in science, thereby blurring, the insider/outsider, teacher/student, and scientist/nonscientist dichotomies in science. This kind of teacher-research highlights the relational and the situated nature of teaching, and requires the teacher to continually re-articulate her positionality and her epistemological and political agendas in the science classroom.

I use the context of my own science teaching to argue from a feminist perspective that compensatory efforts to "bring women and minorities into science" have not been completely successful because they ignore that science and education perpetuate hierarchical dichotomies (insider/outsider; subject/object; teacher/student scientist/nonscientist) which give structure to relationships and bound identity formation in science and education. I argue that unless these hierarchical relationships are explicitly challenged in science class, liberatory education in science is not possible, and the inequities in science education will persist.

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1995

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PART I. INTRODUCTION

Shaking the epistemological tradition of science and science education

In the history of medical science, Aristotle was the first to record a scientific explanation for the process of human reproduction (Tuana, 1989). His argument is straightforward and is based on the concept that the perfection of animals can be determined through the amount of heat they produce or generate: The more mature and more highly developed animals produce heat in larger amounts than the more inferior or underdeveloped animals.

Aristotle uses the heat argument to explain human reproduction: First a male's semen is "concocted" through a heat transformation of the blood to a white substance. As Tuana writes, "He (Aristotle) insists that the appearance of male semen has to be the result of heat...the appearance of male semen must be the result of an infusion of heat that concentrates the potency of the blood and changes its appearance" (p. 148).

Aristotle continues his argument by equating a woman's menses with male semen (i.e. woman's semen). He justifies this belief by writing that, "menstrual discharge is analogous in females to the semen in males...for semen begins to appear in males and to be emitted at the same time of life that the menstrual flow begins in females" (Aristotle, 727/1984, p. 5-10). But a woman's semen remains blood like—because of her inferiority there is not enough heat to allow a woman's semen to undergo transformation. Aristotle also suggests that the female is unable to control her secretion, and that she is unable to produce any life-giving semen during the act of intercourse (Aristotle, 727/1984). Thus the woman's under-developed, blood-like semen is impotent. A man, in contrast, can control the secretion of his semen and is capable of

secreting at every act of intercourse. Thus, the male's white-colored heat transformed semen is vital and must hold the life giving seed. Aristotle's primary conclusion then, is that the creation of new life is dependent only on the man's semen. (Aristotle, 727/1984; Tuana, 1989).

The story of Aristotle and human reproduction is an example of how the social construction of scientific thought is socially constructed and how "scientific fact" is imbued with societal mores and values. His society's assumptions of the inferiority of women influenced his "observation" that women have less heat. As social beings, our cultural, economic and political situations shape who we are and the knowledge we construct. Belief systems reflective of our society become our means for thinking, speaking, acting and constructing ideas about ourselves and the world. Consequently, all science, like Aristotle's science of human reproduction, is inherently ideological.

Despite the growing popularity of the social constructivist standpoint, most scientific discourse is grounded in the positivistic assumption of an objective reality—a reality independent of we who observe it (Segal, 1986; Fox Keller, 1985). Since the birth of positivistic science in the seventeenth century, positivism has developed into one of the most powerful intellectual traditions in contemporary western society. It has dominated the thought, culture, and practices of science, as well as many other disciplines (Carr and Kemmis, 1989; Toulmin, 1990).

Since the seventeenth century, scientific ideology—its values, goals and assumptions (Fox Keller, 1985)—has expanded, but its essence has been maintained. The major premise that has served and continues to serve as the foundation for modern science posits that all scientific facts are grounded in sound scientific theory, largely free of personal, social, and cultural values and distorted one-way views of the world (Longino, 1990; Harding, 1991). This positivistic ideology is reflected in the scientific premise of objectivity, the reductionistic presentation of the nature of science and scientific knowledge, and the authoritarian nature and powerful position of science in society.

Feminist and feminist poststructural critiques of modern science articulate that modern science is biased and partial. They argue that the representation of science as an objective, authoritative, competitive and reductionistic enterprise emphasizes ways of knowing and doing science which are imbued with white, European, middle class and masculine cultural and social values. Consequently, scientific practices and interests which are reflections of feminine, working class or minority lived experiences have been de-emphasized. Feminist scholars suggest that these white, European, middle class and masculine characteristics of the practice and presentation of science are limiting; they force practitioners who have not assimilated into such a way of being—by choice or circumstance—to yield to beliefs about science and ways of knowing and doing science that are potentially contrary to their social identities, lived experiences, and a science they may wish to pursue.

Feminist philosophers and scientists (Bleier, 1986; Hubbard, 1990; Harding, 1986, 1989, 1991; Rosser, 1986; Longino, 1989, 1990; Daly, 1990) challenge the notion that scientific theories and beliefs are objective, and free of personal feelings and bias. They question the notion of objectivity and value neutrality of scientific knowledge. They suggest that because scientific inquiry always has a guide, whether it be curiosity, circumstance, or achievement, it is an artifact of human action and interaction. Scientific questions emerge from, and are interpreted in light of political, cultural and socioeconomic frameworks. For these reasons, scientific knowledge, touted as objective and implicitly understood as "the way of understanding the world", really represents a biased, partial and distorted view of the world¹. This appears to be the case with Aristotle's theory of human reproduction.

¹For example, in evolutionary studies (Hubbard, 1989; Longino, 1989, 1990), a great deal of attention has been placed on "interactional behavior in its relation to the development of human anatomy" (Longino and Doall, as cited in Harding, 1986, 95). It has been studied in great detail as a potential argument for biologically determined sex roles (Harding 1986). The studies, according to Harding (1986) "show a high tendency to project onto ape nature and social relations both racist and sexist projects of the observer's own society (p. 96). They have been used to justify and perpetuate masculine dominance and restriction of women's opportunities (Harding, 1986, p. 83). Thus, Harding (1986) asserts, "androcentric assumptions, then, appear in the collection, interpretation, and use of the data" (p. 96).

Similar arguments have been made to illustrate the limiting aspects of other characteristics of science. For example, modern scientists' "way of knowing" includes an emphasis on distance between researcher and the object of study (Hubbard, 1990). Scientists can and should control their environment and their object, so that neither they, nor their object, are susceptible to outside influences. This separatist and reductionistic way of knowing and relating to the world has been "the accepted method" of scientific inquiry within the science community (Hubbard, 1990). This has prompted feminist scientists and philosophers to question why only a solitary method of systematically interacting with nature is categorized as acceptable while other methods are not (Hubbard, 1990). As Martin (1988) suggests, perhaps it is because the "uniqueness and complexity of individuals are viewed as problems to be overcome by science not as irreducible aspects of nature; personal feelings and relationships are taken to be impediments of objectivity, not ingredients of discovery " (p. 130).

Scientists operating within this positivistic tradition have constructed barriers between themselves and their subjects/objects. In locating their work within the language of objectivity, they have simultaneously assumed an authoritarian status. As Fox Keller (1985) suggests, the aim of scientists since the western Enlightenment has been the control and the domination of nature. Francis Bacon once wrote that science should lead to the sovereignty, dominion, and mastery of man over nature, the "command of nature in action" (Fox-Keller, 1985, p. 34).

Some feminist and feminist poststructural thinkers argue that the denial of the complexity of individuals and their social relations—their locations and interactions as gendered, raced and classed people in a hierarchically constructed sexist, racist and classist society—constitutes a "truth regime." As Foucault (1980) writes,

Each society has its regime of truth, its general politics of truth: That is, the types of discourse which it accepts and makes function as true...[Truth] is centered on the form of scientific discourse and the institutions which produce it; it is subject to constant economic and political incitement (the demand for truth, as much for economic production as for political power); it is the object, under diverse forms, of immense diffusion and consumption (circulating through apparatuses of education and information whose extent is relatively broad in

the social body, not withstanding certain strict limitations); it is produced and transmitted under the control, dominant if not exclusive, of a few great political and economic apparatuses (university, army, writing, media); lastly, it is the issue of a whole political debate and social confrontation (ideological struggles)(pp. 131-132).

Thus, science has acted as a truth regime, a taken-for-granted sociocultural, historical, and epistemological structure which ignores that knowledge is provisional, open-ended and relational. In this dissertation, I challenge the continuing epistemological tradition of science in its intent, methods, content, and method of communication through my science teaching and research.

Why change science and science education?

Conversation, June 15, 1994

Angie: What scares you the most in science class?

Tracy: My ideas being way out there or I guess the white male structure, the discrimination...One thing is very evident at least in the book that we used, very rarely is a woman's name mentioned, and I think that I have become more aware of this. Women are practically nonexistent. You know that is not the way that [it] happened. I don't like this kind of elitism in anything. That is the idealist in me and I like the idea of making it more real to everyone. Whatever level they are at, whatever age they are, whatever race, whatever, money, whatever, so that people can understand it or at least have the opportunity to understand it their own way without fearing that they are going to be excluded.

Tracy was one of my students from the spring semester. In many ways she was typical of the kinds of students I teach (if there is such thing as typical!) in that she was older than the traditional college student (she turned 30 at the end of the semester), she attended the community college part time during the evening so she could keep her day time job as a secretary, and she had little "formal" educational training beyond high school. Tracy, again like many of the students I teach, was taking her initial college coursework at the community college for three main reasons (although I am sure that there are others): The community college has a diverse and flexible evening program unlike the local state university where

much of the science course work is only offered during the day, the science classes are much smaller in size (introductory chemistry classes at the community college have 30 or less students, whereas at the local university, class size can exceed 500 students), and the cost per credit hour is much lower than the state university. This last issue is important because many of the students hold low-paying jobs, are single parents (mothers), or have other financial commitments which take precedence over formal education. Tracy, like many of my students, has also spoken openly about her dislike for science, and the fact that she is only taking my course because it is required of her major.

Despite Tracy's lack of formal education and her "disadvantage" of "being working class," she has excellent insight into what it means to teach and learn science across race, class, and gender. That is, she recognizes that science appears to have little regard for the values of the female, the working class, or the minority student. Tracy speaks from the critical perspective that science and science education in schools operate from the assumption that all students enter school and society with the same cultural capital—the same knowledge, understandings, values, and desires (Harding, 1991; Bourdeau and Passeron, 1977). This assumption of uniformity reflects a white, middle-class, masculine perspective and plays an active role in the reproduction of race, class and gender inequalities (Apple, 1979). There is little incentive as well as little effort towards helping teachers and curriculum developers recognize the cultural, classed and gendered bias characteristic of this structure. Tracy passionately recognizes the messages which have infiltrated her education in science—that her gender is implicitly inferior—and she actively resists.

Many women, working class, and minority students feel that their cultures have been left out in the education of science as well as of all forms of school learning. Studies of girls in England (Spender, D. & Sarah, E., 1980), Canadian working class girls (Gaskell, 1992), Australian students (Connel, 1988), and Latinos in California (Patthey-Chavez, 1993) demonstrate that female, working class and minority students understand, at least implicitly, that schools affirm white, middle-class, masculine culture to the disqualification of their own

views of the world. Consequently, despite the best intentions of teachers, many female, working class and minority students are leaving science in western schools, not because they lack the motivation or intellectual capacity, but rather because they resist the middle-class, white and masculine ways of school science in favor of their own culture.

As a woman in science, I empathize with some of Tracy's heartfelt frustration. I know what it is like to sit in a science class where the emphasis is on facts and figures and where any historical study focuses unproblematically on the bourgeois, European, male scientist who nobly dedicated his life to the advancement of science. I know what it is like to sit silently in science class believing I had no questions that were important enough to ask. Even though I truly liked science in school, and still do like science, I could not help but hide my questions which tried to fit science into my life. Like, do scientists really know that grass does not have feelings? Or, can pregnant women, or even women of child-bearing years, work in the lab without danger to themselves or their children? My girl friends and I talked about it, worried about it, but we never asked. I had been socialized too well. I learned to act like a good student, a good girl and not to question my contradictory feelings.

In my own learning of science, I have found solace in social constructivist theories of the world, especially feminist and feminist poststructural theories which are critical of current hegemonic practices. I have spent much of the last few years reading, thinking, and writing about feminist theory and science education. These readings and writings have helped me to think about my own experiences in science and education in ways which make more sense to me than the more traditional beliefs I was taught to value. These changes in my understanding about science and education have moved me to think about constructing a more liberatory science teaching and learning setting so that other women, like Theresa, who have had their science experiences authored for them in the language of patriarchy and capitalism, can also begin to reposition their own beliefs and identities in ways which make more sense to them.

Positionality, teacher research and liberatory education

Feminist pedagogies, therefore, demand critical examination of what lies below the surface. They demand confrontations with discontinuities, particularities, and the narratives that embody actual life stories. At once, they require renewed attentiveness to the construction of knowledge and the life of meaning. Relational, practice-centered, contextualized, open-ended (Maxine Greene 1992, p. x).

In order to find ways to "critically examine that which lies below the surface" in science and education, so that science class does not perpetuate traditional ideas about what it means to know, do, think, teach, and learn science, I explored some ways in which feminist theory can inform a science teacher's practice both in thought and in action by engaging in teacher research. The idea of positionality (Alcoff, 1988; Maher and Tetreault, 1993) guided my reflections, helping me see beyond the hegemonic lenses I bring to science and teaching. Positionality is a construct that reflects how a person's location within socially- and politically-defined systems of power shape her or his particular understandings and knowledge construction. I believed that my students and I were in a position to construct new insights and interpretations of the present conception of science and science education. Most of my students and I are both insiders and outsiders to the culture of science. From these varied positions, I believed we could deconstruct many of the ideological dualisms that have traditionally structured our vision of and relationship with science: Nature versus science, masculine objectivity versus feminine subjectivity, outsider versus insider, knower versus knowable (Cavazos, 1994). From our unique positions as women, working class and minority students, we could reveal new theories, ideas, visions for science that present an alternate conception of science and who we are in science.

Two intertwining themes are woven throughout this dissertation. First there is the feminist theme of positionality, and how positionality can serve as a helpful construct for someone who is trying to construct a feminist liberatory chemistry teaching and learning setting. The second theme is about my journey as a teacher-researcher creating a liberatory setting for my chemistry students. The two themes are interconnected; my understanding of

positionality and my teaching-researching practice are constantly taking new shape as I learn more about both. My changing visions of each influence the other.

In this dissertation I question prescribed and defined notions of what it means to know and do science, to know and do research, to know and do feminist theory, and to teach. Through my teaching actions, through my writing style and presentation format, through my choices about what to include, what to exclude, what to centralize and what to marginalize I raise questions about valued knowledge in science and about ourselves as men and women in science. Through these actions I push at the boundaries of what counts as science, as education in science, as who can be a scientist.

Overview

This dissertation is organized to show my journey as a liberatory science teacher-researcher. This journey begins with my science autobiography (Chapter 1). Making my autobiography public is important because it is a way to make visible and to explore with informants, students, and readers, the aspects of my own life history which shapes my research and teaching (Middleton, 1993; Maher and Tetreault, 1993, 1994). In the second chapter I show how my reading of feminist literature played a key role in my journey, highlighting the need for feminist theories in science education. Chapter 3 describes the methodology—teacher research situated in feminist theory—and the research setting—urban community college chemistry class.

Chapter 4 begins the story of my beginning efforts at liberatory chemistry teaching and at reflecting on my teaching through the lens of positionality. If I reflected on my teaching through the idea of positionality, what assumptions might I uncover? Two stories of my teaching (Distillation and the Gas Laws) show how I used positionality to reflect on classroom events in order to critique my progress toward the goals of feminist liberatory education.

Analysis focuses on how these reflections helped me to discern instances where my own actions as teacher promoted or hindered the "liberation" of the students are given.

Chapters 5 and 6 describe transitions in my thinking about positionality and feminist liberatory science education in my work with a group of students during the spring and summer semesters. I revisit my teaching in the spring through a series of summer conversations with my students to develop a more multifaceted understanding of positionality.

Chapter 5 examines excerpts of "oral histories" conducted by my students throughout the spring and summer semesters. In analyzing these oral histories I highlight how reflecting on my teaching helped me to explore events in my chemistry classes which offer hope for a feminist education. I then take a closer look at three themes developed across time in the oral histories in the spring semester and how these themes (elitism in science, human element, and political nature of science) wove their way into our relationships with the subject matter knowledge in class.

Chapter 6 explores a series of summer conversations with a small group of students from the spring and how they helped me to rethink classroom events. My analysis focuses on how my initial understanding of positionality kept hidden how I used the agenda of western science to undergird my feminist liberatory agenda. This analysis leads to a new view of positionality and its role in my teaching and research

Chapters 7, 8, and 9 tell the story of my attempts to teach about the gas laws to two different groups of students (spring and summer semester). In these chapters, I show how the feminist liberatory education I tried to construct with the students was partially dependent on our abilities to make our positionalities as teachers, students, gendered, ethnic and classed people in science class a central part of our relationships in science class.

In Chapter 7 I revisit and critique my attempts to teach the gas laws in the spring semester as I look forward to teaching them in the summer. I explore how my reflections on this teaching informed my planning for the summer gas laws unit. A reflection on my own learning of

the gas laws highlights my personal standpoint towards the meaning and purpose of the gas relationships.

In chapter 8 I share large pieces of the two class periods in which the gas relationships were explored during the summer semester. In chapter 9 I analyze what happened during these two class periods along three threads. First, I highlight how the notion of moving relationships guided my teaching and thoughts and actions in my effort to construct a feminist liberatory education. Second, I examine what made these lessons examples of feminist liberatory education (as well as what did not). Third, I join the previous two strands of thinking together by sharing what have I learned about teaching-researching, students, and science as well as positionality and feminist liberatory education as a result of teaching the gas laws in the summer.

Although my journey does not end with Chapter 10, I use this chapter to share with the reader some reflections on my work at this point in my life.

Although this story about my teaching, about the students, and about our lives, is about teaching and learning science, and about the possibilities for liberatory education, it is really about our lives as teachers, students, scientists, non scientists, men, women, working class, middle class, white, Black, Hispanic, and every other identity with which we have been labeled. It is a political commitment to making space in science for our theories and for our lives. I hope that this dissertation story gives insight into the complexities of our lives, and of teaching a liberatory science across race, class and gender without invoking a truth regime of its own.

CHAPTER 1

Positioning myself into this text

Teaching Journal, June 13, 1994

Although extremely tired, I did not sleep well last night. I never sleep well the night before the semester starts, as a student or a teacher. All night the same questions kept re-emerging in my thoughts: How would my class respond to my nontraditional science and teaching beliefs, actions, and decisions? Would I find ways to connect with my students? Would I help them to understand science and themselves in critical yet accepting ways, or would I simply facilitate and perpetuate status quo ideas about what it means to know and do science, and about who can do science? Could I face another semester of studying my teaching—taping classes, transcribing tapes, interviewing students, keeping a teaching journal, and responding to student journals? These activities consume all of my energy, physically and psychologically. Would my department chair in Chemistry catch wind of the changes I have made in the introductory curriculum, against his explicit requests? Would I get fired? Would my students want me to be fired? Would my feminist politics silence my students or provide a space for their ideas to be heard?

Even though class did not start until six o'clock in the evening, I drove to the community college early to pick up my class list; I wanted to learn as much about the students as I could before class started. Unfortunately, the class list never contains much information—the names of the students and their student numbers, gender, home phone number, college majors, and year in school. The list indicates that there are 15 women and 6 men enrolled in my section with declared majors in occupational or physical therapy, although there are a few pre-medical, engineering, and bioscience majors, and a small mix of non-science majors: English, theater and business. Based on past experience, I expect that most of these students are returning to school after a long absence. For some it will be the first attempt at college; for others, simply a change in career. Some students will be young and fresh out of high school, but there probably will not be many of these, because this is an evening course, which primarily attracts "nontraditional" students.

My list indicated that there are no chemistry majors in my course this summer—this means that most students are taking chemistry because their majors require it. If this group is anything like last semester's section, only a handful of the twenty-one students will be looking forward to learning chemistry. Tonight most students will probably tell me that they are either nervous about, not smart enough to, or simply uninterested in studying chemistry. Most will come with the

expectation that I will lecture, at a quick pace, about the multitude of facts, theories, and laws embalmed in their texts. Most will also come with the expectation that memorizing a multitude of facts, theories, and laws is what constitutes learning chemistry.

As I continued to study my class list, there was a knock at my office door. It is really not "my office"—I share it with four other women faculty. We have only one desk, one book case, and one file cabinet, but somehow we get everything to fit. Since I was the only one in the office at the time, I put down my class list, scooted my hard wooden chair back along the scratched linoleum floor, stumbled around a pile of books and a box of lab goggles, test tubes, and beakers, and opened the door.

At the door stood an older man who wore his gray and thinning hair short and his glasses at the tip of his long thin nose. He wondered out loud (and I assumed to me since no one else was in the hall and he did knock at my door) if the students in my chemistry class last semester were smart. Surprised by his comment, I began to tell him about how thoughtful and insightful my spring semester students were (I chose not to describe my students as "smart" because I was and am unsure of its meaning in the context of learning chemistry). He looked me square in the eyes and said he was amazed that all my chemistry students achieved "top grades" when his students were barely passing. I then realized he was responding to the students grades from the previous semester I had posted on the door. Even though not all of my students received "top grades", I chose not to argue, but instead to explain again how thoughtful and insightful my students were. Interrupting me, he made a semi-audible comment about grade inflation and stomped off, down the hall.

As I closed the door, stumbled over the same piles of stuff, and plopped my body back into the chair, which now felt harder than ever, my concentration was shattered. I was angry: I had to defend my students and their integrity against this stranger, angry that I had to be nervous when I gave more than one 4.0 in my class, and angry that I was and am teaching in a department which seems to value impossible exams and student failure. Even if I do succeed in helping students create a place for their voices in science in the space of our classroom, I wonder what good it really does, and what happens when they leave my class for other science classes, for their jobs, and for their families.

Even though I would like to think that tonight, the students and I will begin to create a place in our little classroom for our ideas about science, a shelter from the ever present influence of the powerful institution of science, and the hierarchical structure of education and society, I know that it is impossible. I know that everything we say and do in our class has been inscribed, at least partially, by the innermost workings of science, education, and society, and all of their associated power arrangements which are emblazoned in our hearts and souls. I know that to shake those power arrangements, to challenge them, is what we must do if we are to construct a liberatory teaching and learning setting, but in order to do this we must be aware of where, how, and why those power arrangements exist. We must be aware of how we all participate in and facilitate relationships of power, privilege, and oppression with each other and with science. This is a difficult and complex process given that much of my thinking, and most likely the thinking of my students, has

been, and will be, guided by a master narrative we neither singly wrote, nor completely profit from, but have learned to call our own.

Beginning autobiographically

This dissertation grows out of my attempts as an educator and a scientist to construct a liberatory and inclusive science education. As reflected in my journal entry, there are contradictions and dilemmas endemic to "teaching science to all students" (AAAS, 1989). What does it mean to teach science to diverse students when the science itself embodies only one way of understanding the world? What does it mean to value the ideas of all students when the teacher-student and the scientist-nonscientist relationships are built on hierarchical power arrangements in which the teacher/scientist is considered the knowledge giver, and the student/nonscientist, the knowledge receiver? What does it mean to create mutual meaning among teachers and students when the discourses of science and education are guided by a discourse that does not include the complexity of our lives as gendered, raced, and classed students and teachers? What does it mean to construct relationships inclusive of our complete identities and lived experiences? In short what does it mean to teach to all students a science that is not oppressive in its content, process, language, or privilege?

My struggle with these sorts of questions is relatively new. I have not always believed that schools are places of student resistance or that teachers and students are active agents in constructing and promoting race, class, and gender inequalities. I have not always believed that science is, by its nature, subjective or that it is elitist and excluding in its practices and content. I have not always believed that students and teachers cooperatively construct knowledge about what it means to know and do science, and who can do science. I have also not always believed that this knowledge is inherently political, and permeated and bound by the power arrangements (and their implied set of rules and expectations) active in the classroom.

No, I used to believe that schools and science were authentic meritocracies, inherently good institutions designed to promote, and to accept nothing short of, social justice and human equality. I used to believe that school and science were always right, and that explicitly challenging science or school—to search for alternative visions of science or the self in science—was wrong. When my wants, needs, and beliefs fell in contrast with either school or science, then it was my ideas that were somehow faulty, and when my wants, needs, and beliefs were aligned with school or science, then they were somehow right.

My ideas about school, science, teaching, and learning are not all my own invention. Growing up in a particular culture, I learned to embrace a set of beliefs and biases which shaped and molded my lived experiences (Britzman, 1991). In my life, I have come to know the world from the perspective of a white, middle-class female. I have learned to participate in a particular set of grand narratives (Gore, 1993), and have learned to work and speak in a particular way within historically and socially determined relations of power. Now, as a teacher and researcher, my work is still shaped historically and socially, as I seek to make sense of science education as it intersects across race, class, and gender. My teaching and research are, by their nature, social practices that can only be understood through considerations of history, politics, power and culture (Giroux, 1994, p. 280). As Henry Giroux (1994) writes,

If educators are to take seriously the challenge of cultural studies, particularly its insistence of generating new questions, models, and contexts in order to address the central and most urgent dilemmas in our age, they must critically address the politics of their own location. This means understanding not only the ways in which the institutions of higher education play their part in shaping the work we do with students, but also the ways in which our vocation as educators supports, challenges, or subverts institutional practices that are at odds with democratic processes and the hopes and opportunities we provide for the nation's youth (278-279).

As a feminist educator I feel it is necessary to locate my teaching and research autobiographically. In contrast with the postmodern "vanishing act" (Theile, 1986), I feel the need to acknowledge my own position in discourse and in history, in order to remain critical of

my own complicity in writing science, writing education, writing gender and writing others (Luke and Gore, 1992, p. 7).

How am I positioned into this text?

Believing that the starting point of any research project must be the question, "Why am I interested in this?" we begin to question the roots of our own passion, our motives, our purposes and the terms of our engagements in this work. . . . Once we wrote our autobiographies, we were in a position to examine these relationships (between researcher and researched) because we had finally identified ourselves as players in them (Maher and Tetreault, 1993, p. 22-23).

Making autobiographies public are important in research and teaching because they are a way to make visible and to explore with informants, students, and readers, the aspects of our own life histories which shape our research and teaching (Middleton, 1993; Maher and Tetreault, 1993, 1994). Autobiographies allow us to acknowledge and reveal personal values, beliefs, and needs for our research and teaching, and to begin to recognize the embeddedness of our own assumptions within specific historical contexts (Nicholson, 1990). They create opportunities to draw attention to the multiple and contradictory power relations in which we participate (Arnot, 1989; Middleton, 1993). Therefore I begin my story by sharing how I am simultaneously positioned in multiple discourses, multiple power relationships (Arnot, 1989; Lather, 1991; Middleton, 1993).

Experiencing science as female, experiencing science as Other

Reflecting on science provokes contradictory feelings for me. Science is intriguing and exciting; it is a powerful and imaginative mental understanding of the natural world. Science is silencing, a cold and detached positioning in the Other.

These conflicting feelings I hold about science are not new to me; I have experienced them most of my life. How is it that I have connected to science in ways which are at once

engaging and alienating? By consciously locating my experiences and understandings of science in standpoints of a white, middle class woman, who with some help and a great deal of effort has learned to play the science game, I have begun to make sense of the ways in which the context of my life has shaped my connections to science. Until engaging in feminist and critical critiques of science, I did not have the language to articulate my (dis)comfort with science as I grew in my "chosen" career. Yet the feelings of excitement and rejection were there, waiting for a time, a place, and a way to emerge. Therefore, both passion and reason call me to share with you how I have come to have a conflicting set of beliefs about science.

Today me, Cathy, and Pru had our tootsie toe warmer sale and no one came to buy them. I AM SO MAD!!!!!!!!!!!!!!!!!!!!!! Number one: They are really cool inventions we made that really do keep your feet warm and are comfy. Number two: We spent forever sewing them and Pru kept bossing us so that they looked good. Number three: We even invented a way to make them look like they were packaged at the store with the plastic baggies and cardboard and stuff. And they were only 10¢. I am so mad, but next time we decided that we would just sell flowers. At least that way some people will stop (Personal diary from my childhood).

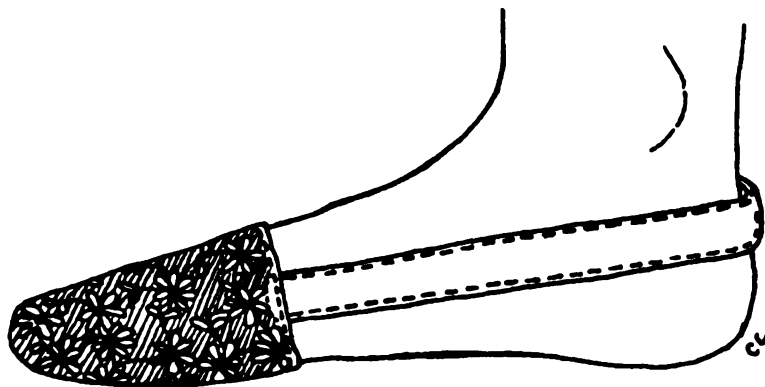


Figure 1.1
Tootsie Toe Warmer (drawn by my sister Cathy)

This entry locates me with two of my four sisters in a small working-middle class white New England town where we spent most of our time growing up. We lived on one of the main roads in town, and my sisters and I took advantage of the busy street by having various sales in order to make a few bucks (to add to our 50¢ allowance, half of which we had to put in the bank or church anyway). We mostly had flower sales, where we sold flowers that we picked from

our neighbors' field (with their permission of course), but sometimes we got adventurous and tried to invent something new to sell. In this case, it was Tootsie Toe Warmers. We were sure we had a winner. After all, they did not have all the hassle of slippers. Tootsie toe warmers could be kept on the feet while shoes are worn, for example. And, they kept toes warm, a place on our bodies which happened to get cold the easiest and the fastest.

A tootsie toe warmer is actually a rather simple yet creative invention (or so we thought). [Refer to Figure 1.1.] We sewed a piece of material (by hand) to look like a partial sock. Then we attached an elastic band that would wrap around the ankle to keep the tootsie toe warmer on the foot. Then we put each pair in a plastic baggie, and stapled it shut with a piece of cardboard on which we wrote, "Tootsie Toe Warmer" along with directions on how to use them and wash them. We even made different sizes (small, medium and large).

My parents seemed to enjoy our entrepreneurial spirit, in part I think because they wanted to instill in us the belief that we could do anything as long as we put our minds to it. I also think that they encouraged our craftiness because, in a family of seven where the father is employed as an educator by a small town school district and the mother is a secretary, there could never be enough sources of income to fill the children's bank accounts, which were supposed to get us all through college.

My parents had strong feelings about our educational future. They wanted to give us the chance to go to college, something that neither of their parents were able to give them (although something they worked hard to give themselves). My dad spent his initial years after high school in the army; my mom, as a secretary at Walgreens. Having been invested with the upwardly mobile attitude of working class families of the post WWII era, my parents believed intensely in the role of education to serve as an economic advancement. In this spirit, after leaving the army my father worked his way through school to earn a teaching certificate in the state of Kentucky. He moved on with his masters and a principal position of a high school, while moving our family around the country.

As my father learned how to play the education game while becoming increasingly aware of the myth of meritocracy, he made it very clear to me that in order to succeed in college I too had to learn how to play the game, or as Delpit (1988) suggests, I had to learn the "culture of power." Consequently, I remember in ninth grade having my life planned out through the age of thirty with every step detailed. I wanted to make sure that my intended actions would be viewed favorably by those with more power. (I must note that at the time my understanding of the culture of power was less sophisticated than I have just portrayed).

It was during my years in high school that my father pursued a doctorate in education (while both he and my mother worked full-time). And, it was during this time that I was encouraged to consider a college education, because I was "a smart kid", and besides, "if something ever happened to your husband, you need something to fall back on." Later, my mother went to college—her first two years at community college—to earn her BA in psychology.

Because we moved a lot, my sisters and I learned to be each other's best friends. We shared many experiences of socialization, first as girls, then as women. Together we learned what it meant to be female, what it meant to be women. We learned to play house and to clean house. We learned to read beauty magazines with a sense of duty. We learned to respect parental authority.

As my story about the tootsie toe warmers shows, my sisters and I spent much of our spare time learning about the natural and physical world around us in ways we could appreciate and value. We learned to build go carts out of old golf bag carts left in our barn by its previous owners. We made "amusement park rides" out of old "big wheels" (wood cable spools). We fixed our bikes, made our own forts. My older sister, Cathy, and I even had our own lawn mowing service. Our next door neighbors owned several acres of land behind our house. Each spring as new life emerged, we spent countless hours collecting bugs, frogs, flowers, rocks, and digging up old bricks and bottles. We nurtured the lilies of the valley and ferns which grew in

our "beauty center," a place of solitude, away from books, school, and adults. Away from boys. It was in this place that we felt safe to keep our discoveries, our secrets and our stories.

It seems as though, at this early age (pre high school), outside of school, my sisters and I had a voice in science, if you consider science to be exploring the natural and physical world. I remember the way we would talk about our discoveries, creations, and imaginations. It was full of our own understandings of the world, full of passion and excitement, full of connection and emotion. Whether we talked about Penelope and Mathilda (two of our frogs in our frog farm) or how useful and spectacularly different our tootsie toe warmers were, we felt comfortable interacting and exploring our world. We talked about and made sense of the world in ways which we could appreciate, in ways which were intuitive. We understood each other and our feelings. Our voices were connected to each other and to nature, and they were our voices, our experiences, our lives, our identities.

In Junior high, I took my first real science class: General science. There are few things I remember about junior high science. I remember studying oceanography. I loved thinking about the ocean creatures and how they lived, what they ate, how they looked. This was particularly exciting, because during the next summer when my family visited the ocean I could explain everything about the ecosystems of the estuaries and ocean to my family (whether they wanted to hear it or not!!). But, I also remember writing 250 word essays for talking during class, doing electricity with the student teacher from the local state university and hating every minute of it, and developing a secret code out of pencil tapping with my friend Lisa, so that we could communicate with each other without getting in trouble:

I promise I will never talk in science class again because I know that it is probably really hard for other students to learn if I am talking and making all that noise in science class, even if we are studying electricity. Besides, I might be bothering other classes in the building. And you know that the home-ec. room is right next door and if I am so loud and they are baking a cake, then I might make their cake fall. Then when they went to take their cake out of the oven to eat it, they might feel sad that it fell.

(This is an excerpt from a 250 word essay I had to write in Mr. Brady's 7th grade science class because I was talking during class. I wrote the essay on 15 small notecards and handed it in that way in order to annoy him.)

I had learned in science class earlier in the year that it was not safe to smell a bottle with chemicals in it because it could kill you or at least burn your nose hairs, and that the proper technique was to waft the bottle odors by your nose with your hand. In our social studies class, we had to make an invention, and I thought that a neat and needed invention would be to have a nose with a chemical detector in it. I thought it would be the coolest project. So, I made a nose out of plaster of Paris and glued some hair by the nostrils. This hair was the chemical detector ends. Attached to the nose was a piece of chalk and a piece of the paper. This was to print out the list of chemicals that the nose smelled. All you had to do was put the nose over the bottle of chemicals in question, and it would print out the chemicals. I was so proud of my project, and I didn't even care when the class laughed because it was kind of funny. Anyway, my teacher gave me a C- because it was not realistic and did not really work. [Despite the fact that the same teacher gave Vernon Berger an A+ when his project—a telephone TV where you could see the person you were talking to—was not realistic and did not really work. And, he only drew a picture of his. I made a model!] (memory from 7th grade).

These entries give access to the possibilities and limitations faced by a small town middle-class white girl in the 1970's. My stories of this age construct a gendered, yet gender questioning, existence. In my seventh-grade science class I learned the hard way to accept the roles and expectations for girls and science. I learned that neither my voice nor my ideas counted. When I tried to express an interest for and creativity in chemistry, I was punished by my teacher for not being realistic. (Even though Vernon was praised for the same thing). When I tried to express a disinterest in electricity by talking with friends in class, I was punished for not matching the expectations of a good student.

By the time I was a teenager, I knew that being a woman meant finding common ground amidst contradiction (Steinem, 1992). My teachers, textbooks, and class lessons were telling me that women were not scientists. They simply did not exist in science. Yet, my love of exploring and theorizing about my world, which I was encouraged to do at home and sometimes at school, told me that I could and should be a scientist. My explorations of the fields and the estuaries, my inventions of Tootsie Toe Warmers and go-carts with my sisters (all of which were explicitly encouraged by my parents) told me that I could be a scientist. My role at home in house cleaning and cooking, my baby-sitting for extra money, learning to crochet from my grandmother, and eagerly learning to wear make-up, shave my legs, get married and have kids, told me I was to be a woman, a mother, a person who was not meant to pursue science. That

I found ways to combine these mixed messages was evident in my every day activities and inventions. For example, the Tootsie Toe Warmers combined my desire to see that everyone's feet stayed warm and my knowledge of sewing with inventiveness and business. My nose-shaped chemical detector grew out of my need to keep the body safe and to help clean the air, and was mixed with my interest in invention and analysis.

But I was not aware of these mixed messages growing up. Although "women's lib" and the ERA were common themes in the news, feminism was a taboo topic in my schools, my church, and my home. Those women were too strident, man-haters, and lesbians. Although Susan B. Anthony, Harriet Tubman, and Wilma Rudolph were three heroes I learned about in my own explorations at the library (albeit forced explorations on the part of my parents), I rarely learned about these women in schools. I never learned about women scientists, except Madame Curie, and I never ever learned about minority scientists. When I did learn about female scientists, (I have no memory of learning about minority scientists in school), they were not heroes like Isaac Newton, Albert Einstein, and Galileo. But, I never noticed. I never really noticed that I was not learning about women or minorities, because I was learning about scientists.

Today I fed:	Fruitfly group A: two slices of banana Fruitfly group B: one slice of banana mixed with one aspirin Fruitfly group C: one-half slices of banana mixed with two aspirin Fruit fly group D: two aspirin.
I removed one fruit fly from each group and analyzed them under the microscope and found that:	
Group A: looked normal	
Group B: looked normal	
Group C: looked sick. I think it was smaller than the normal ones.	
Group D: was dead before I could kill it to examine it. I think it died from the aspirin.	

(Science project notebook , Mr. Brady's 10th grade biology class).

This science notebook entry places me in the grand narrative of a positivistic science. It portrays me as a high school student successfully learning how to engage in the discourse and practice of science. I learned to set up controlled, objective experiments. In the name of science I

killed fruit flies—by starvation or intoxication through diet regulation (I never figured out which) and by suffocation in order to observe them more accurately under the microscope. I felt sad about the poor little fruit flies, but I was awarded for these efforts at the school, district, and state science fairs.

By the time I made it through high school, my ideas about science inside of school were different from my ideas about exploring the natural and physical world outside of school with my sisters. Out of all my sisters who roamed our little section of the planet, only two of us participated in the science of school. My other three sisters pursued no science courses beyond the formal requirements, and yet we all continued our own informal explorations. Did we see the disconnection in this scenario? I did not. I learned that the science I engaged in outside of school in the barn or in the field was not science, but just play. After all, I used no fancy terminology or explanations from books, and emotions and feelings were a part of my play. Exploring was fun, a game, a time to relax and to be. Science was school, books, fancy language, and hard work. What a contradiction.

I cannot write for my sisters, but I know in my own experiences the voice I developed with my sisters on our little excursions to find frogs or build go-carts was not a voice I used in school. No, I used another voice. I spoke the language of the science books we were given. I spoke without emotion, without feeling. Science was a difficult topic, in which only serious, intellectual students engaged. That was the voice I needed to assume. In biology I never talked about our nature walks at home; in physics I never talked about our go-carts; in chemistry I never talked how I made sense of the composition of the world. That would be immature and unscientific for these ideas were grounded in my play experiences, not on rigorous intellectual study. My first science voice, the one I constructed with my sisters, sank away into silence.

As I gained experience in science, both in school and then industry, I refined my acquired science voice. I spoke from a distance: I spoke as if scientific knowledge was real and objective; free of personal or public bias and values. I spoke as if the world of science made more sense than my world of experience. I learned to develop an empirical world view and to understand

science (chemistry) in a rather strict positivist fashion. That is, I was taught to believe that scientific knowledge was real and objective; free of personal or public bias and values. I was also taught to believe that in order to obtain the objective knowledge I could separate myself from my object of study. To mention or even to think that I, the human observer, could be an agent who studies and influences, and that my scientific ideas were wrapped up in and exhibited cultural, social, political and economic values, was absurd. Despite this conflict of identity, I continued to explore the domain of traditional science for it promised to hold the answers. It certainly held the power.

As I grew in my science career, my love for chemistry got caught up in a personal and political struggle. The parts of my voice which had been crafted for me in science were slowly becoming heavy, almost unbearable. Although this understanding of science brought me success (academically and financially) and a certain degree of privilege, it was weighing me down spiritually. It was telling me who I could and could not be. I began to understand that traditional science did not have the room nor the language to express my feelings about the nature of chemistry. I felt that my personal experiences in and feelings for science placed me as Other and my ideas as "necessarily outside of and apart from the public flow of discourse and meaning" (de Beauvoir, 1952, p. xvi - xxix).

I began to realize that the scientific community uses the notion of Knowledge as Truth to their own advantage. For example, when it comes to reporting the results to funding sources, the general public, or even the FDA, science hides behind their Knowledge and their language of objectivity. When I worked at a biotechnology company, I coordinated a lab that performed the final testing on enzymes before they could go out on the market. Many different bits of information went into deciding whether a product was clean or active enough, not all of which were "scientific" or "objective" in the traditional sense. Nonetheless they were things I was trained to do in that particular position. Every Friday when we had our meeting with our salespeople, we would report what products were ready as though we had the objective truth.

After working as a chemist in industry and still feeling lost and disconnected from a world I knew I loved, I felt an intense desire to return to school for a graduate degree. This time, I would return to more than just chemistry. I would also study science education, because I wanted to share the love for science which I experienced as a kid with others, in a nurturing sort of way.

Since being introduced to feminist and poststructural theories in graduate school, I have found this framework useful for thinking about science, science education, myself and others. Through conversations about feminist critiques of science and science education with other women in science and science education, I have come to value my experiences as a woman in science and my beliefs about the nature of science. I have come to believe that as social, cultural, historical beings, we have created our own subjective realities inside and outside of science. I began to understand science and quantum mechanics as embodying masculine characteristics of agency—self protection and assertion, mastery and competition by separateness, isolation, and detachment from feeling and intuition (MacDonald & MacDonald, 1988). And I began to see how these subjectivities are elevated to the level of objectivity or Truth, while the ideas of less dominant people (read: women and minorities) are ignored or viewed as wrong.

For example, in my graduate study, I took several graduate courses in quantum mechanics even though I never felt comfortable nor confident with the topic in the past. Although I managed good grades (actually I had 4.0s in all of these classes), I did not feel as though I had mastered quantum mechanics. As a matter of fact, I still felt mastered by it. How was I supposed to make sense of a world that I could not see, feel or hear? I was not even sure if I believed in atoms, and wondered how people could continue to break the world up into smaller and smaller pieces based on numbers and theoretical speculations. Yet, I neither spoke nor wrote of these dilemmas, for they were not valued in the world of quantum mechanics.

Now as I reflect on or engage in science, I no longer feel intimidated by a foreign way of understanding the world. Although I still feel alienated, for I am attempting to engage in a

world that historically has not appreciated or even respected the beliefs and values that I have learned to cherish as a woman, I understand my discomfort with science not as rooted in a lack of intelligence, but rather with my desire for and belief in a more holistic science. And despite the fact that sometimes I feel as though I cannot do anything about the science that is being taught to me or the science that I am teaching to others—the science I/my students have to learn to "make the grade"—I also feel, in many ways, liberated. Liberated from a science which I let control and define me. By understanding, at least partially, the role that ideology (an ideology my womanhood has prevented me from helping to define²) has in shaping science, in juxtaposition with my own lived experiences and social identity, I have found a new way of making sense of science.

These new and liberating ideas I have about science and the kinds of relationships that are possible in science brings me to my dissertation, and my current struggle with the possibilities for liberatory education in sciences. I wrote in my journal at the beginning of this chapter that I am searching for ways to uncover the grand narratives which structure our thinking and learning in science class. I am searching for ways in which feminist and poststructural feminist theories can help my students and me to create a science teaching and learning setting that seeks to help students and teachers not just understand, but also critique and revision science and our relationships with science. I am searching for ways to create a science education which invites and supports diverse experiences and participation in science in an effort to inform the goal of "science for all Americans" (AAAS, 1989).

² This is a simplistic understanding of the situation. I believe that women have not been allowed by those in power to contribute to defining reality, except in ways which do not challenge the status quo. But, I also believe that my white, middle-class, heterosexual identity has given me more power and authority to name the world than a woman of a different social class or race or sexual orientation might have.

CHAPTER 2

Science for all Americans?

Rereading the research literature: "Science education for all" from a feminist perspective

Educating women in science; educating the Other

In the first chapter, I shared some of my experiences with science. I shared that even though I learned to love the world around me and to question how it works, I also learned to feel otherized from formal scientific practice. Yet, I do not believe that it has been only the institution of science or my individual actions which have named me as Other in my attempts to bring science into my life in an intellectual, professional, and personal way. Educators in science and researchers in science education have also played an integral role.

Being educated in science during a time period marked by an interest in "equal opportunity," I had the privilege of participating in programs and activities aimed at attracting "bright young women into science" (Kahle and Meece, 1994). No longer was I educated by a public who explicitly believed, as had generations past, that my femaleness granted me a significantly lower mental capacity in the sciences (Brickhouse, 1994). No, I was educated by a public who believed that with the right kind of training, I might be able to achieve the scientific intellectual capacity of males. Resources, attention, and expectation were (sometimes) focused on me, a bright young woman interested in and with an aptitude for science.

Over the past thirty years, the women's movement has had a significant influence on many of the policies and practices guiding the education of women in science. Before the women's movement resurfaced in the 1960's, rampant discrimination against girls in schools was common (Kahle, 1985; Kelly, 1985). Little or no opportunity for girls to advance in science existed; teacher support, encouragement, attention, after school activities, role models, and peer support were largely reserved for boys (Matyas, 1985; Smail, 1985). Had a girl wanted to pursue science, chances are she was discouraged away from science and tracked into school programs designed to prepare her for the more traditional female roles of secretaries, housewives, housekeepers, nurses, and elementary school teachers (Gaskell, 1992). In the 1960's, the work of academic and political feminists provided new interpretations of girls' experiences in school science, and as a result, a wide variety of school science activities, special programs for girls in science, and role model programs were developed (Kahle, 1985; Kelly, 1985; Matyas, 1985; Smail, 1985; Whyte, 1986).

Although these programs, along with the growing awareness and concern for the issue of women in science, have impacted the achievement of girls in school science in North America, western Europe, and Australia, statistics indicate that girls' academic achievement and participation in science still trails white, middle class boys (Mullis and Jenkins, 1988; Kahle and Meece, 1994; Young and Fraser, 1994). Furthermore, despite all this money and attention directed towards equity issues in science, large numbers of students still feel alienated from science (Mullis and Jenkins, 1988; Davis and Steiger, 1994; Kahle and Meece, 1994). Many female women and some male students believe that science is dull, not a part of their lives outside of the classroom, and meant for only the intellectual elite. It has been argued that students overwhelmingly believe science to be a body of knowledge which consists of events, facts, and theories existing "out there" and that it is static rather than dynamic (Edwards and Mercer, 1987). The majority of female students feel that science does not connect with their personal lives, and that once they fulfill their scholastic requirements (be it at the high school or college level), they will be "done" with science for the rest of their lives (Koch, 1994). In

fact, most female students who enroll in high school or college science admit that they enroll in science courses only because such courses are either required for college admission or for their college major (Koch, 1994). In many instances, these "negative attitudes"³ about science, which also include low self-esteem and confidence in science, begin to develop as early as elementary school (Mullis and Jenkins, 1988; Kahle and Meece, 1994).

The framers of Project 2061 argue that the low achievement in science in the United States and the low numbers of women and minority students entering the sciences is due in part to "student misconceptions"⁴ about the nature of science, and that many of these misconceptions students hold about the nature of science are partially a result of classroom and lab practice (AAAS, 1989). Lemke (1990) and Edwards and Mercer (1987) suggest that teachers' narrow visions of science and tight control over the discourse and what and how the students learn contribute to these misconceptions about the nature of science.

Since many teachers adhere to a view of scientific knowledge as objective, rational, and mechanistic, they consequently use their authority as the holder of scientific knowledge to engage students in dialogue which emphasizes such characteristics (Edwards & Mercer, 1987; Lemke, 1990). For example, in the science classroom emphasis is often placed on learning irrefutable facts (Lemke, 1990). The science teacher proclaims, with authority, ideas as objective truth, and the students are required to blindly believe. As a woman interviewed by Belenky et al. (1986) suggests, "science is taught as a series of syllabine statements...the teacher is not indulging in conjecture; he is telling the truth" (p. 215).

Furthermore, discussions about science are often decontextualized; they are taken out of their positions as being social, historical, cultural and political. This is due partly to the presentation of facts through the passive voice which depicts science as a simplified description of the world rather than as a social activity (Lemke, 1990). This is also partly due

³I place the phrase negative attitudes in quotes because it implies that it is the attitude not the science which is wrong and I do not believe that is always (or ever) the case.

⁴I place the phrase student misconceptions in quotes because I personally question the validity of "misconceptions" in this (or any) context.

to the lack of discussion on the relationship between scientific knowledge and social, historical and cultural context in which the theories were developed.

Edwards and Mercer (1987) write that through classroom dialogue teachers promote the use of technical jargon over more colloquial language, even at the expense of student understanding. Even when students grasp new terminology introduced by the teacher, it is not clear that they understand what it means. They argue that students sense that the teacher simply prefers the scientific terminology which makes it worth mentioning.

Through classroom dialogue, the teacher's authority position is used to selectively emphasize, interpret, and reconstruct students' comments. This enables the teacher to guide the discourse towards the correct, predetermined answers at which the students must arrive. Because the "correct" science answers developed out of the positivist tradition, the teacher often can choose to highlight the more "rational and intellectual" over emotional, personal and other "nonscientific" ideas. This scientific pedagogical discourse induces students "to think and make judgments according to the constraining influences of a [positivistic] paradigm and to this extent, pedagogy selectively excludes alternatives" (Prelli, 1989 p. 91-92). Thus students are taught to talk a rigidly defined science.

Textbooks also contribute. Courses defined by textbooks help students to construct a narrow vision of science—science as a static conglomeration of facts and theories. Even though students might understand the "in-progress" nature of such facts and theories, students have a difficult time making sense of the conceptual and technological tools and activities used to construct those statements. As Anderson (1991) argues,

Textbooks typically depict scientific knowledge as consisting of content—an array of facts, definitions, formulas, and so forth—and process skills that scientists use when they are discovering new content...The typical textbook depiction of science makes it hard to understand what makes all those facts and definitions worth knowing. The textbooks are full of answers, but they generally fail to inform their reader about the questions scientist were asking when they invented those answers (p. 15).

Project 2061, in their *Science for all Americans*, also argues that contemporary science textbooks and methods of instruction impede progress toward scientific literacy. The textbooks

"emphasize the learning of answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing" (p. viii). Hence students are encouraged to develop a belief system about science that is not actually compatible with science practice or informed visions of scientific literacy.

Therefore, according to the research in science education, many students develop an understanding of science that has been informed by a narrow and distorted vision of school science. Classroom activity accentuates science as objective (factual laden and oriented), authoritarian (teacher and text as holder and keeper of the right answers) and exclusive (because it is frequently pitted against common sense and is comprehensible only to the intellectual elite) (Lemke, 1990). In some of the most recent literature in science education (Brickhouse, 1994) it has been argued that this way of thinking about science is particularly problematic for female students, because many women value knowledge that is "relational, oriented more toward sustaining connection than achieving autonomy" (Luttrell, 1993, p. 506). This perspective, Luttrell points out, is in opposition to school knowledge which is often characterized by reason and abstract rules, mastery over nature, and authority over others (Luttrell, 1993). Consequently, this vision of science is most often dull and abstracted and results in a high level of female student alienation from science.

Teaching for Understanding

Recently, science education communities have concentrated efforts to construct and promote conceptual understanding for all students in science (Osbourne and Freyberg, 1985; Ogawa, 1986; American Association for the Advancement of Science, 1989; Harlen, 1989; Rosebery, Warren, and Conant, 1990; Anderson, 1991; Roth, 1987; Roth and Rosaen, 1991). The resulting reform movements—generally known as "teaching for conceptual understanding"—are based on the theoretical position that science is a socially constructed discipline "with its own

ways of talking, reasoning, acting, its own norms, beliefs and values, its own institutions, its shared history and even its shared mythologies, rather than the acquisition of specific facts and procedures" (Rosebery, Warren, and Conant, 1990, p. 3). This vision of science education promotes the idea that because science is socially constructed, teachers need to enter the teaching profession with "special" knowledge of subject matter and students in order to engage diverse students in meaningful and participatory learning. Calls for reform suggest that teachers need to know more than what is conventionally included in the school curriculum—facts, theories, and procedures fundamental to their subject matter expertise. Teachers need to have a thorough understanding of science, including its content, history, culture, and discursive practices, as well as an understanding of students and educational processes, so that they can provide opportunities for personally relevant engagement in science by students with diverse backgrounds (Anderson, 1991). As Wilson and Sykes (1989) argue, teachers need to be able to move back and forth between a diversity of student understandings and experiences and a deeper and more connected understanding of the subject matter. Without this extensive knowledge of students and of subject matter, teachers will lack the ability to construct and implement a compelling repertoire of teaching activities needed to help students conceptually understand the knowledge base of science and to engage in scientific discourse and practice.

Feminist critiques of teaching for understanding

The "teaching for understanding" movement pushes at the boundaries of the traditional discourse surrounding teacher knowledge by arguing that teachers need to have a thorough understanding of the content, culture, and discursive practices of science if they are to help students develop conceptual understandings in science. Feminist interpretations of teaching for understanding agree that these new emphases are important, but suggest that their importance lies in more than "conceptual understanding for all." A feminist interpretation suggests it is important to make explicit the content, culture and discursive practices in science class so that

students and teachers have a basis from which to understand and critique the knowledge base of science. If the valued scientific knowledge (the canon of western science) is typically not open to critiques by the students, the valued knowledge of science rather than the knowledge of the student (or the teacher) becomes the curriculum in the science classroom.

Furthermore, in teaching for understanding, relationships between students, teachers and subject matter knowledge need to be problematized. In traditional science classes, the valued Knowledge, Authority and Power of science undergirds relationships between science and students, among students and between students and teachers. In many instances, traditional power arrangements are taken for granted and assumed to be natural. To claim uncritically the knowledge base of science is to perpetuate relationships of power and domination.

This feminist interpretation of recent science reform initiatives leads to the following questions: What is the purpose of teaching science to students, if the result is that they understand it, but remain oppressed by it? Can students be taught to understand the content, culture, and practice of science, including its hidden agenda? In other words, do teachers teach a science which has been constructed within and helps to promote a limited ideology, or do they work to rebuild that science and include the perspective of women and minorities as one way to begin building a science of the future?

Teaching for understanding, when not concerned with helping students critique the culture of science, like the compensatory programs aimed at my own intellectual development in science, can define women, minorities and the working class students as outsiders to science and as inferior to science. These research agendas and educational programs are often nestled in the politics of assimilation and use the construct of difference as a legitimization of dominant society rather than as a potential for revisioning. They focus time, attention, energy and money away from the real inequalities perpetuated in science education by locating their conversation in the discourse of equity—how can we bring all students up to the standard level? The focus is necessarily on redefining women, minorities and the working class in the language of patriarchy and capitalism instead of on the sexist, racist and classist hierarchical formation of

difference. As a result, these groups are prevented from entering the discourse of science on their own terms because their place in science is in "compensatory discourse" which "write their differences as at risk and in need of recovery, remediation, special inquiries and policies" (Luke & Gore, 1992, p 6). The female, minority and working class experience in science remains unvalidated because these reform agendas assume that it is the "habits of mind"⁵ held by women, minorities and working class people which are in need of revision, instead of the narrow habits of mind held by the communities of science practitioners and science teachers.

Feminist theorists suggest that the inequities in science education cannot be solved by providing "at-risk" students (girls, minorities, working class people—all those who do not fit the mold) with more exposure to science or even by simply acknowledging that science is socially constructed, as some of the most progressive reform efforts have attempted. Instead, because of the hierarchical positioning of science in a raced, classed and gendered western world, such theorists argue that the history of participation in science—a participation marred by the silencing of women, minorities and the working class—has resulted in a white middle class masculine construction of science (Fox Keller, 1985; Bleier, 1986; Harding, 1986, 1991; Longino, 1989). The political and social efforts of the past two centuries that limited the representation in western science have resulted in a scientific culture imbued with a set of norms and values which conform to white, middle class, and masculine world views (Longino, 1989). This argument lends a new perspective to the interpretation of school efforts to make science education inclusive.

⁵This phrase, habits of mind, is taken from the American Association for the Advancement of Science's work on reforming science education (*Project 2061: Science for All Americans*). In this text the authors of the project refer to these habits as the values and attitudes students must acquire to become scientifically literate. Many of these habits, although not all, are characteristic of masculine socialization habits.

Rethinking science education from a feminist perspective

Thus, while tentatively proffering identity papers we have marked with poststructural feminisms, we refuse to align with, or pay homage to, what others totalize as "postmodern [or poststructural] feminism," a feminism that "rejects all forms of essentialism" (Giroux, 1991, p. 44). Through our engendered thinking and situated knowledges (de Lauretis, 1990), as women in education, our positions are feminist. Poststructural or postmodernist theoretical tenets have been helpful to the extent that they fit with our feminist political project(s) and our attempts to construct pedagogies. Through the naming of our feminisms as primary...we adamantly resist the hidden agenda of erasure that drives much of our current postmodern theory and analysis (Luke and Gore, 1992, p. 5).

To situate my feminist thinking, I use the thoughts of Luke and Gore (1992) to label myself as a poststructural feminist thinker. That is, I situate my work within the feminist poststructuralisms recognizing the importance of deconstruction of taken-for-granted historical, social, theoretical and linguistic structures (Luke and Gore, 1992). However I do not espouse an anti-foundational epistemology for fear of relativist thinking and loss of responsibility. As Nancy Hartsock (1990) argues, an anti-foundational epistemology, the denial of the subject, and the refusal of identity can serve to further marginalize already marginalized groups. Therefore the feminist position from which I write reflects a subjective, contextual, particular, and uncertain reading of the texts in my material-theoretical life: "There are no finite answers, no certainties in any one position" (Luke and Gore, 1992, p. 5).

I recognize curriculum as political text (Pinar & Bowels, 1992) and schools and science as legitimizers of hegemonic ideals (Weiler, 1988; Gaskell, 1992; MacDonald & MacDonald, 1988; Bleier, 1986; Harding, 1986; Longino, 1989). I also recognize teachers and students as agents and actors within schools who actively and collectively shape and reshape their own understandings of the world from specific standpoints. Hence, students and teachers co-construct knowledge within a politics of location and identity. This is important because it suggests that knowing—knowing science, knowing education, knowing ourselves, knowing others—is historically and politically contextual. These understandings allow for the intersubjective

deconstruction of scientific knowledge and the construction of alternative visions of science and self (Harding, 1986; Smith, 1987). This theoretical framework shapes the way I read science, education, teaching, learning, my students and myself. As the Women in Science Education (WISE) group (1995) to which I belong write,

The notion that science and scientific knowledge is androcentric in nature provides a particularly interesting context for looking at the construction of gender and of relationships of power and authority and voice in classrooms where women teach and/or women learn (Lewis 1990). The very fact that science is constructed – as a discourse, as a set of knowledges, as an expression of identity –provides us with ways to construct science and science education differently, in ways that encourage understanding through critical empowerment, liberation through knowledge of the discourse and its contingency, and interaction with ever changing visions and versions of self and knowledge (p. 2-3).

My choice to situate my work within this theoretical framework is a political commitment to acknowledge my own position in science, education, discourse and history. It is a choice to try to work towards a more inclusive and liberatory understanding of the uses and abuses of the science in all of our lives.

Questioning the "all" in science for all

Feminist theory provides a new lens to reflect on inclusiveness in science education. The conceptual framework central to this effort focuses on rethinking the nature of science and science education rather than trying to reach equality in the science through the implementation of compensatory programs. From a feminist perspective, it is critical that conceptions of science change to include the perspectives and insights of women, minorities, and working class students who have been kept from participating in the inner circle of science (Harding, 1991). Attention must be paid to the lived experiences of all people, but especially the experiences of the groups still struggling for a space in science, so that construction of an

inclusive vision of science and science education is possible. Evelyn Fox Keller (1985) describes this need:

A healthy science is one that allows for the productive survival of diverse conceptions of mind and nature, and of correspondingly diverse strategies. In my vision of science, it is not taming nature that is sought but the taming of hegemony. To know the history of science is to recognize the mortality of any claim to universal truth. Every past vision of scientific truth, every model of natural phenomena, has proved in time to be more limited than its adherents claimed. The survival of productive difference in science requires that we put all claims for intellectual hegemony in their proper place—that we understand that such claims are, by their very nature, political rather than scientific (p. 178-179).

These views represent a fundamental shift in thinking in science education circles, because it shifts the reform focus from centering on the deficiencies held by women or minorities to deficiencies and discriminatory practices in science and education. This shift in thinking raises new questions about science education: "Can a science and science education be constructed that is liberatory, rather than oppressive, to those students who historically have been marginalized by the science endeavor?" "Can we teach a science which is open to multiple ways of knowing in order to help all students value the contributions made by those traditionally silenced in science?"

Questioning race, class and gender

Feminist theory grew out of women's lived experiences being oppressed by men and masculine structures. Historically, much of the academic work published by feminists has totalized women's experience within social and cultural characteristics shared by many white, bourgeois intellectual women (hooks, 1981). Claims for women's ways of knowing and gendered expectations were based on an excluding and essentialistic notion of what it means to be female. As bell hooks argues (1981) in *Aint I a woman: Black women and feminism*, this feminist standpoint further marginalized working class and minority students.

Since the second wave of feminist writing in the 1970's there has been a (slow) growing emphasis on the sociological tri-lens of race, class, and gender as significant dimensions of radical political feminist discourse (Middleton, 1993; Luke and Gore, 1992; Weiler, 1988; Gaskell, 1992; Amos and Parmar, 1981; Anyon, 1984). As Kathleen Weiler (1988) writes, "the ways in which the three dynamics—class, race and gender—have found expression in individual lives and social relationships has formed the agenda for a variety of critical studies on gender and schooling, work that is only beginning" (p. 57). This is a difficult and complex process, as the intersections of these experiences are always historically and socially located. Therefore any theorization about the politics of knowledge or identity must write against tendencies to essentialize race, class and gender (Luke and Gore, 1992, p. 7).

In my dissertation I have tried respond to the need for feminists to theorize across race, class and gender. This has grown out of my recognition of my privilege as white middle-class American woman and in my inability to locate my own experiences in either the middle or the working class essentialized notion of womanhood. This is how positionality is important in feminist teaching. In my theorizing about feminist liberatory education and the teaching and learning of science, I have tried to interrogate claims to an objective science and a generalized notion of what it means to know science by valuing my students lived experiences as raced, classed and gendered people. Teachers and students are multilayered and therefore gender, race, and class subjectivities can lead to different readings of science and education (Weiler, 1988). Likewise these multiple subjectivities lead to different forms of marginalization by and affirmation from the traditional discourses and practices in science education as well as my own enactment of my feminist agenda. My goal as a feminist teacher-researcher is to try to read subjectivity and to politicize its artifacts. I believe that this way of practicing and examining my teaching-researching efforts will help me to teach for liberation. It will help me to recognize and write against my own location as a raced, classed, and gendered person acting within and among various power laden arrangements which attempt to force us into normative patterns of behavior (Davidson, 1994). As Kathleen Weiler (1988) writes

Feminist teachers if they are to work to create a counter hegemonic teaching, must be conscious of their own gendered, classed and raced subjectivities as they confirm or challenge the lived experiences of their students. This does not mean avoiding or denying conflict, but legitimizing this polyphony of voices and making both our oppression and our power conscious in the discourse of the classroom (p. 145).

Questioning the idea of liberation

As I wrote in the first chapter, I often felt alienated from science, because what I was supposed to learn did not always connect with my experiences and intuitions about the world. By developing a more diverse understanding of the nature of science through examination of historical and philosophical literature, I began to draw connections between some of my feelings towards and beliefs about science and the theoretical positioning of the scientific discipline. I began to understand that it was (or ought to be) legitimate to have feelings in science, to feel connections to my object of study, to characterize and make explicit the values embedded in my own scientific theorizing. Scientific knowledge, in fact, could be made stronger, more objective, through such explications (Harding, 1991). These explorations of feminist critiques of science also liberated me from feelings of intellectual deficiency and from feelings of fraud (MacIntosh, 1980). I began to explore and recognize my personal experiences and ways of knowing and talking about the world in science and education as valid and as valuable. I began to envision a need to search for alternative scientific explanations.

The liberation that I experienced is, in some ways, different from the kinds of liberation I have read about in the education literature. Like other poststructural feminist scientists and educators, I have found the construct of liberatory education (as it has been conceptualized in critical theory) helpful in identifying the need to uncover power relations embedded within the discourses and practices in education (Weiler, 1988; Ellsworth, 1989; Gore, 1993). But, like other feminists, I take issue with contemporary liberatory efforts in education, because they do not match my own set of experiences in science. For example, in much

of the liberatory literature, oppression has been labeled only through social class. Freire and others engaged in critical liberatory efforts ignore the oppressive nature of the patriarchal structure controlling educational processes (Weiler, 1991). Gender and even ethnicity have not made their way into the mainstream discourses of critical liberatory theory. Knowledge, although viewed as a social construction and a political act, has not been read as a gendered experience (Ellsworth, 1989; Weiler, 1991). In my own learning of quantum mechanics, I wondered about the female and non European chemists, and I also wondered why I was expected to break the world up into smaller and smaller pieces based on numbers and theoretical speculations, when those very same numbers and theoretical speculations seemed to also point towards a more wholistic understanding of the world.

To address a feminist liberatory education for all students means something more complex than freeing students from the ideological constraints which bind their thoughts and actions (Freire, 1989/1970; Habermas, 1972; Shor, 1980, 1988; Giroux, 1988; McLaren, 1989). Feminist theorists envision liberation as less authoritarian and more contextualized (Ellsworth, 1989; Lather, 1991; Weiler, 1991). That is, neither students nor teachers are ever "freed" from ideological constraints, but teachers and students, together, explore multiple perspectives in science as one way to begin to deconstruct the beliefs they hold about science and themselves as teachers and students, and gendered, raced, classed and sexual people (Ellsworth, 1989). Feminist liberation is a political agenda aimed at understanding and critiquing the influence of dominant ideology through the context of lived experiences.

Positionality is a key piece of feminist liberatory education. Positionality accents a need for feminist liberatory teachers to recognize that dominant ideology becomes infused with views of school, science, and society, and hence is a part of who we are. Through pedagogies and curriculum that explicitly relates the students' as well as the teacher's viewpoints and experiences to the subject matter, feminist liberatory educators can begin to involve students in a search for new and multiple meanings in science education which are personally relevant, yet critical of generalizations and simplifications. Such understandings of positionality, on the

part of teachers, appear to be critical if students of underrepresented or misrepresented groups are to have access to cultural and gender connections to science in schools. Equally important, such knowledge provides a framework on which teachers can build with students a larger, broader, and more informed picture of science.

In this study I explore the implications that feminist liberatory education has for science teaching. To help create a vision for feminist liberatory education, I share several stories describing my own science teaching and learning. These stories focus the role of positionality and its connection to developing a science for all.

CHAPTER 3

Transformative Praxis:

The Politics of Feminist Teacher Research

I [engage in] feminist efforts to empower through empirical research designs which maximize a dialogic, dialectically educative encounter between researcher and researched...What I suggest is that our intent more consciously be to use our research to help participants understand and change their situations. (Lather, 1988, 569-581).

Where does this chapter belong?

Feminist teacher action research, although a (semi) mainstream form of research at Michigan State University, is marginalized in the education field, and I wanted to "set the record straight" with any skeptics who may question the "rigors" of my research practice. Yet constructing the text of my dissertation with the methodology preceding (temporally, spatially and intellectually) the story of my teaching efforts left me feeling rather uncomfortable. Placing methodology first made the reader take a very long time to get to my story of my teaching, and it also highlighted my methodology at the expense of my story. This contradicted my teaching and research practice. It also falsely suggested that my methodology was conceived in full before the events in my dissertation story.

So why did I want to put the methodology in the background? Why did I choose to keep methodology at the beginning? Methodology traditionally suggests a devotion to an "experimental method" employed to be able to do "rigorous" and "value free observations" and to induce-deduce objective and maybe even generalizable results. When I write about

methodology and experimental method, I refer vaguely to the five-step method taught to all science students in K-12 science classes around the United States (and most likely many other countries too): Question-hypothesis-experiment and data collection-results-conclusions. But, I only do so with the added caveat that no scientist ever really follows this method step for step all or even any of the time (Harding, 1986; my own experiences in scientific research). Yet the notion of "scientific method" , acts as a smoke screen for objectivity (Harding 1986). If a (or any) "rigorous" scientific method is followed, then a (or any) results will be valid, reliable and objective. I do not make these claims for my project.

My reasons for originally wanting to appendicize my research methodology are multiple. My research methodology did not precede my study; it shaped my study as my study shaped it. It did not lead me to discover any objective or generalizable truth about teaching science; it did provide me with a set of tools to name my subjectivities in teaching-researching. My dissertation is about redefining science and a science education that is at once critical and inclusive—a science education which continually is rescripted in the classroom through the interactions of multiple subjectivities. In the writing of my dissertation and the mind set I take to research design and explication, I work for the same critical and inclusive qualities I strive to enact with the students in my science classes. Therefore, the writing of this text—a physical artifact of my study—must reflect the same standpoint. Therefore, shaking the powerfully positioned meanings we have in science for methodology requires me simultaneously to make explicit and to marginalize my scientific method.

In my current reading of this dilemma, I chose to place this writing about methodology in chapter 3. Before, I give my reasons, I would like to write that if anyone would like to skip ahead to chapter 4, please do. Do not feel constrained by the traditions of the dutiful reader.

I have decided at this point to keep the methodology as chapter 3 because, as the title suggests, this chapter is about research methodology, and therefore about an ideological framework within which knowledge is constructed towards particular goals and subjectivities (Hasbach, 1995). In this sense, then this chapter is not just about the methods I used to gather

and construct data. Rather, it is primarily an argument for a politically located methodology. I hope in my descriptions to come my actions as a teacher-researcher challenge the traditional five step method of scientific research, the belief that a well constructed method yields objective and generalizable results, and that research design is separate from (and conceived prior to) the acts of research and the knowledge constructed through those acts.

This difficult decision to locate a discussion on methodology in the body of the text is a request I make to readers to understand my methodology as located politically, historically, and socially, just as my teaching is. It is an attempt to marginalize the idea that methods are the body of a project.

Research in science and research in science education: Paralleling traditions

We see clearly the parallels between a pedagogy of positionality and a methodology of positionality. Interaction and exchanges with our informants have enhanced our understanding of their contexts as well as our ability to depict their construction of meaning in their classes and beyond. During this process we recognized the strength of our yearning for a master narrative, the narrative that will "get it right" once and for all. But when research becomes a collaborative relationship between subjects and researchers, this yearning is continually checked. These interactive processes have made for us more deconstructive, more aware of our own positions, and more tolerant of our ambiguities and our disagreements (Maher and Tetreault, 1994, p. 229).

The tenet that school science is excluding in its practice is central to this dissertation. Paralleling this ideological standpoint is the belief that research methods in science education are also reminiscent of the same excluding practices. Positivism retains its "hegemony over practice" (Lather, 1991, p. 2) in many science education circles, and authoritative, reductionistic, and perceived objective processes deny the inherently culture-bound product and process of such work. Harding (1987) describes this view:

Critics argue that traditional social science has begun its analysis only in men's experiences. That is, it has asked only the questions about the social life that appear problematic from within the social experiences that are characteristic for men (white, western, bourgeois men, that is). It has unconsciously followed a "logic of discovery" which we could formulate the following way: Ask only those questions about nature and social life which (white, western, bourgeois) men want answered (p. 6).

Harding and other feminist theorists argue that in a patriarchal society like the United States it is the "white, western, bourgeois and masculine" vision that has been captured in research with little attention given to women's, the working class' and minority's visions of reality. Consequently, research methodology and its resulting "knowledge" are "partial, perverse and distorted" (Hartsock, 1979).

Weiler (1988) continues this argument:

Women researchers and theorists have come to see that in the dominant western intellectual tradition, male experience is taken as the norm, as what is truly human. Women therefore by definition are either insignificant or incomplete. Thus women know who they are through a double process. On the one hand, women know themselves through the male hegemonic vision of reality, in which acting subjects are men and women are something other...On the other hand, women as human beings are subjects, and have the ability to act and critique their own experiences, even if that capacity is denied in structures of knowledge and in the language itself. Therefore women exist in a particular tension of both being subjects and being denied as subjects. The recognition of this dynamic has led feminists to question the ability of male thought to address and adequately comprehend the experiences of women (p. 58).

Weiler is making an important point here. She is arguing that traditional research methodologies are not adequate for research by women, with women, or for women because the positivistic paradigm has uncritically accepted a masculine framework as a referent. She argues that if women are to be anything but hurt by current research practices (as both the researcher and the researched) then a new methodology must be practiced which calls into question the methodology, assumptions, and language of the intellectual positivist tradition. This methodology must "unsettle traditional assumptions about knowledge as they challenge familiar beliefs about women, men and social life" (Harding 1987, p. 189).

Building an inclusive methodology

Many feminist educators and sociologists have collectively been building a feminist methodology and epistemology (Smith, 1979; Stanley and Wise, 1983; Harding, 1987; Weiler, 1988; Middleton, 1983; Lather, 1991; Maher and Tetreault, 1993; Hollingsworth, 1994a). This

movement grew out of the desire of women researchers to begin their research by defining themselves as women, and by making problematic the rationalistic and objective traditions within the positivistic methodological framework (O'Brien, 1983; Harding, 1987), and the intersection that gender has with knowledge and power (Weiler, 1988; Harding, 1986).

Yet, hooks (1990) reminds us that male intellectual tradition has not only been oppressive to women, it is also oppressive to the research for and by minorities and the working class. Furthermore, women's lived experiences are not singular; they also cut across race and class. To build on Weiler's argument, research methodologies need to make problematic traditional assumptions about research and epistemology through the traditional sociological tri-lens of race, class and gender (Middleton, 1993).

Reinharz (1992), in her review of feminist research methodology, suggests that there are a multitude of definitions, actions, and theories of feminist research which range from case studies to experimental studies to action research. Bringing together several strands of feminist revisioning of social science and qualitative research, there are several themes and assumptions which have influenced my own research actions and agenda. With the growing body of literature in feminist research methodology, these themes and assumptions which guide my practice, are not inclusive of all feminist research.

Assumptions about feminist research which have guided my practice

✿✿ Feminist researchers recognize their own raced, classed, and gendered location in the research process; they recognize their own positions as subjectively privileged and oppressed (Maher and Tetreault, 1993; Weiler, 1988; Harding, 1987). This assumption is central to my research agenda, in part because it is intimately connected to my research questions (how can thinking about positionality help me to construct a feminist liberatory teaching and learning setting?). It is also central because it is a constant reminder of the situatedness of knowledge and research. For example the act recognizing my own location as raced, classed, and gendered

takes on different meanings in different contexts: When I am teaching I experience power arrangements differently than when I am in a chemistry department meeting or when I am having a personal conversation with students or colleagues outside the classroom.

☛☛ Feminist researchers emphasize lived experiences and the significance of everyday life (Harding, 1987). Lived experiences are our situated readings of our life events (Britzman, 1991). Lived experiences serve as a source of new theory because they uncover the values, experiences, beliefs and needs not always recognized in research on and by mainstream culture (Hollingsworth, 1994a). This is particularly important to me in this research project because I am trying to make sense of teaching a "feminist liberatory science" across race, class and gender. There are many truth regimes functioning in science and education that attempt to define our learning and our lives. Without creating situations to value and explore lived experiences, I may be serving only to replace one truth regime (mainstream culture) for another (my own grounded in feminist theory) (Gore, 1993). These emphases on lived experiences and the significance of everyday life require that the personal become political; that positivism is rejected for more phenomenological and interactionist approaches; that an interactive (rather than hierarchical) relationship between the researcher and the researched develop (Weiler, 1989). As Oakley (1981) writes:

A feminist methodology of social science requires that...the mythology of "hygienic" research, with its accompanying mystification of the researcher and the research as objective instruments of data production be replaced by the recognition that personal involvement is more than a dangerous bias—it is the condition under which people come to know each other and to admit others into their lives (p. 58).

☛☛ A third assumption in which I ground my research is that feminist research is inherently political and that feminist researchers make a political commitment to addressing oppression (sexist, racist, classist) and changing society (Weiler, 1988). As Lather (1991) suggested in the opening quote to this chapter, "What I suggest is that our intent more consciously be to use our research to help participants understand and change their situations." I do not want to research or teach in a way that will alienate my students from science or from

their own stories of their lives. In my research and teaching I want to help my students change the science in their lives and their classroom.

✿✿ The fourth assumption I bring to my research agenda in many ways supports and requires the first three: Feminist research is praxis. Feminist praxis is lived theory in action. Praxis, according to Lather (1991, p. 11-12) has two requirements. First, it is composed of theory relevant to the world nurtured by action in it. Second, there is an action component that grows out of "practical political grounding." In my research my thinking and my actions have evolved over time, affecting each other reciprocally, shaped by my changing understanding of feminist and poststructural theories, my students and our changing visions of each other and science (WISE, 1995). Through locating my research methodology as a subjective political act for social change I am creating a form of transformative feminist praxis. A political commitment in research to change and be changed is a form of feminist praxis because it "encompasses both reflection and action as a form of inquiry that promotes a better, fairer, more humane world" (Miller, 1990, p. 13).

Framing the questions

As I suggested earlier, my research desires and questions developed out of my gendered, raced and classed life both in and out of science. I wanted to learn how to construct a feminist liberatory teaching and learning setting in science so that my students would not have to wait until they were in graduate school (as was the case for me) to learn that their ideas are valuable in science (and that it is not only their fault or their "lack of intelligence" which makes them not do well in or be bored with science). Having been influenced by the feminist poststructural studies in education, I was worried that if I could not meaningfully and continuously deconstruct my own truth regimes in the classroom, then I would not be able to construct a liberatory feminist science setting. Like Sue Middleton (1993):

I was a feminist educator who was both experiencing and studying the contradictions, tensions and joys of being a feminist educator. My questions came

from inside what I was studying...As Dorothy Smith (1990) expressed it, "as thinking heads—as social scientists—we are always inside what we are thinking about; we know it in the first place as insiders" (p. 51).

The origin of my research questions lay "in the contradictions, tensions and joys" of my life. I felt a passion for science, yet I also felt otherized from it. I longed for an education in science, yet I felt oppressed by it. How could I create a science teaching and learning setting for my students so that they could also feel a longing and a passion? How could I create a science teaching and learning setting which did not otherize and oppress students, especially those traditionally marginalized students? How could I work through my own experience as both privileged and oppressed so that I did not assume uniformity among my students and their wants, needs and beliefs? How could I work through my own experience as both privileged and oppressed so that my science teaching did not uncritically reflect a white, middle-class, masculine perspective at the expense of all other perspectives?

Changing the questions

In my dissertation I have tried to find ways to bring a feminist liberatory perspective to teaching chemistry to urban community college students. I began this research project intending to learn more about how thinking about positionality could help me to construct with students a liberatory teaching and learning setting in chemistry. To do this I wanted to ask the questions: What are the multiple positions I hold as teacher-researcher in science class, and how do they shape the contexts which shape my reflections, decisions, and actions? How do the layers of my positionality shape what goes on in my classroom and the ways in which I make sense of what goes on?

As I learned more about teaching, about liberatory education and about positionality, I found that these questions were too structured: The value of positionality in my dissertation was not in categorizing all my actions and decisions as a way to learn more about why I do what I do in the classroom. I felt that these questions I constructed were asking me to do that. As I

began to understand how science education practices have traditionally structured and bound our thinking about science, about relationships in science, and about identity in science, I realized that I had to work against bounding my (and the students) actions and decisions if we were going to construct any sort of liberatory education. Therefore, I needed to change my research questions. Instead of asking how do my multiple positions shape my teaching actions, reflections and decisions, I began to wonder, how does thinking about the positional nature of the politics of knowledge and relationships in science shape how the students and I think and act in the classroom. How does making positionality an issue in science teaching and learning create opportunities for moving relationships in science? And, how does working to bring in the students and my own lived experiences without categorizing them (as scientific/nonscientific) create opportunities to understand, critique and revision science?

Designing a research methodology, designing a class, designing our lives

As many women and men active in political struggles in education argue, there can be no single research strategy or pedagogy of empowerment, emancipation, and liberation. Therefore, in this research project I drew from a wide array of research and teaching methodologies within the feminist and poststructural traditions. To engage in teaching and research that is consistent with my epistemological and political commitments, I engaged in a combination of qualitative methodologies including: Teacher research (Cochran-Smith and Lytle, 1990; Ellsworth, 1989; Hollingsworth, 1994a; Lather, 1991) feminist interactive ethnography (Harding, 1987; Weiler, 1988; Hollingsworth, 1990; Maher and Tetreault, 1993), and collaborative conversation (Hollingsworth, 1994a).

I used these methods collectively to construct a feminist research methodology. As I suggested earlier, my choice of defining my qualitative research methods as feminist is intentional. I chose not to engage in traditional qualitative research because, as I described earlier, it operates under the assumption that both the research and the researcher can remain

uncritical, unpolitical (Bogden and Biklen, 1992). Feminist ethnographic research methods allowed me, the researcher, to acknowledge my influence in order to move beyond "interpretation and description" into the activist and political realm. I brought this feminist stance to my dissertation by 1.) asking questions which challenge traditional behavior and beliefs as one way to uncover situations of domination and oppression in my science teaching and learning (Personal Narratives Group, 1989; Hollingsworth, 1990); 2.) making my position as researcher and as researched equally problematic and open to critical examination (Hollingsworth, 1990, p. 4); and 3.) continually reconstructing my research methods around new interactions, experiences, and insights.

Teacher-research

Teacher-researchers are uniquely positioned to provide a truly emic perspective that makes visible the ways students and teachers together construct knowledge....Because their research process is embedded in practice, the relationship between the knower and the known is significantly altered. This obviates the necessity of "translating findings" in the conventional sense, and moves teacher research toward praxis, or critical reflection on praxis (Lather 1986)...With this different epistemology, teacher research, which is currently marginalized in the field, would contribute to a fundamental reconceptualization of the notion of a knowledge base for teachers (Lytle and Cochran-Smith 1992, p. 448).

Cochran-Smith and Lytle (1990) write that "the voices of teachers themselves, the questions the teachers ask, the ways teachers use writing and talk in their work lives, and the interpretive frames teachers use to understand their practice (p.2)" are pieces which are missing from the knowledge base in education. Although I am not the typical teacher⁶, I do believe that my own engagement in teacher research will help to understand how theory and practice blend together in the classroom. With the current momentum to prescribe a knowledge base for teachers, I hope that my own efforts as a teacher-researcher in the classroom will contribute to

⁶I do not teach five or six classes all day long, five days a week and I do have the support of a community of intellectuals who have the time to value theory and research.

this effort in a way which is unsettling. I hope that my efforts highlight the situated and relational nature of teaching and knowledge in the classroom, and how it is impossible for a teacher to know "what you need to know" without knowing the students and learning about their lived experiences.

I believe strongly that the educational field has much to gain from teacher research. As Cavazos (1994) points out, the voices of teachers and the voices of women are missing from science educational research. Through teacher research, I hope to contribute to the research efforts to make problematic the relationships between the knower and the known, the researcher and the researched, and knowledge and authority (Lytle and Cochran-Smith, 1992). Although teacher research lends itself to these self-reflexive analyses on research, knowledge, and power, leads to serious questions of generalizability. If the theoretical framework brought to this sort of research is one that seeks to make sense of classroom practice in light of traditional assumptions about students and school (i.e. the uncritical and the unpolitical), then like other forms of research, teacher research can and will contribute to the legitimization of oppressive research and teaching practices that counteract feminist agendas (Hollingsworth, 1994a). By engaging in a form of teacher research that seeks to challenge and transform traditional assumptions of students and school, I hope to not only push my own practice as a teacher towards more liberatory aims, but also to create new spaces in teacher research for nontraditional voices.

Teacher research is also critical to my research agenda because of my needs and desires to address ideological concerns in the teaching and learning of science. I believe that in order to come to a greater understanding of how a feminist agenda is lived in the classroom by teachers and students, it is necessary to understand how a teacher's actions and reflections can be informed by underlying assumptions about science and school. Reflecting on what I believe it means to bring a feminist agenda to science education, it became obvious to me that the ways in which I act upon my own feminist teaching agenda are contextually dependent. I make sense of my feminist teaching agenda in connection with my understanding of myself and the world, the

understandings and experiences which my students bring to class, and my interpretation of those experiences, and my beliefs about the content that I teach. Therefore, as a white feminist female teacher hoping to construct a liberatory teaching and learning setting, I feel it is important for me to understand how my lived experiences shape my connected understanding of school, science and students. My hope is to be able to use this reflexive thought and the subsequently informed actions to move science teaching towards its liberatory potential.

I formally constructed my teacher-research project around multiple feminist interactive ethnographic methods. Through the course of three semesters, I audio taped most (and transcribed some) of the chemistry classes I taught⁷, allowing me to revisit events in the classroom through listening and reading. I often chose to transcribe tapes of classes which were particularly interesting to me either because they felt transformative or exciting, or made me feel like I wanted to bury my head in the sand.

At the end of each semester, I interviewed as many students as volunteered to be interviewed (a total of 21 students, one time each). These interviews lasted from thirty minutes to ninety minutes, and each interview was audiotaped. In the interviews, I asked the students for reactions to the course, what they thought they learned in the course, and how their ideas about science and their relationships with science changed or did not change throughout the course of the semester (refer to Appendix B, Interview Protocol). I also partially transcribed some of these audio recordings.

Other forms of data collected included keeping a teaching journal, reading and responding to student journals (of which I kept copies if permitted by the students), and collecting course products (text, handouts or activities used in the course, student writing, notes of my planning for the course, including notes of planning with other course instructors). Keeping a teaching journal was particularly transformative for me because, even though I have kept journals/diaries in the past, they were never really the kind that I would reread over and

⁷For a more quantitative description of my methods, please refer to the data collection chart in the last section of this chapter.

over again (except for good laughs several years later), searching for meanings and insights into who I am, who I believe my students are, and what I expect science to be. My journal entries are often too painful to read because it forced me to continuously confront my beliefs and my teaching practice. It served as a source of liberation in that it gave me a place to work through ideas that otherwise would have remained muddled in my mind. It also gave me a place to value my own voice in science teaching.

Reading and responding to student journals was equally transformative. Often times in science class students will hold back their ideas about chemistry, about themselves and about others. Journals gave me a way to communicate with some students in a more personal way which has given me deeper insight into the wants, needs and beliefs of my students. It has also given me insight into just how much the power arrangements shape what remains unsaid in the science classroom.

Collaborative conversation

Collaborative conversation played an integral role in my research. Engaging in conversations with fellow teachers, researchers, and students helped me develop a growing awareness of the practice and tensions I experience as a feminist science educator. Conversations also helped me to uncover the assumptions I live by. I believe that this awareness of teacher-researcher assumptions is vital because it enabled me to re-create a life both inside and outside of teaching and research around new understandings and insights. Through "collaborative conversation" (Hollingsworth, 1992) knowledge of self and of science can be challenged. In the process multiple opportunities to weave together knowledge of self and others were created. Conversations helped to create opportunities to deconstruct and reconstruct lived experiences as teachers, researchers, and students. They helped to nurture instances of re-vision.

Through the course of my dissertation, I engaged in two different kinds of collaborative conversation, one of which was planned, and the other of which was an outgrowth of the project. The planned conversations were those with fellow teachers and researchers. Originally, I planned to engage in weekly conversation, journal sharing sessions, and classroom visits with another teacher interested in exploring feminist issues in teaching. I hoped that this effort would help me to reread my own reflections and classroom actions from multiple perspectives. Because of time constraints and other factors, I changed my plans. Instead, I engaged in personal conversation and email conversation with a feminist woman (Constanza Hazelwood) who was not currently teaching, but who had a great deal more experience teaching science than I. Constanza was able to help me work through many questions and issues in my teaching because she shares many the experiences of being a woman, a feminist, and a scientist. In addition, she was able to help me keep race and ethnicity highly problematic because of our different cultural perspective.

Conversations with Constanza about science, teaching, research, methodology, and theory pushed my thinking in so many ways through the course of this study. As we wrote in a paper together during this past year, "Conversation has been central in helping us to deconstruct the master narratives of our theoretical positionings, which have helped us to recognize how our thinking has been structured and how we need to blur boundaries without ignoring or erasing them: Researcher/researched, self/other, theory-practice, insider/insider, and gender, race and class" (Barton and Hazelwood, 1994). I consider these conversations a form of transformative praxis. For example, our conversations helped us recognize that there are power differences between us, there are different forms of privilege and oppression that shape our lives and that we often leave these differences out of our conversation as we focus on our common experiences. This awareness of difference and the initial absence of this topic in our conversations moved us to re-examine our research practices and explore our conceptual understandings of Self and Other.

The other form of collaborative conversation which was central to my teaching and research, was not planned as part of my original methodology. The conversation process began at the end of the spring semester, when in response to something I wrote to Tracy in her journal, she came up to me after class and asked if we could continue the conversation we started in the journal and in class over lunch during the summer. Of course, I immediately accepted the invitation because I wanted to hear more about Tracy's wants, needs and beliefs. I also believed that it would help provide a needed perspective to my dissertation. For both personal and political reasons, I took her up on this offer. I also took that moment to invite other students to continue to the conversation with me over the summer. Three students took me up on the offer: Tracy, Laurie, and Gene. We met at various eating establishments, and talked the lunch or dinner hour away. My conversations with Laurie and Gene ended with summer, not because of a lack of interest I think, but because of other pressing commitments: Gene relocated to another town to start a new job teaching ninth grade physical science and coaching football, and Laurie's family, work, and school commitments ate away her free time. Tracy, however, continued to meet with me and I found her input into my project invaluable. In a critical, yet caring way, Tracy helped me understand my own feminist liberatory agenda from the perspective of a working class student who has boycotted formal science courses for a decade.

This change in methodology shaped my dissertation in ways that I had not expected. By inviting students to assist in the analysis of the course, it was not so easy for me "to impose alien constructions on their experiences" (Middleton, 1993, p. 69). It required me to reinterpret my reading of our chemistry class together and the nature of feminist liberatory education. These conversations became more than a casual interaction; they became an intervention by me into Tracy's life (and Laurie's and Gene's) and Tracy's (and Laurie's and Gene's) into mine. This kind of transformative praxis moved me towards a more collaborative construction of reality, helped me to construct new interpretations of my prescribed research questions, and transformed my vision of feminist liberatory education.

Data Collection Time Line

January - May 1994

- Taught two sections of chemistry at the community college: The "spring afternoon section" and the "spring evening section."
- Audiotaped all classes taught.
- Collected and/or photocopied student work (including journals, homework, in class assignments, papers and exams).
- Kept a teaching journal (which I wrote in before and after teaching class each Monday and Wednesday, and which I wrote in on other days of the week when I was reflecting on my teaching).

May - August 1994

- Interviewed the spring evening students. I interviewed ten (of fourteen) students for 40 to 60 minutes each. Each interview was transcribed.
- Engaged in collaborative conversations with three former students:

Tracy: Tracy and I had a series of eight conversations between May and March, each lasting between 60 and 90 minutes and each over lunch at local restaurants and coffee shops. Our conversations still continue.

Gene: Gene and I had a series of three conversations between May and August, each lasting between 75 and 120 minutes and each over coffee at local restaurants and coffee shops. Our conversations ended early August when Gene moved away from the area to assume a new teaching and coaching position.

Laurie: Laurie and I had a series of three conversations between May and August, each lasting between 45-75 minutes, all of which were held in my office after her scheduled work hours near my building. Our conversations ended in August when she started her school-work-family routine again.

- Taught one section of chemistry at the community college: The "summer evening section."
- Audiotaped all classes taught.
- Collected and/or photocopied student work (including journals, homework, in class assignments, papers and exams).
- Kept a teaching journal (which I wrote in before and after teaching class each Monday, Tuesday, and Thursday, and which I wrote in on other days of the week when I was reflecting on my teaching).

August - December 1994

- Interviewed students from the summer semester. I interviewed eleven (of twenty two) students for 30 - 45 minutes each. Each interview was transcribed.
- Continued to engage in collaborative conversation with Tracy (refer to above).
- Taught one sections of chemistry at the community college: The "fall evening section." (although I do not write about this class in the dissertation, it undoubtedly influenced my writing during this time)
- Audiotaped all classed taught.
- Collected and/or photocopy student work (including journals, homework, in class assignments, papers and exams).
- Kept a teaching journal (which I wrote in before and after teaching class each Monday and Wednesday, and which I wrote in on other days of the week when I was reflecting on my teaching).

As the time line for data collection indicates, many of the activities involved in my dissertation from teaching to collaborative conversation to journal writing served both my teaching and my research. This overlap is significant because each thing I did as a teacher or researcher informed the other. For example, most of the summer conversations (and a few interviews) occurred while I was teaching during the summer semester. New insights I had from teaching went into my summer conversations, and new insights from summer conversations went into teaching.

Because I was continually writing about my teaching through journal writing and other more formal writing activities as I was teaching, the writing in this dissertation spans a wide time frame, and therefore a changing knowledge. Consequently in all of my writing, there are several different voices intertwined together in a semi-coherent text: My voice as a teacher, a researcher analyzing her teaching in action, a researcher reflecting on her teaching after time and with the help of students, and a researcher reflecting again on her teaching after even more time and after having had a series of conversations with her students. These different readings are reflexive; each inform and distort the other. Sometimes when I read my writing with a "fresh eye" it is hard to tell where these voices converge and diverge, because they play off

each other and become parts of each other. This teaching/researching/learning/writing process is not linear. It is not possible for me to say that I wrote this as a teacher then reflected on it as a researcher. These voices which are part of me are self-reflexive and cannot be separated.

The Setting: Feminist Teaching in Chemistry at the Community College

...education represents both a struggle for meaning and a struggle over power relations. Thus education becomes a central terrain where power and politics operate out of the lived culture of the individuals and groups situated in asymmetrical social and political positions. This way of understanding the academy entails a critique of education as the mere accumulation of disciplinary knowledges that can be exchanged on the world market for upward mobility (Mohanty, 1994, p. 147).

Chandra Talpade Mohanty, in her essay, *On Race and Voice*, argues for a political and transforming vision of education. This notion of education is central to me as a feminist science teacher. Science education is about more than passing on the disciplinary knowledge of science. This political and critical view of education suggests that education is about issues of power and relationships. As Weiler (1988) suggests, "teaching extends beyond subject matter knowledge; the centrality of teaching lies in a recognition of the values of students' own voices, subjective experiences of power and oppression, and the worth of their class and ethnic cultures" (p. 148). From this perspective, as a feminist teacher of science, it is my goal to raise questions and issues with students which unsettle accepted social reality in the science classroom and in science. Yet science class is an incredibly complex social site marked by multiple interacting layers of power arrangements and social and institutional forces which shape and define the boundaries of what is possible.

Feminist science teaching at the community college takes place within the wider cultures and institutional structures of school and science which bound our visions of teaching, learning, science, and selves. Although teaching science at the community college is more flexible than teaching science at the high school because we are "granted" two hour rather

than 45 minute blocks for teaching and learning, the structure of the science education at the community college is still rigid. We are prescribed times and locations to meet as well as a curriculum to enact⁸. In the chemistry department, we are told that to meet on Mondays and Wednesdays from 6 to 8 PM in room 203 of the local high school. We are told that we will use a particular preselected textbook, *Introduction to Chemical Principles* (Peters, 1991) and that we will cover the first 18 chapters before the semester draws to a close:

Chapter One - Learning Chemistry
 Chapter Two - Matter and Energy
 Chapter Three - Measurements and Mathematical Tools
 Chapter Four - Measurement and Mathematical Methods
 Chapter Five - Atomic Theory and the Periodic Table: The Beginning
 Chapter Six - Atomic Theory and the Periodic Table: A Modern View
 Chapter Seven - Chemical Formula Problems
 Chapter Eight - Chemical Reactions and Equations
 Chapter Nine - Quantity Relationships in Chemical Reactions
 Chapter Ten - Chemical Bonding: The Formulation of Molecules and Ionic Compounds
 Chapter Eleven - The Structure of Molecules
 Chapter Twelve - Inorganic Nomenclature
 Chapter Thirteen - The Gaseous State
 Chapter Fourteen - Liquids and Solids
 Chapter Fifteen - Solutions
 Chapter Sixteen - Reactions that Occur in Water Solution: Net Ionic Equations
 Chapter Seventeen - Acid-Base (Proton-Transfer) Reactions
 Chapter Eighteen - Oxidation-Reduction (Electron-Transfer) Reaction

We are told what the homework problems will be, how they will be graded, and when they are due. We are told our progress will be measured by departmentalized exams to which they are no alternatives. At the community college where I teach, the students and their

⁸I was not sure how to write this phrase. I do not believe that the science curriculum is this external set of curricular materials that a teachers has her students do. I believe the curriculum entails what goes on in class (explicitly and implicitly). However, I believe that the chemistry department generally views the text and associated activities as the curriculum-- that there is nothing else worth mentioning in a discussion of what students learn in science class.

teacher, all of whom come from different life circumstances, are expected to accept passively these rigidly defined structures.

Even before our class officially starts—before we ever have the chance to express our needs, desires and fears for an education in science much of our lives in science and education have been inscribed. Many of our lived experiences, our visions for a socially transformed world, even our visions of gaining access to the culture of science, have been thwarted.

The department's prescription of what students need to know and how it is they are to know it imposes a vision of homogeneity in experience and circumstance. There is the implicit expectation that students will assimilate into the culture of science; that all students will come to learning science with the same cultural capital; that all students have the same (ab)uses for science. This is supported by a neoconservative society's vision of equity and science's vision of objectivity. The students in my chemistry class come from diverse backgrounds. GCC primarily serves the city community, and works hard to reach out to the working class community through its day, evening, and weekend programs as well as its off campus teaching locations. The majority of the students in my particular classes at the community college are white, (although in some of my classes, nearly thirty percent are African American, Hispanic and Asian students), and working class. There is a small number of professional students in each class and young students from middle class families. And so despite our vast differences, we each enter the course to be equally yet unequally inscribed by the dominant discourses in science and education.

The physical structure and space of the classroom also communicates messages. In the front of our classroom is a blackboard and a teacher's workbench-desk which is located on a raised platform. Spread out through the room are several rows of student benches (which we rearranged to a horseshoe design). There is an empty bulletin board to one side of the room and a counter covered with books and papers on the other. In the back of the room are locked shelves filled with lab equipment. Our study of chemistry and our vision of what it means to know and do chemistry is immediately physically bound. Chemistry takes place inside the

walls of academe and science. It requires expensive equipment that is to be locked out of the reach of ordinary people. It requires a sullen and serious atmosphere, and an expert who intellectually and physically can stand above the rest of the class.

It is no wonder that when students come to class for the first time, they have certain expectations about science, school and about teaching and learning, all of which are based on a positivistic and imperialistic world views. Although these are all ideas which I try to challenge through my feminist teaching practice, these ideas and expectations are not easily erased in the context of school, even when they are ideas and expectation which leave students and teacher feeling uncomfortable or marginalized (Weiler, 1988).

Within these structural limits I work hard to challenge these ideas and expectations that are held tightly by the students and promoted by the institutions of science and education. Challenging these ideas is difficult because they permeate everything we say, do, or experience:

Decolonizing educational practices requires transformations at a number of levels, both within and outside the academy. Curricula and pedagogical transformation had to be accompanied by a broad-based transformation of the culture of the academy, as well as by radical shifts in the relation of the academy to other state and civil institutions. In addition, decolonizing pedagogical practices requires taking seriously the relation between knowledge and learning, on the one hand, and students and teacher experience on the other. In fact the theorization and politicization of experience is imperative if pedagogical practices are to focus on more than the mere management, systemization and consumption of disciplinary knowledge....this pedagogy is an attempt to get students to think critically about their place in relation to the knowledge they gain and to transform their world view fundamentally by taking the politics of knowledge seriously (Mohanty, 1994, p. 152).

Pursuing the kind of systematic changes required for a socially transforming education as they are laid out by Mohanty are extremely difficult . Such changes require challenging accepted definitions of school and science, deconstructing an ideology of white masculine middle class privilege, and establishing purposes and goals for a science education meant for critical consciousness rather than fact-accumulation. This is especially difficult because the very institutions within which we must work have prefabricated obstacles and boundaries such

as prescribed texts, syllabi, exams, homework, definitions of science, definitions of success. We must climb over or break these obstacles through even before class officially begins.

I naively thought that if I approached the department chair with well-developed and substantiated reasons for reconstructing my section of the course (from the homework to the exams), he would grant me the freedom to rethink chemistry education in the space of my class with my students. I wanted to construct my own exams in content and form and in negotiation with the students. I wanted to negotiate topics of study with students. I wanted to rethink the grading schematic so that student grades were not solely a function of their performance on five prescribed exams. I wanted to engage students in thoughtful discussion, writing and action oriented activities designed to promote a critical awareness of the nature and practice of science. Surprisingly, when I ran my proposed revisions for the course by the department chair to let him know that I was intending something different for the students in my section, he vetoed my decisions. He said it was important for the introductory chemistry classes to be as consistent as possible with each other so that students would be neither unfairly advantaged nor disadvantaged (the notion of objectivity at play?). What I think the department chair failed to recognize is that the inflexible structure of the course immediately and intensely unfairly advantages or disadvantages students. He also reminded me that this was a chemistry course, and our responsibility was to teach chemistry.

Afraid for my students, afraid for my job—I was on a semester to semester contract—I decided partly to enact the required curriculum. That is, I chose, from the outset, to follow the order of chemistry topics prescribed by the department so that students were not disadvantaged during the departmental exams. Despite the fact that as the semester progressed we shaped this order of topics to fit our needs better (in terms of how much time we spent on particular ideas, which ideas we covered in detail and which we skipped), the choice to impose this order in itself was problematic because it imposed a knowledge base to be learned and a hierarchy of valued knowledge.

I did not present the textbook for the course to the class as "the textbook for the course." I found this text book highly problematic in its presentation style and content. Few ideas were presented with adequate explanation and evidence for their existence. In my own reading of the text, I found the author consistently asking me implicitly to believe him without having access to his social and historical location or even access to the research data and experimental design supporting the theoretical arguments presented in the book as fact. Furthermore, the sparse social, cultural, and historical information presented in the text was skewed. A superficial reading of the text, gives one the sense that a select group of bourgeois white men constructed chemistry alone. There is no mention of the women and minorities who broke the discriminatory barriers and engaged in "formal" scientific exploration. There is no mention of the people who worked outside the institution in their own version of scientific exploration (such as midwives). There is no mention of the women and minorities who supported the formal activities of science through their demanding, yet often times demeaning, jobs which kept society running "smoothly." So, instead, I used it as a reference. I could not order new books or course packs because of the department chair's decisions, but I did choose to use my Xerox budget (and then some) photocopying thought-provoking supplementary readings.

I also constructed a grading system consistent with what I perceived to be the needs the students brought to learning chemistry. I still gave five exams⁹, but devalued their worth through creating student projects (oral histories, reconceptualized periodic table, papers), and journals. On the two exams which were my responsibility, I pushed on the boundaries of what counted as an appropriate exam. I also gave them choices about of how, when, and where they took their exams. On the exams that I wrote, I provided the students the option to taking the exam I constructed, or working within a framework I constructed, putting together their own exams. I also chose to create opportunities for students to partially construct their own grading process. Students could create their own learning project to share with the class. The worth of

⁹Three of these exams were departmental; two of these exams were instructor specific.

the project in determining the students grade was negotiated between the student and myself. It was generally viewed of by the students as "extra credit" work because I did not officially require it and because it was perceived as a way to improve their grade.

At the beginning of the semester, I discussed with the students the department's policy on homework and make up exams and how those policies left me feeling uncomfortable as a teacher. The homework policy was that students would answer all the questions at the end of each textbook chapter and turn them in for a total of 10 points (out of 700) at the end of the semester. As a teacher this was not the only kind of homework I wanted students to do. I believe that chemistry class is only partly about learning the disciplinary knowledge. It is also about gaining access to the culture of science (which is much more than content knowledge) and about developing critical awareness and revisioning. Sharing these ideas with the students, I allowed the students to propose alternatives for homework. Because the students did not have any alternatives to offer I suggested that we decide our homework as we go along in the course, and that way it would be more likely to fit what we needed. The students passively agreed.

Finally the departmental policy for missed exams was that a student who missed an exam would receive a zero regardless of the excuse, and that at the end of the semester the lowest exam grade would be dropped. I suggested to the students that we negotiate missed exams on an individual basis because we cannot predict what kind of events our lives will bring throughout the semester.

I felt like this discussion with my students was a monologue. I opened the floor for alternatives and but was the only person to suggest alternatives. It was not at all like women's studies courses I have taken where we spent at least two class periods negotiating the syllabus. I knew these students were not used to having this kind of freedom in their science classes, and was worried that extending the conversation over two or three class periods might put me in the position of too strongly defying the department and my threatening my teaching contract. As I learned more about my students and the science in their lives throughout the semester, I also

learned that their voices need to play a larger role in constructing the syllabus despite my contract with the department. Consequently as a result of this learning on my part, and as a result of the students finding spaces in science class for their lives, we were able to revisit our conversation about the departmental requirement outlined in the syllabus and to reconstruct our syllabus three quarters of the way through the semester.

There are many more obstacles to realizing the goal of a feminist science class beyond these imposed physical requirements: First, feminist goals appear to be in opposition to the goals of science and education (as they are both currently practiced). Science and education both operate within the positivistic paradigm which acknowledges only one acceptable world view. This world view is so unproblematically accepted in science education that it is believed to be objective. Second, the multicultural, multiclassed and multigendered community college setting creates a complex set of interactions inside and outside the classroom between teacher and students, teacher and science, students and science and among students. As Weiler suggests, the difficulty in achieving [feminist] goals in multicultural and mixed-class public school settings becomes obvious through an examination of classroom discourse. In class, teachers and students negotiate meaning through their own set of lived experiences. Yet, the question of whose ideas are legitimized through such a negotiation process is difficult to answer because of the multiple and interacting power arrangements in the classroom. "[C]lassroom discourse... is never neutral, but is always situated in the context of a socially and historically defined present. Teachers and students use language to assert their own power and to try to create some sense for themselves out of a complex social setting" (Weiler 1988, p. 128-9). Thus the possibilities of and obstacles to counter-hegemonic teaching in science are complex, shifting, and multiple.

Science class is a microcosm of the larger society including the institution of science with its practices of inequality and oppression. Teachers and students make sense of classroom interactions (with others and with science) through their lived experiences—their own social and historical location (Gore, 1993; Britzman, 1991; Weiler, 1988). As both of these obstacles

indicate, there are tensions between the "power of institutions which have been created under particular historical, economic, and social conditions, and the will individuals, who may be in opposition to those forces, and who themselves can influence the present structure of the institutions" (Weiler p. 147).

In the next chapter I explore my attempts to teach a feminist liberatory science education which occurred at the beginning of my dissertation journey. In these stories I try to find meaning in positionality as a way to push my thinking about feminist liberatory education. What I learn is that there is much more at play in bounding our thoughts than these physical structures of school.

CHAPTER 4

Starting to Teach a Feminist Liberatory Science (Confessions of an ambivalent daughter)

In this chapter I share initial attempts to create a feminist liberatory setting for teaching and learning. I also share my efforts to use the concept of positionality to reflect on the process of constructing such a setting in two different chemistry classes. How did my positionality influence my teaching actions and decisions? How did the students' positionalities influence their responses to the science and to the class?

These guiding questions were based on three beliefs. First, I believed that reflecting on my teaching (my teaching actions, decisions, interactions with the students) through the lens of positionality would enable me to uncover some of the assumptions (about teaching, learning, students, gender, race, and class) which I uncritically let guide my teaching practice. For example, this reconstructive process would enable me to explore my simultaneous positioning as privileged and oppressed, and the influence this had on my vision of science education. Second, I believed the lens of positionality might help me to understand more fully the students' responses to my teaching. Third, I might find ways to help the students explore the situational nature of knowledge and knowing science. In this chapter, I explore how my thinking about positionality was useful in my efforts to begin to construct a feminist liberatory teaching and learning setting in these three ways. I also hope to articulate the limitations in this particular kind of thinking.

Beginning to draw connections between feminist liberatory education and positionality

In this section, I share with the reader the kind of thinking that guided my research at the outset. As the stories in this dissertation unfold, they reveal changes in my ideas about positionality and feminist liberatory education. But, in this chapter, I describe my initial ideas about the usefulness of positionality in constructing a feminist liberatory science education setting.

The intent of my dissertation was to learn about how "my positionality" influenced my teaching actions and decisions. I hoped that the examination of my teaching through positionality would enable me to recognize and make problematic how socially and culturally derived "norms" for science and teaching uncritically guided my science teaching practice. When I began my dissertation study, I had clear ideas about what I believed a feminist science education looked like and how thinking about positionality was going to help me achieve my goals. For example, I believed that, generally speaking, a feminist liberatory education would be one where the students would have a chance to:

- socially construct and understand the canonically accepted knowledge base of western¹⁰ science;
- critique that knowledge from "marginalized" perspectives;
- rethink the knowledge base of western science by merging the first two goals (understanding and critiquing science) and by becoming the authors and authorities of their own experiences.

I also believed that positionality would help me to do this by:

- providing a framework from which to analyze classroom interactions and the knowledge that is generated in these interactions;
- providing a language by which to locate myself in relation to the students, the students in relation to me, and all of us in relation with science.

¹⁰I am resisting capitalizing the "w" in western as a way to decenter the authority of science.

Positionality

Positionality is the "knower's specific position in any context as defined by gender, race, class and other socially significant dimensions" (Maher and Tetreault, 1994 p. 22). It locates teachers, researchers and students, and their interpretations and analysis of what happens in classrooms within multiple ideological positions. This kind of thinking about what happens in classrooms is important because it highlights how each person's positionality influences the social construction of knowledge. It emphasizes the relational or situated nature of knowledge (Haraway, 1988). It also implies the relational or situated nature of power and authority in the classroom (Maher and Tetreault, 1993, 1994).

In my early reading of the literature on positionality (Alcoff, 1988; Maher and Tetreault, 1993, 1994; Harding, 1986, 1991; hooks, 1990), I understood the idea of positionality as something static. Positionality was something that could be defined or labeled. For example, I could define my own positionality as that of a white woman with European ancestry, female, middle class, a chemist, a student, a novice teacher. As Maher and Tetreault (1994) in their study of feminist classrooms describe,

[Positionality] has made an important difference in our study, for example, whether teachers and students were male or female, white or African-American, heterosexual or lesbian. And those differences have varied according to history, religion, experiences, and "cultural practices" that brought participants to each classroom and positioned them there....In sum, exploring the meanings of positionality...entails basic challenges to our conventional notions of communication and knowledge construction. In these groups, we saw how knowledge could emerge from the acknowledgment of deep positional differences. The layers of language, emotion, and conflicting meaning implicit in different positions can be plumbed, raised to the surface and explored (p. 22, 200).

Maher and Tetreault argue that each person is "positioned" by their own set of multiple identities and lived experiences, and that students and teachers bring this to the classroom. Thinking about each student's and each teacher's positionality is critical in understanding knowledge construction in the classroom, because experiences as "male or female, white or African-American, heterosexual or lesbian" (coupled with social, cultural and historical circumstances), shape how teachers and students make meaning.

I also believed that positionality is inherently political. With a growing knowledge of my own positionality as well as the positionality of the students I teach, as teacher, I could "choose" which pieces of my positionality I wanted to use to make sense of a situation. This choice could be either oppressive or liberating for myself and others. It could be used to give myself power or it could be used to critique the claims of the "center."

With this knowledge of positionality, I believed I could sort of deconstruct my teaching practice to begin to uncover how the specific pieces of who I am guide my teaching practices. Just as Maher and Tetreault and the teachers in their study used positionality as a framework for understanding how students "fashioned" ideas in terms of race, class, gender and sexuality, I felt that this sort of deconstruction could be particularly helpful in making sense of how I used my privilege as white, educated, and middle class to my own advantage (or to the advantage of a society built on racist and capitalistic ideologies). Additionally, I felt that deconstruction could be helpful in making sense of my oppression—of how I allowed a patriarchal-controlled science and society to control me and the students in science class.

In this sense, positionality is intimately connected to teaching. As a teacher, it made sense that deeper knowledge of my positionality would enable me to create a different foundation from which to act in a feminist liberatory classroom. In more traditional classrooms, teachers make decisions based on their knowledge about subject matter, students, and pedagogy. If I could add to this list a knowledge of positionality, then I felt I would have a more informed standpoint from which to explore the ideological foundations of school and science, or to problematize the hegemonic curriculum. In other words, teachers and students could begin to reflect on their multiple roles in order to make sense of and reassess their assumptions about each other as agents in a raced, classed and gendered world.

Part of this consideration of how positionality influenced my teaching actions and decisions also applied to students. As a science teacher interested in helping students become "liberated from science," it is important for me to understand teaching and learning science in the context of my own and my students' lives: Who we are as raced, social classed, aged,

gendered, and educated people, who we have been in school and science, and who we want to be in school and science. How did the students' positionalities shape the way they learned science in my classroom, or the way they interacted with me or with each other?

My plan was clear: I would teach science from what I believe to be a feminist perspective, and then I would reflect on my teaching to try to understand how my own positionality influenced my actions, interactions, decisions, and responses, and to understand how my students' positionalities influenced how and if they learned science. This process would help me to uncover assumptions I used uncritically, and perhaps unknowingly, in my teaching: Assumptions about what is science, who can do science, what it means to teach and learn across race, class and gender.

Positionality and science teaching and learning

The following two stories illustrate how I used positionality in the context of my attempts to teach a feminist liberatory science. The first story occurred in the Fall of 1993 and describes my attempts to teach a lab class on distillation to a group of students at the local state university. This story illustrates my attempts to reflect on the class conversation through the lens positionality, and how this reflection helped me make sense of the role that positionality plays in classroom discourse and the connections it has to issues of voice and authority. In this story, I ask the questions, "How does positionality shape authority in our class? How does positionality shape whose voices are heard in class? What does thinking about the construct of positionality in the context of voice and authority teach me about feminist liberatory education?"

This first story takes place in a setting different from the rest of the dissertation. The class was taught at a large research university. Most of my students were white and enrolled in preprofessional programs. I was a teaching assistant, not the official instructor for the course. Being the teaching assistant, I was responsible for the students in the section, but had no control over the formal curriculum. I include this short vignette, which describes my attempts to teach

a chemistry lab on distillation from a feminist perspective, because it provides insight into my initial beliefs about positionality and feminist liberatory education.

The second story occurs in Spring 1994 and describes my attempts to teach the gas laws to introductory chemistry students at an urban community college (GCC). This story builds on previous reflections on my teaching and regards my struggle to find ways to create a feminist liberatory teaching and learning setting. It becomes clearer to me that central to my struggle to create a liberatory setting is a set of conflicting ideas about what I and my students want, need and believe to be true in science class and in our lives. We need to learn (conceptually understand) the science described by the institution of science and prescribed by the department, yet we need to allow our own science to take shape in class and in our lives. This story illustrates how my thinking about positionality was useful in that it helped me to understand this conflict, but it left me semi-paralyzed as to how to deal with conflict.

The role of positionality in simple distillations

Teaching about distillations

Distillation was one the topics required by the university's chemistry curriculum. Although an explicit curriculum had been clearly defined—students were to have practical laboratory experience in simple distillations—I also sought to use this curriculum to help students think about connections between science and western social values. The distillation lab provided an opportunity for students to set up a sophisticated system of glassware. In the course textbook, glassware joints were described as "male and female." As the teacher, I used this terminology to explore issues of ideology and science by engaging the students in a conversation about the use of the sexual metaphors to name glassware joints. After all, I was very uncomfortable with the sexual metaphor commonly used to describe glassware joints, and I also felt that it was a blatant example of how values are inherent in scientific discourse. This was also a safe example, because it did not personally involve the students. During the course of

this conversation we discussed how I/we¹¹ thought the names for glassware joints became standard, why I/we felt comfortable or uncomfortable using that terminology, and how I/we could deal with that issue in our lab.

I started the class discussion by asking the students if they were familiar with the glassware involved in distillations. As we talked about the glassware and how it was assembled, there was a need to refer to glassware joints by name. When the conversation reached that point, I asked the class if they were familiar with the naming of glassware joints as male and female. I then asked the class how they thought the names were constructed. After a few moments of silence followed by laughter, the students did not seem to want to, or know how to, answer my question. I felt uncomfortable pushing the students to answer this question. I told them that I thought it was a sexual metaphor. I believed that if I had, I might have been abusing my institutional authority as teacher to force students to say something they might have thought would get them in trouble with the college.

I wanted to discuss with the students their ideas regarding the context of the construction and legitimation of this sexual metaphor, not the actual metaphor itself—which is where the students seemed to concentrate their attention. I seemed unable to do anything but make them laugh. This was bothersome in two ways. First, I felt that their laughter trivialized what I considered to be an important conversation. Second, I was angry at myself for approaching this issue from my perspective. When they did not respond as I hoped (they laughed or kept silent instead of discussing the issue, probably because they were uncomfortable), I used my institutional authority as teacher to push the conversation forward in my desired direction which I assumed was best for the students.

After the laughter subsided, I returned to the question of how the glassware joints inherited the names "male" and "female". After a few moments of silence and a few quiet interchanges between students, Jason, a white male student, asked jokingly if they needed to be

¹¹I use this I/we notation because I facilitated (and forced) much of the conversation.

graphic. I chose not to respond to his comment. Barb, another white female student then suggested that probably "some guy was sitting around a lab one day with some other guys" and that they were probably "cracking jokes, playing with their equipment." Jen, also white, spoke up in support of this thought by stating that it was "probably true because science has mostly men." Mark, an African-American then said, "don't blame it on me, I didn't come up with the names!" After this set of ideas made its way onto the floor, the majority of the students concluded that a select group of men created the names in jest, not intending to hurt anyone or to make anyone feel uncomfortable. We then discussed alternative names to use in class.

Reflecting on teaching distillations through positionality

Reflecting on this class conversation helped me begin to make sense of the role that positionality plays in classroom discourse, and the connections it has to issues of voice and authority. As I reread transcripts of the class conversation and the notes I wrote after class about my feelings and what I thought transpired in class, specific questions kept re-emerging in my reflections: "How was authority constituted, and how did this shape what was learned, and by whom? Whose voices were heard in the classroom? What does thinking about the construct of positionality in the context of voice and authority teach me about feminist liberatory education?"

What constitutes authority and how is it connected to positionality? As the teacher of this lab section, I held a certain degree of authority. According to the tradition and rule of the academy, my students are expected to listen to me and follow my guidance. My attempts to engage the class in a conversation "outside" of traditional science conversations were sustained by my institutional authority. In one sense then, the classroom discourse was dominated by me, the teacher. Yet, even though I could control the topic of discussion, classroom discourse involves meaning making between students and teachers. Classroom discourse is not neutral; it contains the ideas, beliefs, and experiences of all involved. Any interactions I had with my

students in the course of our conversation regarding the naming of glassware joints, contained multiple belief systems—mine, the students, and the larger society in which we live and work.

The nature of classroom discourse convolutes ideas about classroom authority and its connection to positionality. Even though my position as teacher and scientist places me at the top of the power hierarchy in the classroom, my existence as woman places me in the position of perceived societal inferiority, or as Weiler (1988, 137) writes, "a subordinate subjectivity in a patriarchal society." And, although my male students experience a subordinate subjectivity as students, they also experience perceived authority as males in a patriarchal society (Weiler, 1988). As I attempted to construct a conversation around non traditional—patriarchy challenging—issues, two men in my class appeared to use their societal authority to bypass my institutional authority, and to control the tone and intent of the conversation through their jokes. Did those two men in my course attempt to use their authority as white males to shift the intent of the conversation? In their experiences as men, was a critique of the masculine nature of science trivial? How about the women? Did they participate in the conversation because they were playing the role of good student (as women are often socialized to do), or did they see this as an opportunity to begin to redefine a science education from which they have historically been excluded? What about Mark? Did his comment about not being involved in the construction of the metaphor emerge from the fact that he had not personally been involved, or that the culture of science has historically denied the participation of African-Americans? Finally, what about the three white women and one white man who barely contributed to the conversation? Why did they act as if they had nothing to offer, and what role did I play in contributing to their silence?

Deeply embedded in the notion of authority are the questions of whose voices are heard and by whom are they heard. I believe my voice was heard, although not always valued, because I was able to use my institutional authority to focus the classroom discourse. Because of me, we entered into a discussion about the sexual metaphor involved in the naming of glassware joints. As a woman, using my institutional authority to engage the class in a conversation

outside the sphere of traditional science, I created a context for the voices of other women in the class to be heard. Four women appeared to respond by deeply and seriously involving themselves in the discussion. The voices of the two joking men were also heard. Their laughter spawned further laughter and joking which not only trivialized the importance of the conversation, but made it difficult, if not impossible, for any students to engage seriously in conversation without fear of harassment and ridicule.

But on a deeper level, I am not sure that my voice was heard by the students, that I heard the voices of the students, or that the students even heard each other's voices. Although I was semi-successful in engaging the students in a conversation about the role that dominant ideology has in shaping science, I am not sure that many students internalized this message. Although I asked the students to examine the meaning of science from the standpoint of their own experiences as women and men, very little of the conversation focused on such an exploration. Our time and energy seemed to be spent, instead, moving beyond the "silliness" of the issue. I expect that part of this breakdown in conversation was due to my own inability to listen to my students: A great deal of the students' science education experiences have provided them with a context to think about science as objective and constituted by detached ideas, not as personal, or containing harmful or sexual ideas. How could I expect them to rethink their experiences in science in the course of one semester—one class period—when it had taken me years to formulate ideas critical of science? Furthermore, why did it bother me so much to have the students challenge my authority? Did I not want their voices to be heard? These reflections raise serious doubts as to whether we, as a class, would ever be able to come to a shared voice on issues of ideology and science. Was consensus, and all that is implied in the word, even a desirable goal for our conversation? Was it even possible for us to learn enough about each other in order to reposition our assumptions about the other and about science in order to construct a liberatory dialogue?

Reflecting on positionality and its connection to voice and authority in this classroom episode revealed to me new pieces of a feminist liberatory education. First, it is clear to me

that to address a feminist liberatory education for all students means something more complex than traditional notions of liberatory education. Liberatory education has traditionally been conceptualized as freeing students from the ideological constraints which bound their thoughts and actions so that students can find truth in their lives (Freire, 1989/1970; Habermas, 1972; Shor, 1980, 1988; Giroux, 1988; McLaren, 1989). Feminist theorists, in contrast, envision liberation as less authoritarian and more contextualized (Ellsworth, 1989; Lather, 1991; Weiler, 1991). That is, neither students nor teachers are ever "freed" from ideological constraints, but teachers and students, together, explore multiple perspectives in science as one way to begin to deconstruct the beliefs they hold about science and themselves as teachers and students, and gendered, raced, classed and sexual people (Ellsworth, 1989). Thus, feminist liberation is a political agenda aimed at understanding and critiquing the influence of dominant ideology through the context of students' lived experiences.

Using positionality to reflect on classroom events helped me critique my progress toward the goals of feminist liberatory education; it helped me discern instances where my own actions as teacher promoted or hindered the "liberation" of the students. For example, my reflections on positionality and the class described above suggested that perhaps my efforts were more in line with a traditional liberatory education than a feminist one. I wanted to help students understand the ideology guiding the construction of scientific ideas and language, but I tried to have them do so from the standpoint of my own experiences. My teaching actions suggested that I knew how to "unoppress" the students. As long as they listened to me, engaged in the kinds of conversations I wanted, and acknowledged the same kind of oppression that I believe existed, they too would feel liberated. Although I tried to enact a political agenda aimed at helping the students understand and critique dominant ideology, I did so through generalized assumptions about female lived experiences and student oppression. By using gender as a totalizing focus, I made my white, middle class, heterosexual, feminist ideology the norm. In the process, my students' readings and interpretations of the ideologies of science, and of my pedagogical practices were silenced.

Learning from the distillation lab

This story illustrates how positionality influences activity in science classrooms. My initial efforts were not completely successful because I asserted my own subjective history, experiences, and stories as a woman to define the normative position (Ellsworth, 1989). I believe, however, that my attempt to uncover the power-knowledge relationship in science was a good starting point for exploring connections between power, privilege and oppression. Analysis through positionality helped me see how dominant ideology becomes infused with views of school, science, and society, and hence is a part of who we are. This reflection was only a starting point, however. I decided I needed to make positionality an issue in the classroom with the students, to help the class as a whole to develop a continuing awareness of how our positionalities shape our learning, teaching, and using of science. In the class on distillation, I used positionality as a tool for my own thinking, for my personal analysis of what went on in the classroom. In the future I decided to use positionality more publicly with the students, to make what we say and who we are in class more of an issue. That was part of my next attempt to teach the gas laws in the spring semester (the next story). I hoped that this approach would push my liberatory teaching past my own desires for liberatory science education, and open it up more to the needs of the students. I hoped that this would help shape the forms of education in our science class so that my teaching would not exist as another truth regime, as is the case with many liberatory agendas (Ellsworth, 1989; Gore, 1993). The next story tells about my attempts to teach the gas laws in ways that make our positionalities in the classroom more visible.

The role of positionality in teaching the Gas Laws

In this story about my attempts to teach the gas laws from a feminist perspective, I struggled with the questions: What does a feminist science classroom look like? What might be important for the students to think about the gas laws, the nature of science, their own learning

of science, and their own (and others') positionalities? How do my reflections on teaching through positionality inform me and the students about a feminist liberatory science education?

Before I share this story, I want to share some of my feelings. I have resisted writing this story (and the rest of the stories about my teaching). I do not think that they are "good" examples of feminist liberatory teaching. To think about what I did and why I did it is painful. Sometimes when I listen to the tapes, or read the transcripts, my teaching notes, and my reflections, I have to pause frequently. I have difficulty addressing the degree to which I invoked my authority or that of science to guide our conversation rather than to acknowledge the ideas of the students. Mainly, though, I did not know what else to do. My teaching journal gives some insight into why I feel this way:

Teaching Journal April 13, 1994 ,

HELP!! I am beginning to wonder if teaching chemistry from a feminist perspective is even possible. How am I going to get through the rest of the semester? The only reason why the topic of nomenclature was not a disaster was because the students and I decided to engage in acts of "political resistance," and so the emphasis on their "memorizing" the zillions of rules the department thinks are important became an opportunity for us to critique that practice¹². But as for actually critiquing the chemistry, I am at a loss. What is even worse, is that what is next on my teaching agenda is gases, and the gas laws....

Teaching journal April 16, 1994.

...Part of what is at issue here is the fact that I have not located much literature which critiques chemistry from a feminist perspective. I have learned very well the canon of science for the field of chemistry (and in particular quantum mechanics) that I find my vision clouded when I try to look beyond or around what I know in order to create a more "inclusive" science. So, as I try to teach my students about gases and about how to be critical of a theory of gases, and even about how to reconceptualize gases, I feel like we are the blind following the blind. Before, during and after class, I struggle with the issue of "what is it I am supposed to (want to?) teach?" I know that teaching about gases without a critical perspective will most likely lead to the alienation (oppression) of students from (by) this topic, just as had been my own experiences. Yet, I do not know for myself what a critical perspective of gases looks or sounds like. I do not think that I know how to be critical of gases. Furthermore, this topic is one of those topics that I have always dreaded thinking

¹²I write about this in chapter 5.

about. Its always been sort of boring. Nothing has ever really caught my interest in this particular topic...

As my journal entry indicates, a great deal of my struggle with teaching chemistry from a feminist perspective is that even though my feminist teaching goals are clearly established (to help students understand, critique and revision science), I have little idea about how to achieve them. I do not know how to critique the chemistry, so how am I supposed to help students do it? Even if I am keenly aware of the "position" that I bring to teaching science, how can I use that knowledge to critique when I cannot think of any other way to conceptualize the subject matter knowledge myself? I am often left feeling paralyzed. Reliving that struggle is painful. It reminds me how difficult it is to create a liberatory teaching and learning setting in science. This struggle is in the back of my mind constantly. It shapes the way I approach feminist science education and positionality. I will return to this question in descriptions of my teaching of the gas laws during the summer semester (Chapters 7, 8, 9), because the question never left me.

For now, onto the story...

The Context: Teaching at Great Lakesville Community College

This particular semester I did not teach on the main campus of Great Lakesville Community College (GCC), but at an extension site located in one of the Great Lakesville high schools only three miles from GCC's main campus. So, as I have done every Monday and Wednesday this semester, I left my office at GCC at 5:30 PM to drive to Great Lakesville high school to teach chemistry in the GCC extension program from 6-8 PM. GCC is a two-year community college located in downtown Great Lakesville, a midsize city in the midwest-great lakes region. Sandwiched between the state capital district and low income housing, GCC, services a diverse (race, ethnicity, class, age, gender) population.

From what the administrators at the community college tell me, there are several reasons for the existence of these extension sites. First and most importantly, extension sites

make access to the physical location of school easier for the students. Since many students at GCC are also part- or full-time workers and parents, long distance travel is often out of the question. Second, because most of the extension schools are located in high schools or community centers, they may not be as intimidating as a college setting. This is an important issue because many of GCC's students are returning to school after long and potentially alienating absences from formal schooling. The third reason is because of limited classroom space on campus. The extension sites accommodate the college's overflow needs.

Based on discussions with the students, it appears that most of them are taking chemistry through the extension program to meet official requirements, but they give other reasons as well. Most of the students said they chose this particular section because it was an evening section (although there was another evening section offered at the college) and therefore fit better with their work and family schedules. Shellie, Mary and Dave told me they were taking the course at the high school because they felt intimidated taking a course at the college. They also said that they would hopefully have a smaller sized class at the extension school. Shellie, Tracy and Laurie said that they wanted a woman instructor, and my name was the only female name in the course catalogue for introductory chemistry that semester.

I was not surprised with the students' reasons for wanting to take their courses through the GCC extension program. Most of the students were older than the traditional college student (over 25 years), although there were four (out of fourteen) students in my course this semester who can be categorized as "traditional aged" students. Most of the students attended the community college part time during the evening so they can keep their daytime job as secretaries, health care assistants, custodians, factory workers, teachers, librarians, data processors, and cosmetologists. There were two students (including one high school student) who are full-time. All but three of the students (a teacher, a chef, and a data processor) have little "formal" educational training beyond high school.

I liked teaching for the GCC extension program because, like my students, I also liked being "off campus." I liked being away from the authorities. When I taught on campus I always felt highly self-conscious of my decisions to move away from the more traditional (and expected) classroom practices. When I taught in the extension program, I felt more freedom to explore nontraditional teaching ideas: I was not as worried about the noise level in my room, the way the tables are arranged, or that I am not located in the front of the room. I also felt more at ease helping the students to critique science. However, there was one thing that I did not like about teaching for the extension program. Whenever I needed equipment for class from paper to hot plates, I transported it (alone) from the community college to the high school. So, because of what I planned for the gas laws, I left the community college for the high school with a car full of equipment.

The drive from the community college to the high school was a short one, only about three miles. But, because of the afternoon rush to leave the capital district, I typically was stuck in stop and go traffic, and that was always problematic when I was transporting lab equipment in my car. Although my trip from the college to the high school was usually uneventful, I was always afraid that any lab equipment I was transporting would fall over and break. In this short commute, I drove by a few fast food joints, convenient stores and gas stations, several cramped, old single dwelling houses, and equally run down duplexes, and some small locally owned businesses. On warmer, dryer days, a quick glance around the neighborhood revealed the racial and ethnic diversity. There seemed to be a mix of white, Black, and Hispanic people playing and walking around, although there always seemed to be more white people than minorities.

When I finally got close to the high school I never felt like I was "in the city" like I did when I was at GCC. Perhaps it is because closer to the high school there are residential communities that appear to have a little more money than the communities surrounding GCC. Or, perhaps it is because of the huge park across the street along with the school's own football

field hides the urban nature of the area. In any case, I wonder if this played into any of my students' decisions to take their evening courses through the extension program.

I arrived at the high school with no time to lose. I usually arrived at class at least 15 - 20 minutes before we are scheduled to start so that I can mentally prepare myself to teach but also so that the students have a chance to talk with me before class if they need to. On the day I taught the gas laws I barely arrived at the school ten minutes before the start of class. I underestimated the time it was going to take me to make the several trips needed to get all my equipment from my office to my car. And, then I needed to transport it all inside in less than ten minutes. As usual, when I had a lot of stuff to carry into the building, I looked around the parking lot to locate one of my students in order to find help carrying my equipment. Usually I arrive at the school too early to find anyone, but on the day I taught the gas laws, because I arrived only ten minutes before class, I found two of my students. Thankfully, both Shellie and Gene agreed to help me cart my equipment to our room.

Because this set of lessons on the gas laws fell two thirds of the way through the semester, the students have had a chance to get to know each other through group work, oral history conversations, and class projects. They have also come to know me through the same activities, through journal writing, and through short conversations outside of class. The students have come to expect that I will not stand up in front of the class and lecture for two hours, even though that is the norm for the chemistry department on campus. They have come to expect that they cannot make any statement about any scientific idea without providing justification (which can include personal stories and experiences). They expect that I will inevitably mention the name of a women scientist, and sometimes, but not always a minority scientist¹³ whose work in our current area of study has been ignored, appropriated, or undeservedly discredited in our textbook. And they have also come to expect that I will tell

¹³The work of minority scientists has been difficult to find.

stories of my own experiences learning or "doing chemistry" on the topic of study, and that I will be critical of the textbook and the institution of science.

Planning to teach the gas laws

As outlined in the common syllabus for the chapter the departmental goals for the students in this unit on gases were:

- Given a gas pressure in atmospheres, millimeters of mercury, centimeters of mercury, inches of mercury, Pascal's, kilopascals, or pounds per square inch, express that pressure in each of the other units
- Given the initial pressure (or temperature) and initial and final temperature (or pressure) of a fixed quantity of gas at constant volume, calculate the final pressure (or temperature).
- Given the initial volume (or temperature) and the initial and final temperature (or volumes) of a fixed quantity of gas at constant pressure, calculate the final volume (or temperature).
- Given the initial volume (or pressure) and initial and final pressure (or volumes) of a fixed quantity of gas at constant temperature, calculate the final volume (or pressure).
- For a fixed quantity of a confined gas, given the initial volume, pressure, and temperature, and the final values of any two variables, calculate the final value of the third. (Initial or final conditions may be standard temperature and pressure, STP).
- Given values for all except one of the variables in the ideal gas equation, calculate the value of the remaining variable (Departmental syllabus, Chemistry 125, Spring 1994).

My goals for the students were:

- To get through the department's gate keeping requirements;
- To understand conceptually the relationships between pressure, volume, temperature and amount and be able to apply these relationships to everyday situations and to be able to use the mathematical formulations;
- To understand why these "gas laws" (Boyle, Charles, Gay-Lussac, and Avagadro) were created, and how they are historically situated;
- To understand how the textbook misrepresented the development of the gas laws;
- To understand the socially and culturally constructed nature of science, and to recognize the value-imbued nature of scientific knowledge.

As my list of objectives illustrates I had several main teaching goals for this portion of class. First, I felt it was important for the students to have a conceptual understanding of the gas laws of western science (using the language of western science), because this would allow students partial access to the "culture of power" in science. Delpit (1988) and Michaels and O'Connor (1990) make the argument that all students should be provided opportunities to engage the various disciplines deeply and intellectually, and that part of this process is making the rules, structures, content, and discursive practices accessible to all students. The purpose of this action is not to enculturate students into intellectual traditions which have denied their cultures historically. Rather, the purpose of teaching students the culture of power is to help them become "bilingual," as well as to help them realize that society is unfairly based on an exclusive model. If power is to be enacted for social transformation, then those "without privilege" must begin to find inroads into the culture of power through learning the language and practices of the center.

Second, I believed it was important for the students to have an understanding of the socially constructed nature of knowledge and the resulting biases in that knowledge. This means two things in my teaching practice. First, I wanted to help the students understand that the knowledge which emerges from the academic disciplines (or anywhere else for that matter) is laced with ideology. Second, I wanted the students to believe in their own ability to construct knowledge in science—that knowledge about science does not solely emanate from the top of the hierarchical research ladder in science. New knowledge, more personally relevant and meaningful knowledge is created in the classroom through our experiences and interpretations.

Third, I believed it was important for the students to be critical of the science they were learning, and critical of the processes employed to obtain that knowledge. Maher and Tetreault (1994) suggest that "the dominating themes of the traditional disciplines also teach students overtly, and by implication, about themselves" (p. 56). Because science imposes a world view continuous with masculine, middle class ways of perceiving and benefiting from the

world, students outside that cultural group learn that their ideas and ways of perceiving the world do not count in science. There are few opportunities in the formal study of science for students to have their own ways of perceiving the world encouraged. For example, feminist philosophers and scientists have argued that science is falsely regarded as objective, unemotional, and purely logical, and that scientists work to dominate nature and society through an authoritative, competitive, and reductionistic practice (Harding, 1991). Yet, socialization studies suggest that many women (and some men) are socialized to think and act in ways which emphasize connection, caring, emotion and subjectivity (Belenky et al 1986; Harding, 1986; Luttrell, 1993). Furthermore, cultural studies show the importance of connection in Mexican-American families (Patthey-Chavez, 1993); Mexican-American women also learn that family and relationships are important. I am not suggesting that these two categories are mutually exclusive or that all women or all minorities have ways of being in the world which are in stark opposition to the ways promoted by science. However, I am arguing that science, because it has been refined to embrace a limited way of thinking about the world (primarily by white men), denies equally valid epistemological stances (typically not characteristic of white men). I believed that bringing a critical stance to learning science would help us to work through the excluding nature of science because this process would require teachers and students to reconstruct scientific knowledge in the classroom through the values and the lived experiences of students, women, minorities and other marginalized groups.

This critique of science can be incredibly complicated in the context of science class. If we want to create a liberatory setting then the scientific claim to objectivity, authority, certainty, and epistemological essentialism must be epistemologically and politically challenged. Critiquing science in class shifts the emphasis in science learning from conceptual mastery of the known to inquiry that rejects the authority of the science master narratives and requires a self-reflexive process. These abstract thoughts full of feminist and poststructural intent are easily overlooked in science class even by radical educators, because in science class the emphasis traditionally has rested on the transference of an historically proven body of

knowledge. This element of a feminist liberatory education is the reason why I believed positionality to be so important. If, as a class, we were to critique science, then we must work that critique into the knowledge base and the processes used to obtain that knowledge. We would need to know how our lived experiences shaped our knowledge construction in science. Therefore, making our positionalities explicit as part of our talk in science would help us to make sense of our beliefs in science.

Therefore, since the beginning of the semester, I have been in a quandary about what to teach and when it should be taught. There is often a competition between the departmental goals and my own. For example, the department expects that the students will learn a broad survey of basic facts in chemistry in a course of fifteen weeks. I, too, want the students to have a broad understanding in chemistry, but I want to give them a chance to conceptualize it and question it, not merely memorize it. It is difficult to get through the departmental prescription while still creating liberatory opportunities for students.

This would not be a problem, except that the students were also expected to take a departmental final, written by the department chair, and two departmentalized regular semester exams (two others were to be written by me). This semester, the gas laws were going to be included on test IV (the gas laws are in chapter 13 of 16 chapters covered this semester and the department chair follows the text closely). I thus felt extra pressure to make sure that the students developed an understanding of the material as presented in the textbook. I knew this situation became problematic a week earlier, when we decided to engage in acts of political resistance¹⁴ regarding the departmental mandates.

In my mind, the main "chemistry" theme in learning about the ideal gas laws is exploring the relationships between pressure, volume, temperature, and amount, and why these relationships exist. I thought about what would be the best way to help students think about these connections, and decided that perhaps the best way to teach this unit would be to combine

¹⁴Refer to chapter 5 and Appendix E for specific examples of how the students and I engaged in acts of political resistance.

an historical approach to the development of the gas laws together with some personal exploration of the various physical relationships. I felt this would be appropriate because it would allow me to place the development of the gas laws in a social and historical context. Students could then make sense of how and why these laws developed.

These ideas for class fit well with my vision of science as socially constructed. It would also allow me to bring in a feminist critique of science in a way that may not appear so intrusive: With an historical presentation of the gas laws, it would seem natural to talk about the people involved in such explorations, and especially to talk about the people who were involved but were not given credit for their work. The students so far this semester have already connected to this theme through some of the oral histories as well as through our study of atomic theory. An historical perspective would allow us to critique the development of science from the perspective of the social environment, and to critique the omissions of the textbook. By joining this historical presentation with personal exploration, the students would have an opportunity to learn how these people created their theories, and that one does not have to be a genius to do such work.

This approach fit well with my vision of positionality. I wanted to make positionality an issue in the classroom, so that the students and I would develop a continuing awareness of how positionality shapes how we learn, teach, and use science. I felt it was important to teach science in a way that would allow those pieces of our identities, which were silenced by traditional science practices to have a chance to "speak." I felt it was equally important for us to be able to interpret western science from these silenced identities. By approaching the gas laws historically and personally, I hoped we would thereby find the bias in science.

Teaching the gas laws in the spring

My class the spring semester was fairly small—only fourteen students. We meet in the physics room at the high school where lab benches replace the typical desks. Unlike most

chemistry rooms, however there are few sinks (only three) and few gas outlets (only two). I had the students arrange the lab benches in a horse-shoe shape so that they would be able to see each other instead of facing the traditional front of the room. Because the tables are wide, students sit on both sides of the table, although most student sit on the outside (refer to Figure 4.1). The walls in the class were bare for the most part. The one side of the room that was covered with a bulletin board had a single poster on it of Albert Einstein's face. Each week the students and I would add our own stuff to the bulletin board—periodic table, light spectra from their experiments, and their revisioned periodic table. After several weeks of finding our stuff on the back table each time we returned to class, we learned that we needed to take it down at the end of the period. It was a constant reminder that it was neither our room nor our school.

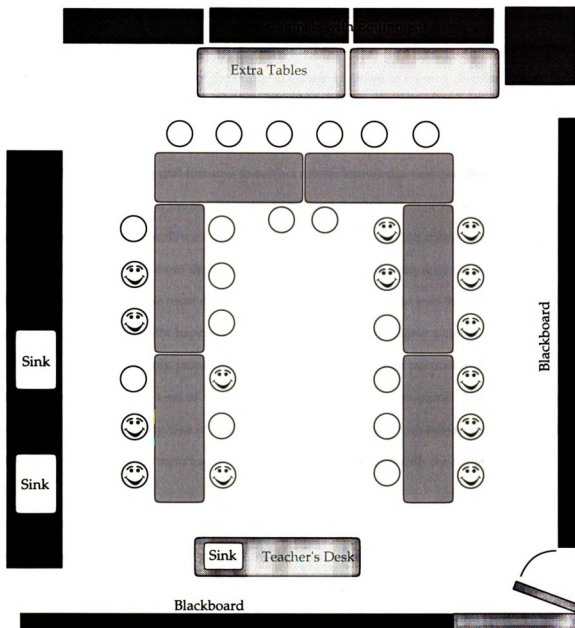


Figure 4.1
The Classroom

As usual, we began class with an oral history¹⁵. Gwen shared with the class her sister's work as a blood pathologist—what she did and why and how she got there. Gwen talked about some of the discrimination her sister currently faced at work and also previously in her years as a student of science. I thought her story was particularly interesting because it presented to the students some of the critiques I shared (elitism in science, discrimination against women) in a way which was closely connected to the life of one of the students in our class.

Moving from the oral histories to subject matter knowledge was problematic for the entire semester. Although the students and I (appear to) value much of what happens in these oral history conversations, I/we have a difficult time making explicit connections between what we talk and think about the oral histories and learning the required subject matter knowledge. This day, like most days, we made an abrupt transition into the chemistry to be learned. As it occasionally happens, today's transition is particularly painful, because the oral history was incredibly provocative, and as I share later, this particular oral history followed on the heels of a set of transformative oral history conversations. The transition was also painful because today, like most days, we were transitioning into subject matter where I felt clueless as to how to weave a feminist liberatory perspective with the subject matter to be learned.

We moved from Gwen's oral history of her sister to chemistry, through my initiation of a discussion about the nature of gases. As a class, we talked about the molecular conceptualization of gases at the beginning of the semester, and so I expected that most students would have a beginning foundation from which to begin thinking about the gas laws. To help the students recall our past conversations, I asked the students to think about their past learning and experience with gases both in and out of science class. This question, with a little prodding on my part, led to wide array of student ideas about gases, some of which fit easily

¹⁵Refer to Chapter 5 for a more detailed discussion of the oral histories.

into the canon of science, and others which were more easily considered outside of the traditional canon of science (which did not make them incorrect). I wrote all of the students' ideas on the board and did not differentiate between the canonically acceptable ideas and the unacceptable ideas.

Shellie offered an idea first. She suggested that gases "are invisible because you can't see most of them." I was glad that Shellie proposed an idea right away. At the beginning of the semester, Shellie, a young white mother of two, was highly vocal of her dislike of and discomfort with science, especially chemistry. I have tried to give her special attention across the semester, I think because I see a lot of myself, my sisters and my friends in her¹⁶.

After Shellie's opening comment, several other students shared their ideas, which I wrote on the board. For example, Laurie suggested that "Maybe because they could spread out enough that you could not see them. Don't gases spread out more than liquids?" Tracy, another quiet student who was unreserved about her dislike of and discomfort with science early in the semester, tentatively proposed that "Gases move faster than solids or liquids, and that is why they take up more space, and that is why you probably cannot see them too." Sue, an older single woman, entering college for the first time in her life, followed Tracy's comment with two of her own: "First, I wanted to say that I agree with Tracy and that is the same reason why [gases] don't have to be in such a rigid shape because they can move all over." Shellie also added that "Well, you know, there are the noble gases...They are not reactive."

This process of students sharing ideas continued until a large list of ideas was generated. We then briefly discussed and elaborated on the students' ideas as a way to move on to the gas laws. Part of this process involved the students thinking of examples from their own lives which helped to explain the theories they proposed. For example, Gene described how

¹⁶Shellie chose not to continue with formal schooling after high school because she "just didn't like it, especially science" and she "had kids to raise." Although my situation is drastically different than her situation (I went to college after high school and I have no children), after studying chemistry at the undergraduate and graduate levels and in industry there were many things in science I just did not like. And, a few of my sisters Cathy, Michelle and Christine all never took science after high school because they did not like it.

heating a substance "gave it more energy so that the particles could move around." In some cases, "it could turn it into gas" and so that was evidence for gases taking up more room than liquids and solids. We did not conclude anything specific in this part of the conversation: My sole purpose here was to help get the students ready to think about the physical properties of ideal gases (Although I did pose challenging questions to the class related to some of the more obviously "incorrect" ideas. For example, what exactly did Shellie mean when she said that gases were invisible? Are all gases invisible? How could the insight that many common gases are invisible be useful to us? The purpose was not to teach the students anything new about gases, but for me to get a feel for what they remembered and thought important about gases, and for the students to rework some old ideas about gases through class conversation before we started the gas laws. I also wanted the students to explore their personal experiences or encounters with gases so that after we worked our way through the gas laws, there would be a space in our conversation already created to draw connections between the gas laws and our everyday lived experiences. Creating this space was important because it was a way to bring more of ourselves into science. I wanted to continue scratching away with the students at the impenetrable wall that surrounds science and suggests to students that scientific knowledge comes from above, not from within our classroom community.

The first of the gas laws: Boyle's Law

We began discussion of the gas laws by creating a large empty chart in our notes:

chemist	P	V	T	n	relationship	equation	examples

Figure 4.2
Gas Law Summary Table

I then told the students that we were going to do a set of experiments to derive the "gas laws." I asked them to study each experiment carefully, recording all their observations in their notes, so that each group could deduce the relationships between pressure, temperature, amount and volume.

We started with Boyle's law (an inverse relationship between volume and pressure). To address Boyle's law in class, we first explored cooperatively experiments which demonstrated his law, drew our own hypothesis as to what his law is, looked at his experiment, his life, his work and why he did what he did, considered possible missing information, and came up with examples of Boyle's laws from our lives. This first part of class was no different than any other progressive science class. I worked with the students to help them develop conceptual understandings of the science at hand. Yet, I believed this constructivist slant to teaching subject matter knowledge was critical to building a more critical approach which would dominate a later part of the lesson. That is, we would take our

conceptual understanding along with some other historical knowledge and critique the science we learned.

When we started Boyle's law, I did not give the students the mathematical definition of Boyle's Law (inverse relationship between volume and pressure). Part of my plan was to have the students derive the law, so that they would develop a personal conceptual understanding of the relationship between pressure and volume. Furthermore, I wanted the students to understand that they are as capable as Boyle, in this instance, in creating chemistry theory. Finally, I wanted to emphasize with the students that chemistry knowledge we created, we do not just obtain from the books. I then shared with the students my plan for class and a little information about Boyle himself:

Angie: What we are going to do here is a set of experiments, and we will decide for ourselves what we think Boyle's Law is. Then we will compare our experiments to his to see where we match and don't match. Then I want to share some stories with you about Boyle. When and where he worked, and other things that were happening at that time, so we can get a good idea of what it was that was going on that facilitated his research. I want to figure out with you sort of how the society he lived in shaped why he created that law. You know, why does your book not mention anyone else, like women for example. We've kind of talked about this before, especially with some of the oral histories.

Well, actually, maybe I should tell you just a little bit about him right now, so we know what we are getting into. Let's see, Boyle lived in the 1600's and he was independently wealthy. At the time Boyle studied chemistry, science history research, well my science history research, suggests there were two basic kinds of chemists, the "practical" chemists who were the pharmacologists attempting to discover new reactions and new substances, and who were only secondarily concerned with human improvement potions. The other kind of chemist was the theoretical chemist. The theoretical chemists were typically the rich men to whom chemistry was an avocation. This avocation thing is sort of silly I think because they held positions which required very little of their time and energy and so had a great deal of time to spend on chemistry. This is not to mention the scientists, like midwives and other people like that who were not considered one of these kinds of chemists. But anyway, Boyle was a rich avocation theoretical chemist. He wanted to prove that the universe acted like a machine, to consider the world as a great piece of clockwork. So, he studied the physical properties of air in a vacuum, by a pump built by his assistant, Robert Hooke. Now, I don't know much about Hooke, but I think this is good for now. Keep this story in the back of your minds, we will talk about it later.

Because I wanted students to understand Boyle's law before we used this story to critique the work of Robert Boyle, I postponed discussion of this story until later. I told this story up front because I wanted to express that knowledge is constructed from specific standpoints; I wanted to reintroduce the notion that not all standpoints are traditionally represented. I also wanted to set the scene for a constructive "psychic disequilibrium." As Adrienne Rich writes,

When those who have the power to name and socially construct reality choose not to see you or hear you, whether you are dark-skinned, old, disabled, female or speak with a different accent or dialect than theirs, when someone with the authority of a teacher, say, describes the world and you are not in it, there is a moment of psychic disequilibrium, as if you looked into a mirror and saw nothing (as quoted in Maher and Tetreault 1994, p. 201).

Making visible and problematic our own partial invisibilities in the mirror through examining who really is present in the gas laws, we might have a space to begin to create an awareness of who we are and how our lives connect (or not) to the science prescribed. As Maher and Tetreault (1994) write, we begin to "create a positional awareness" (p. 202); we begin to create a place to think about positionality in science.

After sharing a brief introduction of the life and work of Robert Boyle, the students and I performed two experiments which demonstrated Boyle's Law (an inversely proportional relationship between pressure and volume). The first of the two experiments, involved an Erlenmeyer flask half filled with marshmallows connected to a vacuum pump. When the vacuum pump was turned on, some of the air was sucked out of the flask and the pressure inside the flask decreased. This caused the volume of the marshmallows to increase because the air inside the marshmallows expanded. Then when the vacuum was released, some air was allowed to return to the flask, the pressure increased again, and the marshmallows returned to their normal size (refer to Figures 4.3 and 4.4).

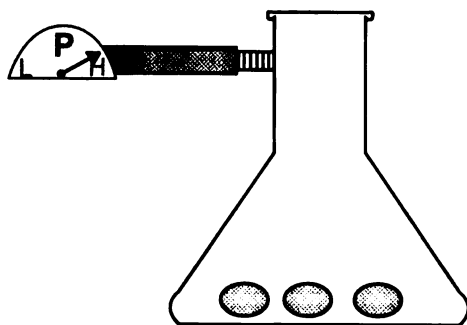
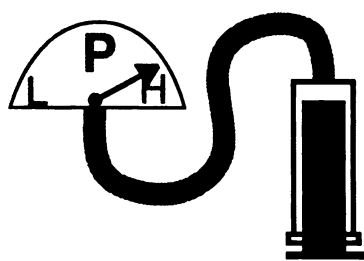


Figure 4.3
Marshmallows at High Pressure



Figure 4.4
Marshmallows at Low Pressure

The second experiment, involved a piece of demonstration equipment from the college, specifically designed to illustrate the gas laws (refer to Figures 4.5 and 4.6). It consisted of a square piece of transparent plastic. Embedded in this plastic is a pressure gauge with a mechanical dial. Connected to this pressure gauge is a thick piece of plastic tubing which is connected to a syringe, also embedded in the square piece of plastic. The purpose of this piece of equipment is to illustrate that when the volume of a system increases, the pressure decreases and when the volume of a system decreases, the pressure increases. Therefore by changing the volume of the system by either pushing or pulling the syringe handle in or out, the pressure gauge would indicate the change in pressure within the closed system.



Figures 4.5 Syringe
at High Pressure

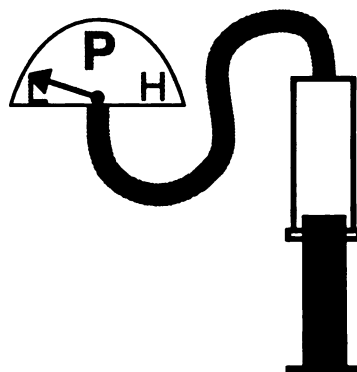


Figure 4.6 Syringe
at Low Pressure

After we did these two experiments, I asked the students to work with their groups to try to determine relationships between temperature, pressure, volume, and amount, and to

provide evidence for their claims. After discussing the experiments with the people sitting near them, many of the students appeared to deduce that pressure and volume were related, as part of our class exchange indicates:

- Gene: When you decreased the pressure in the flask, the marshmallows grew.
- Angie: Okay, what does that suggest? What does the fact that the marshmallows grew suggest? [I am writing the students' ideas on the board.]
- Gene: You said that the vacuum changed the pressure, so then the pressure effects the volume.
- Angie: Okay, do people have other ideas, explanations or other evidence from the experiments? Mary?
- Mary: I agree with Gene. First the marshmallows grew, then they went back to their normal size.
- Angie: Okay, the marshmallows grew, then the marshmallows shrunk back to their normal size. Do you think that is important because the pressure affected the volume? Okay, let me back up. What do you mean by that Mary?
- Mary: [pauses]. When you changed the pressure in the flask, the marshmallows changed size, so that means the volume changed too.
- Angie: Okay, the volume of what? The marshmallow? Something else? Mary, or what do other people think? And what about the other experiment.
- Bret: Both experiments are showing the same thing, the pressure affects the volume.

It seemed like the students were making connections between the pressure and the volume. This is what I had hoped. But, it was not clear to me if they really understood that connection or were just stating what they thought I wanted to hear (many of the students had their textbooks with them, and could very easily have looked up Boyle's law, especially while we were doing the experiments). Because I felt it was important for the students to understand the science before we could critique it or even before we could talk about its limitations, I wanted to push them a bit more on this relationship.

In response to Bret's ideas, I asked the students, if the pressure affected the volume or the volume affected the pressure or both. No one volunteered an answer, so I called on Sue, who

was quiet most of the discussion. Sue suggested that the pressure affected volume because in the marshmallow experiment we changed the pressure which then changed the volume of the marshmallows. Then Dave disagreed because, as he suggested, it was the other way around with the other experiment: "We changed the volume which then changed the pressure." Our discussion about which caused which went on for several more minutes, as I asked the class to try to find evidence to support either claim. We began to build a list of ideas on the board in order to help us decide which caused which. We ended up tentatively concluding that we could not reach a conclusion. Consensus was reached that they both influence the other, and that it depends on the situation, but that there definitely existed a relationship between pressure and volume.

I wanted the students to begin to think about this relationship through the language and ideas of atomic and molecular theory so that they would have a deeper conceptual understanding of why the pressure and volume were related, and also so that they would have a traditional foundation that we could draw on later when we went to critique Boyle's Law. So, at this point I suggested to that the class that:

we think a little more deeply why this [relationship] might or might not be the case. Take a few minutes to think about the nature of molecules, and try to come up with an explanation, a theory, as to why this could be the case. Use pictures if they help. Then, after you have at least a partial explanation, share it with your group members, and have your group try to come up with a common explanation. Then we will talk about [an explanation] for the class.

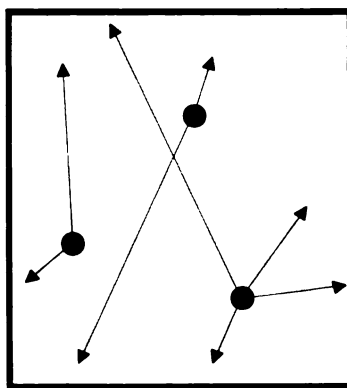
During this time the students worked in small groups of four or five students. Because the class is small to begin with, there were only three small groups. Although I suggested to the members of the groups that they work through some of the experiments in their groups as they formulated their ideas, only one group took advantage of that opportunity.

After fifteen minutes, I asked the groups to report to the class the theories which they developed. My plan was to write each group's theory on the board, and then, with their help, to draw out any similarities that would lead us to a more sophisticated understanding of the gas laws.

The first group to explain their theory was led by Gene and John (also Sue and Jake were in this group). Gene went up to the board with John. As Gene shared with the class the theory that their group created, John drew a picture on the board. Gene told the class that their group decided,

since gases are made up of particles which were in constant motion, that when the volume of the gas was forced to become smaller, then the particles would have less space to move around, and so they would hit the walls of the container more often. That would make it seem like the pressure was greater inside the container (Refer to Figure 4.7, for group 1 picture).

Gene then went on to say that this could work as an explanation for what they saw happening with the pressure and volume because it explained why the pressure decreased when the volume increased and vice versa. I asked Gene to write out his groups explanation on the board, because after all groups presented their ideas, we would return to the various theories to make sense out of what people said. I also asked the rest of the class to write any questions that they might have for each group in their notes because I wanted to wait until each group presented before we had any questions or discussions.



"Pressure on sides
on the container"

Figure 4.7 Group One's Drawing

The second group was led by Gwen (Bret, Mary, Kris and Pete were in this group too). Gwen shared with the class that when they were thinking about their theory, they were thinking specifically about the case of the marshmallow. First, Gwen said they were thinking

that when the pressure in the flask was increased the marshmallow shrunk in size and that this was because the pressure was pushing in on the marshmallow. Gwen suggested that her group thought that when the vacuum was released, more air went into the flask and so there were more air particles to push on the marshmallow and so it shrunk in size. Gwen then suggested that this theory also explained the pressure-volume relationship.

The last group to explain their theory was led by Dave, Shellie, and Laurie (Tracy was also in this group but left class early for phone line counseling training). Shellie started the group's explanation by sharing with the class that they discussed what a good theory might be and came up with a bunch of ideas, none of which she was sure was right. She then asked Dave to explain their theory to the class¹⁷. Dave then told the class that their group decided on a theory that was similar to the first groups'. He said that his group knew that the decrease in pressure caused the volume to increase—they saw this with the marshmallows and with the syringe. Then Dave told the class that their group believed that

the vacuum sucked the air out of the jar, and so that meant that the air inside the marshmallows had more room to move because the other air was not in the way. It spread out. And then the marshmallow spread out with it. And the pressure is related to this because... (turning to his group members) What did we say?

Laurie jumped in and added,

we knew that the pressure decreased because you told us that, so that maybe the pressure decreased and that is like the air leaving. And so the air in the marshmallows isn't forced to stay in the small place of the marshmallows. We were trying to think about other examples, to explain this, but all we could think of was blowing up balloons, but that is not really the same thing.

And Dave jumped back in and said, "but it was sort of the same thing because the marshmallows grew because they were squishy, you know like balloons. I mean it's not like a brick or something."

After each of the groups presented their theories and wrote them on the board, I asked the students to think about reasons why they might agree or disagree with the presented

¹⁷The gender dynamics really bothered me here. I wish I had encouraged Shellie to explain the ideas herself instead of allowing her to call on Dave.

theories or any questions they might have for the various groups about the theories. I wanted to have a discussion about them and come up with a general theory for the class to learn. My plan here, like the plan in many constructivist classrooms, was to invite debate in the class by having the students introduce their own theories for Boyle's Law rather than explicitly telling it to the students. This decision was intentional for many reasons: First, I believe that students construct their own knowledge about science, and I wanted to make that process explicit. Second, I wanted to complicate the traditional hierarchical structure of knowledge possession in science class: The teacher-scientist/student-nonscientist hierarchy. Finally, I wanted to shape the students' understanding of the gas laws around their experiences and interpretations. I could not do this without inviting their theories to be central to this process.

This discussion was slow in starting. The students seemed to be either unable or unwilling to challenge each others' theories for Boyle's Law. Gene started the conversation by saying that he agreed with all the theories because all the theories were explaining what we saw in the experiments: "Actually all of the explanations are getting at the same idea." When I asked Gene to explain what that idea was, he said that like his group said, the pressure and the volume are related because,

well it's like Gwen said, the marshmallow air grew in size because there was more room for the air, and then like we said, when there was more room for the air, they didn't have to bounce off the walls so much, and so there is less pressure. It is all connected. I don't know how else to say it.

I asked Gwen to respond because Gene used her idea. She said that she agreed with him, and that "to get back to what we talked about earlier, I think this shows that it's not the pressure causing the volume or the volume causing the pressure it's how they both cause each other, or wait, they both cause the other."

I spent most of this time calling on students to share their responses. Although this process seemed to be helpful in getting the students to be more careful, thoughtful, and thorough with their explanations, I was uncomfortable with my active role in manipulating the students into acquiring knowledge that I (the department, the institution of science?) had already

prescribed for the students to learn—what students need to learn about the gas laws in introductory chemistry. This felt contradictory to my feminist liberatory agenda, in which I felt called to create knowledge with the students that is personally meaningful and relevant in their lives while simultaneously teaching them the culture of power in science. I know that part of my teaching agenda is to weave the students' experiences into the learning of the gas laws, so that they will be able to draw connections between these gas laws and their personal experiences, or even so that their experiences will be a basis for understanding the gas laws. But, somehow, just weaving student experience into a set of predefined knowledge did not feel right. In any case, even though it was the students who were doing the explaining, and the developing of ideas, I felt like I made a decision to manipulate students' observations and experiences to insure that they would "discover" a predetermined law. This action affirms the common belief that in introductory chemistry, the students ought to learn certain things about the way chemists have theorized about the world. Because I wanted the students to have a chance to explore what they believed important about gases and the relationship between pressure and volume (not just what the book believed important), and because I wanted to learn more about what the students thought was personally important about gases. I next presented the students with two questions that I wanted them to write about in their journals:

- Why are these ideas important for us to think about?
- Can you think of some things in your lives involving gases and pressure and volume which might be good examples for what we are talking about?

After a writing period, I asked the students to share examples from their lives which displayed the pressure-volume relationship. Gwen started the conversation by sharing with the class that,

I have to agree with the last group that presented there, said that marshmallows were sort of like a balloon. But you can't add more air, so maybe squishing on a balloon. You know if you sat on it. Soon the pressure is great enough, the balloon pops. That's an example that describes pressure and volume.

John followed Gwen's ideas by sharing with the class that the balloon was also like car tires. Car tires are filled with air, and that puts pressure on the wall of the tire. Too much pressure can cause the tire to explode.

Then the conversation shifted focus. After John's remark, I asked the class for comments. Gene followed with a story of his own. He shared that pressure and volume could also be explained by an experiment like the marshmallow experiment. He suggested that if you take an Erlenmeyer flask and put a half blown up balloon in it, then it will change its size if you change the pressure in the flask. In this instance, Gene played his typical role of bringing us back to the traditional science. He seems to do that often in class. Perhaps he is thinking of his own science class that he teaches; or maybe he feels more comfortable than many of the other students in that culture of science. Gene, unlike many of the other students in this class, already has a bachelor's degree.

I asked the class to respond or to share stories of their own. Mary raised her hand and said that she really did not have a personal example, but wondered if that was reason why her shampoo sometime exploded in her suitcase when she took airplane trips. I wondered if everyone in the class has even had a chance to fly on an airplane before. I know I never flew on an airplane until I was in college. Those were the kinds of trips that my family never took. If we ever went anywhere, we drove. I wonder if our conversation is denying access to science to those people who could never afford to fly. Shellie responded to Mary that her shampoo sometimes explodes when its on airplanes too, but that she thought it was from turbulence. The conversation was momentarily sidetracked while the students and I talked about whether we had the experience of having our shampoo explode in our suitcase. I asked the class how we could find out what was going on with the shampoo. Then Bret came back with an experiment that could be used to prove Mary's situation. He said that instead of a balloon, we could put a bottle of shampoo in the flask then change the pressure. When I asked for further responses to Bret's ideas, Pete jumped in the conversation (Well, he really didn't jump in, Pete is rather subdued sort of person, I can not really see him jumping into anything. He slid into the

conversation.), and suggested that another experiment we could do would be to just squeeze the shampoo bottle with our hands and see if the shampoo comes out. He said that squeezing the bottle puts pressure on the bottle, just like the flask would, but his way was easier. But then he added, that "shampoo was not really a gas so that the experiment did not matter." So, I suggested to Pete that maybe what was also important was the air that was inside the shampoo bottle, if the bottle was not full, sort of like the marshmallow. Pete's comment suggested something altogether different. Very matter of fact: You are wasting our time sort of thing. Dave and Sue both followed Pete with stories of their own: Dave said that we could do another experiment with the syringe, maybe change the gas that was inside and see if it affected the pressure. Sue, took up Dave's idea and said we could do the same thing with the marshmallow experiment. Gene then said we could use different sized marshmallows to see what happened.

These questions that I asked only partially elicited the kinds of responses for which I had hoped. I had hoped that my questions would create a chance for students to bring their personal ideas about science into our conversation. This way, I thought we would be able to begin to explore how our lives (and therefore, our positionalities) shaped the ways in which we thought about science. It seemed like Mary's comment about shampoo dealt with the personal experiences with pressure and volume. Yet, most of the students' stories and explanations, including my own about the marshmallows were very "textbookish"¹⁸, leaving little room for either personal theories or experiences with gases to be made explicit in their ideas. Even though Gwen's and John's opening remarks about the balloon and the car tires were connected to the kinds of daily activities they engage in, their examples still seemed contrived for the occasion. These kinds of student comments suggested to me that science, to my students, was still what we read about in the textbook or at least what they could apply to the textbook.

¹⁸By textbookish I mean that the idea did not really sound connected to everyday experiences. With the case of Gene this may be an unfair statement because as a science teacher he may deal with Erlenmeyer flasks and vacuum pumps all the time.

And, why shouldn't it be? Every time we consider a new topic in class, part of my agenda this semester has been to ensure that the students have a conceptual understanding of the canonically acceptable science. When this understanding is reached, I would then use it as a foundation from which to critique science.

I hoped that by asking these questions the students would begin to value their experiences as much as the experiences of other more formal chemists. These questions would help the students begin to think about why they personally thought it was important to think about gases in their lives. Asking these questions was also important to my feminist agenda, because I wanted to make positionality explicit in class. If I asked the students to think about why gases were personally important and if we discussed how their lives and the gas laws intersected, then we might be able to uncover how our knowledge of the gas laws cuts across race, class and gender.

I felt frustrated with the direction of the conversation. Perhaps I was not making my intentions explicit enough to the students; although we were discussing scientific ideas about the nature of gases, we were doing so in an abstract and decontextualized manner. Maybe this does already suggest something about positionality. The white men were pushing the conversation back to these abstract terms. Mary and Shellie tried to think about shampoo and Pete tried to silence them. The gender dynamics seem salient here—both in terms of how discourse dynamics forced our conversation to shift focus and also in what topics were valued. Yet, social class also subtly wove its way through our understandings at multiple levels. First, Kathleen Weiler (1988) suggests that the female teacher faces the resistance and use of male privilege in boys, who of course have a vested interest in maintaining their own gender privilege, particularly if they face race or class oppression (p. 126). Perhaps this is why Pete tried to delegitimize our discussion about pressure and volume. Another issue is that the students' lives do not intersect with the kind of science going on here. Maybe science represents a world view threatening to their own classed, raced, and gendered identities and that the thought of sharing experiences in class which centralize these experiences makes students feel

too vulnerable. How easy it is for me to forget my own privilege in science. Although I do not think science has valued my experiences as a female, I did grow up in a white "upwardly mobile" family who valued the culture of education because it was a way to move forward economically.

I shared my frustration with the students: "I am afraid this is getting too boring, too abstract. Well, I feel that way anyway. And, I do not want you to think this stuff is abstract, so let's try harder to talk about it with some personal examples." I then contextualized for the students why I felt this way. I shared with them that

Because you know, when I learned this stuff in depth in college it was in a course called "Thermodynamics". And I really did not like that course at all. We kept talking about all this stuff and my teacher, he never used examples that made sense to me. Sometimes he used examples, but they were examples that well, really didn't mean anything to me. Like once I remember him talking about these cylinders filled with gases. The closest he ever came to a real example was something about a car engine or something. See, I can't even remember, maybe it wasn't a car engine. I do not know, something that was completely meaningless to me. I do not want that to be the case here. We do not have to make it so separate from our lives because that just makes it so elitist. You know, like we could never do it.

Despite my disappointment in my attempts to engage students in a more personal exploration of the pressure-volume relationship, I felt as if the students were understanding Boyle's law. Now that the students appeared to have a beginning conceptual understanding of Boyle's law, I wanted them to begin to consider some of the philosophical and historical issues related to the original construction of this law. The social and historical essence of science generally has been ignored or overlooked in science class (Rosser, 1986; AAAS, 1989) and in society. I wanted the students to recognize that "as a social activity, science inevitably reflects social values and view points...The direction of scientific research is affected by informal influences within the culture of science itself, such as prevailing opinions on what questions are most interesting or what method of investigation are most likely to be fruitful" (AAAS, 1989, p. 9). Project 2061 is clear in its mission to have students recognize this history and social construction of knowledge as a part of the nature of science. Project 2061 recognizes science as a human enterprise, yet my reading of the project's publications suggests that this is important

only insofar as it has shaped the focus of science historically—to help the students understand why we know about the things we know about. It does not, however, suggest that thinking about the social nature of science is important to locate the "bias" in its knowledge, or to make problematic the questions which have not been studied. In contrast to reform initiatives like Project 2061, I believed that this understanding about the bias of scientific knowledge could be used to recognize the nature of scientific ideology (theoretically and politically), critique science knowledge as is the case with Aristotle (refer to Introduction), and learn about how knowledge construction is driven by politics and power arrangements.

To engage students in a social-historical understanding of Boyle's law, I had a two-step approach: First we would make a critical historical exploration of Boyle's work to understand what he did and why he did it. Then we would look critically at the rest of the history happening around his work: Who else was (not) involved and why.

I began by sharing with the students Boyle's experiment where he "proved" the inverse relationship between pressure and volume. I shared with the students that Boyle took a curved glass tube, a J-tube (closed at the same level in each arm of the tube) (refer to Figure 4.7). Since the two levels were the same, Boyle assumed that the gas (air) in the closed portion of the tube was at the same pressure as the air in the open arm of the tube (at atmospheric pressure). With the confined gas as the sample for his experiment, Boyle then subjected it to changes in the pressure. He poured more mercury into the tube and observed the changes in the two levels (refer to Figures 4.8). I then asked the class to hypothesize what happened in Boyle's tube based on what we explored earlier.

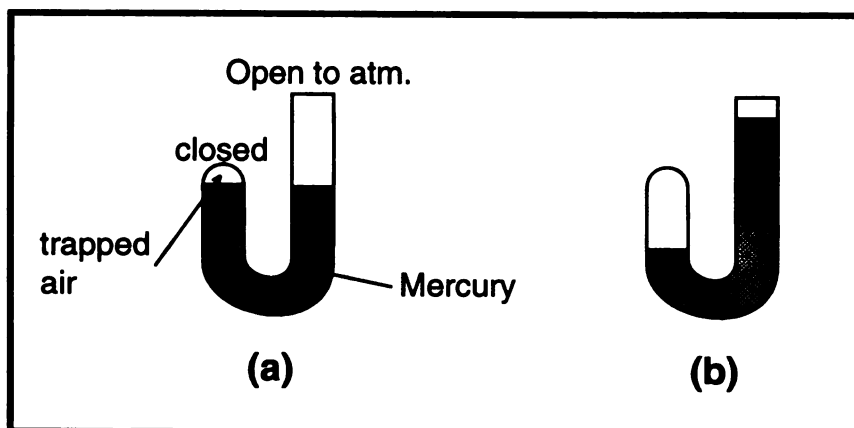


Figure 4.8 Boyle's J-tube Experiment
 (a) High Atmospheric Pressure
 (b) Low Atmospheric Pressure

After this discussion, I asked the students if they thought that Boyle did all the work by himself in order to come up with the law which expressed the relationship between pressure and volume. I felt that this shift from talking about Boyle to the work of others was important because it required the students and me to think beyond the prescribed science (and scientist) to an imagined science (and scientists). Moving outside the traditional realm of science to our own imagined science, we might be able to begin to locate new voices and ideas. The exclusionary nature of science could at once be made explicit, critiqued, and changed at least in the space of our classroom. This process would open new avenues for the students and me to redefine science and our images of ourselves in science.

Several students suggested that Boyle probably did not do all the work by himself ("some technician, what was that guy's name you mentioned" did the experiment "with him" or "for him"). I asked the students to think about why it might be the case that only Boyle received credit for the work, and why it might be the case that I was unable to locate any historical evidence that might suggest otherwise. Shellie responded to my question almost immediately by sharing with the class that

what happened with Boyle may have been the same situation as what happened with Rutherford....If you read our book you would not know that the woman helped him do experiments for the atoms, and you have to find out that

information in some old book hidden in the back of the library, like the book we found the information about the woman who helped Rutherford¹⁹.

Most of the students seemed to nod in agreement. I asked the other students to respond to Shellie's comment. Gwen immediately responded by saying that she agreed with Shellie, and that she wished that the books that we used in class would list the work of all people. She said that it made her angry that they "had to pay over \$50 for a book that is inaccurate and unfair." Then Dave spoke up. He shared with the class that he agreed that "it seemed like science could be really unfair to women and minorities but that things were changing." He reminded us that Boyle's work "took place in the 1600s and society was generally unfair to women and minorities at that time." Again I see the dynamics of gender shape our critique of Boyle's work. Two women were vocally angry that they never hear about women. Yet Dave countered their critiques to insist that was a long time ago. Although he did not explicitly state it, the implied message was clear: Things are different now! When I asked the students what they thought about these ideas, the general response was that it was difficult to learn about the work of women and minorities because of the social norms in Europe during the 1600s and 1700s.

To complicate the historical analysis of Boyle's work with the gas laws, I shared with the students the story of Laura Bassi and how her research critical of Boyle's research on the gas laws was ignored. Laura Bassi was a scientist from the early eighteenth century who tried to repeat Robert Boyle's classic experiment with the "J-tube." When Bassi repeated Boyle's experiment she received a range a results depending upon the humidity of the air in her lab. She used her results to explain possible complicating factors when determining empirically the

¹⁹When our class studied the atomic theory and the periodic table, one of the activities our class did was to try to reconceptualize the periodic table, given what we knew about atoms, what we needed to know for our lives, and what historical information we could learn. In searching for historical information to supplement the students own personal research efforts, I found an old and rather dusty book in the chemistry library. In this book, Sheila, who was reading about the discovery of the elements, found information which supported the idea that Rutherford, who was given credit in our textbook for "discovering the proton", did not carry out all of his experiments. He had a great deal of help from a woman named Harriet Brooks.

relationship between pressure and volume. I told the students that although her work was recognized by the scientific community, it was never really valued, and her ideas were never considered important in the pressure-volume relationship.

When I asked the students for personal responses to this story, many of the students shared frustrations that Bassi's work was not valued and had questions about why science is this way. As Shellie suggested:

That's really too bad. Geez, it just reminds me of what I hear all the women saying.

Or, as Gene said:

You know, just because the scientists are so elitist, they are missing out on a lot of important information. I think we have to tell students that.

And as Dave argued:

I agree with what is being said. We need to listen to what everyone says or we are going to miss out. I wonder if we might have the cure for AIDS if people listened more.

These comments made by Shellie, Gene and Dave speak clearly about how each of these students own oppression by class and gender intersect with the institution of science and how they are attempting to negotiate meaning in that context. Shellie was focused on the oppression of women in science—how these women feel. Gene and Dave are more opportunistic. I believe that the masculine construction of science shifts the emphasis for them. They appear to view the gender issue in terms of what "scientists miss out on" and on the detrimental impact that has on the advancement of science, rather than on how the women feel.

After a few moments of silence, Laurie raised the idea that perhaps the "scientists did not think that way [that science should be biased]". She referred to her oral history project on the male doctor who believed that science was perfect the way it was. Shellie backed up Laurie's statement by suggesting that many scientists get so much into their work, that they "just don't have an awareness of what going on." Gene then commented by saying that "some scientists" might feel the way we do because his oral history person certainly talked about the elitist attitude in science.

I had mixed feelings at this point. I was happy that I had a chance to share with the students the story of Laura Bassi, and that they listened. I was also glad that Gene and Shellie seemed to make connections between the story of Bassi and some themes developed in the oral histories. But, I was also disturbed by the kinds of responses which were made public including my own responses.

To me it is clear that my gendered subjectivities sensitize me to women's experiences in science and that many of the women have picked up on this theme thus far in our conversation—Shellie, Laurie, Gwen. Many of the men seem to either resist or reshape this theme by talking about these ideas from the standpoint of science's loss, rather than women's oppression. But, we are more than gendered people—there are other elements to our subjectivities which define us and our experiences in science. Any talk of race and class is absent from this picture. Instead of explicitly problematizing this issue, I chose to get the students to explore their personal ideas and experiences with science as a way to bring in the multiple subjectivities contextually. I wanted to help students to locate differences in their feelings and perspectives in science. In this way race, class and gender could be made problematic because science represents middle class masculine culture and most of my students do not.

Most of the students nodded their heads in agreement with Laurie's comment, but no one else volunteered to share an idea. Since no one volunteered I shared with the class:

I find these comments very, very interesting. You all seem to believe that science has an element of unfairness or whatever to it. I think that my ideas and some of the oral histories have helped us to see that. But I am really curious, do you think that scientists would agree with you? Do you know what I am trying to say? I mean it might be easier for me to see this because as a woman I experienced it. Or it might be easier for you as students because like we said the elitist attitude is always pushing on you, telling you what you need to know or do. But what about the scientists?

My purpose in asking the students for personal responses to Laurie's comment was to open up a critique of Boyle's law that was grounded in the students' experiences. I felt that this was important because moving the critique into the realm of the students' experiences provided the students and me with a context to construct and interpret a more personally relevant science.

Alcoff (1988) writes about the importance of cultural discursive contexts in relation to womanhood. I believe the same holds true for students' conceptions of themselves as students of science:

the identity of a woman is the product of her own interpretation and reconstruction of her history, as mediated through a cultural discursive context to which she has access... Positionality shows how women use their positional perspectives as a place from which values are interpreted and constructed (p. 434).

By asking the students to contextualize their responses with a story which challenges the epistemological traditions of science through their lived experiences, I believed that the students and I could develop a continuing awareness of how positionality shapes our learning, teaching, and using of science.

First, it seemed to me that we were still afraid to be critical of the institution of science, or to talk in a way that might point responsibility to someone (scientists? themselves? me?) to begin to change science. For example, I told the Bassi story separate from contemporary society thereby validating Dave's idea that things have changed. Shellie pointed out that Laura Bassi experienced the same terrible situation as other women. Gene pointed out that the elitist attitude in science is causing scientists to miss important information, and Dave pointed out that if scientists listened more to each other, science might be more advanced. Each of the students raised a serious and very important issue, yet no one (including myself) pushed each other to expand on their ideas: Why are women feeling this way? If things are so much better now, why is the work of Laura Bassi or other women and minority scientists not being included in contemporary textbooks? Why is it that if we want information about the female scientists of Boyle's time, we have to go to the library and embark on a research mission, whereas all we have to do is open the text to learn about the male scientists? Finally, why do these questions never come to my mind until after class is over? By declaring that things are better now and not problematizing these issues, we have denied our own responsibility, as well as that of science to begin to act differently.

I concluded our study of Boyle's Law by asking the students to think about three questions in their notebooks: How might Boyle's Law be different if the work of Laura Bassi was valued (or if the work of other nontraditional scientists we haven't even heard about been valued)? And, is it fair to call the relationship between pressure and volume, Boyle's Law? What does what we learned have to say about how fair science is?

Looking at the other gas laws

Our exploration of each of the four gas laws followed the same routine: The students and I would do several prescribed experiments, and then we would deduce the relationship. We then brought our study of the gas laws back to our lives by thinking about how all this stuff connected with our everyday experiences. We explored more carefully the relationship and the social historical context which made this "discovery" possible. Finally, I tried to bring a critical perspective to that discovery by asking the students to think about whose ideas were missing from the picture, and what this meant for the law [refer to Figure 4.9].

For example, to understand more fully Gay-Lussac's law, we first did experiments which demonstrated his law, drew our own hypothesis regarding his law, looked at his experiment and his law, looked at his life, his work, and why he did what he did, looked at work that was missing from our picture, then came up with examples from our lives. In the process of moving through this series of activities, students were able to develop a conceptual understanding of the scientific ideas behind Gay-Lussac's law while simultaneously having access to the cultural and social mores which made Gay-Lussac's work possible, and which did not allow the work of Madame Josephine Gay-Lussac to receive credit. We developed our own hypothesis as to how these social and cultural influences "bias" his gas law.

chemist	P	V	T	n	relationship	equation	historical problems	examples
Charles	S*	V**	V	S	T↑V↑ and T↓V↓	$\frac{T_1}{V_1} = k_b$	Why can we only find information about one man?	balloon on flask
Gay-Lussac	V	S	V	S	P↑T↑ and P↓T↓	$\frac{P_1}{T_1} = k_b$	Josephine GL did much of the work that Mr. GL given credit for.	soda bottle filled with water - heated and cooled
Boyle	V	V	S	S	P↓V↑ and P↑V↓	$P_1 V_1 = k_b$	Laura Bassi's complications	marshmallows tires shampoo
Avagadro	V	S	S	V	P↑n↑ and P↓n↓	$\frac{P_1}{n_1} = k_b$	Why can we only find information about one man?	blowing air into non stretchable bag.

Figure 4.9
Completed Gas Law Summary Table

Reflecting on Positionality and the Gas Laws

As I described at the end of my reflections on the distillation story, it seemed to me that it was important to think about positionality in two ways in the context of teaching chemistry class: As a teaching tool in class, and in personal reflection after class.

Positionality as a teaching tool

The first way I used positionality in teaching the gas laws was as a teaching tool. I believed that if we could begin to make our positionalities in science class an explicit part of our learning and critiquing of science, then we would be able to re-position ourselves in science and create new relationships within and understandings about science. If I asked the students to think about why gases were personally important, and if we discussed about how their lives and the gas laws intersected, then we might be able to uncover how our knowledge of the gas laws cuts across race, class and gender. I tried to highlight these efforts in my story telling.

For example, towards the end of our discussion about the work of Laura Bassi, I asked the students for personal responses to her story. In this conversation, I tried to make the students' understanding of science as women, students, nonscientists an issue by responding to the students' ideas with the comment:

I find these comments very, very interesting. You all seem to believe that science has an element of unfairness or whatever to it. I think that my ideas and some of the oral histories have helped us to see that. But I am really curious, do you think that scientists would agree with you? Do you know what I am trying to say? I mean it might be easier for me to see this because as a woman I experienced it. Or it might be easier for you as students because like we said the elitist attitude is always pushing on you, telling you what you need to know or do. But what about the scientists?

My purpose in challenging the students to rethink their responses from their standpoint as students and as women and some men was to help some of us to develop a continuing awareness of how positionality shapes our learning, teaching, and using of science.

I also learned that making positionality explicit in the teaching and learning of science is difficult because of the unquestioned acceptance of the traditional emphasis on the mastery of a specific and predetermined body of knowledge. When the students and I were discussing their theories about Boyle's law, I began to feel uncomfortable with my role in manipulating the students into acquiring knowledge that I, the department, and the institution of science prescribed for them to learn. Although I was trying to value the students' personally meaningful and relevant knowledge, I was valuing the knowledge base of western science as well as my own set of ideas. Although these two kinds of knowledge are not mutually exclusive, I do believe that they are sometimes not very complementary. I therefore felt like I would never know if the students had knowledge which was different from western science, because I established early on in the gas laws lesson that what was most important was mastering the knowledge of science. Despite the fact that I tried to ask the students to explore what they believed about gases and the relationship between pressure and volume, the students' responses were depersonalized and textbook-like. I hoped that my questions would create a chance for students to bring their personal ideas about science into our conversation—

how certain things that happened in their lives gave them insight into pressure and volume. This way, I thought we would be able to begin to explore how our positions as raced, classed and gendered people shaped the ways in which we thought about science. Yet, with the exception Mary's remark about the shampoo, the students' ideas about pressure and volume, were textbookish, leaving little room for either personal theories or experiences with gases to be made explicit. This suggested to me that my students still saw science as what we read about in the textbook.

Positionality in reflections of what happened in chemistry class

Teaching Journal 5/3/94

The end of the semester is nearly here, and I am finding myself caught up in a range of contradictory commitments. What is it really that I should have accomplished—or have helped the students to accomplish—in my role as a chemistry teacher of urban community college students, a chemistry teacher in a traditional chemistry department, and a white middle class feminist and science education researcher trying to help students feel "liberated" from what I consider the oppressive institution of science? After having taught nearly a semester, and barely muddling my way through teaching atomic theory, gas laws, stoichiometry and reaction energetics, the same questions keep emerging in my positionality reflections: Does a "new and liberatory science" need to start from the old traditional science? If it does not, then how will the students learn the acceptable way of talking about chemistry? If it does, then how will we be able to make our ideas count in the shadow of western science?

At the beginning of the semester, I had been thinking that students needed a strong grounding in traditional science in order to be able to critique science and to begin to move science in a new direction. I felt that this stance was justified because I believed that in order for the students and me to create a new science we needed to understand traditional science. We needed to be able to make decisions about where traditional science is "lacking" the ways it theorizes about women and about the world...Yet, as the days pass I feel more and more uncomfortable with this view. My students seem to understand traditional science, and they even seem to be able to begin to critique it.

In teaching atomic theory and the gas laws, I felt that we had to start by developing an understanding of the canonically accepted knowledge base in science. With the periodic table we started with Schrödinger's formulation of the atom and how it played into Mendeleev's and Meyer's reasoning for the periodic table. Then we reconceptualized the periodic table and rebuilt it in ways that were more useful and more meaningful to us. Tracy, Gene, Shellie and Laurie all told me in their own ways in their journals after our attempt as a class to revision the atomic theory and

the periodic table that they understood atomic theory (to some degree) and why the periodic table is set up the way it is and makes sense (again, to some degree). The periodic table is logical in its construction. And because it makes sense, because it is logical, they all felt that putting those thoughts to the side to come up with their own theory for the periodic table was difficult, even though they were able to work together and use each others' ideas.

In studying the gas laws, I had the students learn the western formulation of Boyle's, Gay-Lussac's, Charles', and Avagadro's Laws. We all knew that these were the acceptable ideas in science and no matter how we critiqued them, they still seemed to be more important than any personal story we could tell about them.

The students' journal writing reminds me of a conversation that I had with Constanza, a fellow science teacher and scientist. I told her that I had a difficult time reconceptualizing science with the students because I have been so enculturated into the field that I know no other way of dealing with the "make up of the world." Constanza also voiced a similar concern. "It is so hard to integrate who we are and what we believe as scientists and science teachers with who we are and what we believe as women with radical agendas." Together we decided that to reconceptualize science is very difficult and will probably take a long time because we are so enculturated in traditional science. Not only do we need to unravel (not unlearn!) the ways in which we have been taught, we need to begin to construct new ways of thinking about the same events. Even this thought is problematic: To reconceptualize the same events means that we have accepted traditional science's taxonomy of the world.

Why is it that I want the students to understand traditional science in order to be able to critique it, when many women in science, like Constanza and me, feel almost unable to reconceptualize science because we have learned it so well? Do I want my students to learn traditional science in order to critique it because part of me is afraid to undermine the great and powerful science? I do believe that science is very powerful and sometimes great. I probably would never be alive or even born if it were not for the "wonders of modern science." My mother's appendix burst when she was in her early late teens and would have died without the advent of antibiotics and other medical miracles. That is, I have been taught to believe that she would not be alive without the wonders of modern technology, but is that really true? (In 10th grade biology, my teacher asked if any one in the class ever needed antibiotics for a serious illness. When a few students raised their hands he told them they were lucky to be living in the 20th century because they probably would have died if they were born before the discovery of penicillin.) But, let's take a minute back to examine this situation. If you think about the kind of science that I would like to see in the world, a science which is more cooperative, more natural, less materialistic, and less reductionistic, who is to say that penicillin would not have been developed? After all, nuns in the 19th century before Fleming's discovery of penicillin, were using bread mold to cure infections (Stein, 1991). Who is to say that we might not have an alternative and more natural cure? Who is to say that my mother would have died without the rise of modern medicine?

I know that the argument for learning traditional science is that history has already happened and despite who created it, how and for what reasons, modern

science still exists and has many workable solutions to problems in our lives, not to mention the control factor. Modern science can even be fun and enlightening. How can students even begin to make inroads in science without the background? Yet, how can students begin to change science when the enculturation process makes traditional science so much of an unchallengeable reality?

As my journal entry highlights, I used positionality as a lens to make sense of my teaching practice. This process helped me to articulate one of the dilemmas I struggled with while teaching chemistry during the spring: Choosing whether to allow the department to prescribe science for the students or choosing to allow the students to shape science even if that meant not learning what the department prescribed. All throughout the spring semester, I seemed to act this dilemma in my teaching practice, but I could not define the reason beyond saying that "I do not know how to integrate my feminist thinking with teaching science" or "I find myself moving back and forth between teaching traditionally and teaching feministly." Using positionality to think about my beliefs and actions and my students' beliefs and actions helped me to understand in a deeper way why I felt like I was living contradictions in my teaching.

Several examples of this struggle are evident in the course of teaching the gas laws, each of which pushed the struggle in a new and more complicated direction. The first example is about learning the canonically accepted form of the gas law before looking for ways that the pressure-volume relationship exists in our personal lives. When I asked the students to share some personal experiences with the pressure-volume relationship in gases, I felt torn about their depersonalized responses. I wanted to value the ideas that the students were expressing. So, if they were expressing depersonalized and abstract ideas, that really reflect their interest. But, I also wondered if they were sharing those ideas because they thought that was what I wanted to hear. Did they really feel their more personal ideas were not that valuable? Or were they unable to think up any personal experiences which connected with the gas laws (after I cluttered their minds with vacuum pumps and syringes)? Did my choice to have students conceptually understand the western formulation of Boyle's law prevent the

opportunity for students to develop their own science about gases and pressure and volume? As I suggested earlier in the story, this action on my part may have set up a hierarchy of valued experiences where the ideas and ways of knowing not traditionally experienced in science were diminished.

It seems silly to think that our efforts to understand Boyle's law could impede our own science (whatever form that might take). But I do know that when we studied the periodic table, our decision that we could not see beyond the contemporary periodic table to construct one of our own (although painstakingly we tried). Somehow the power and authority of science managed to control us, to blind us to other possibilities for experiencing the periodic table, and later, pressure and volume. We could not seem to get beyond Erlenmeyer flasks and vacuum pumps as we created contrived situations in an attempt to explain the pressure-volume relationship. I do not deny that these situations may have been effective explanations that helped the students in their conceptual understandings of the science. Yet, I could not help but wonder if these examples perpetuated the notion that science is abstract or unmeaningful in our lives or that science is ungendered, unraced, and unclassed. This suggests to me that another reason why I felt so torn between the two agendas is that they bring radically opposing epistemologies and political standpoints. At one end I am asking students to accept a positivistic science—a set of ideas constructed primarily by and for a select group of white men and declared objective and generalizable. At the other end, I am struggling to locate with the help of the students a socially constructed science, as well as the multiple subjectivities we bring to shaping and understanding that science.

A second example which shows how I struggled between valuing a prescribed science versus allowing the students' experiences to shape an imagined science was when I tried to help the students develop a social cultural understanding of that work. In this situation, I expected the students to learn the canonically accepted form of the gas laws (for example, Boyle's Law) through exploration. I then presented them with information about the historical development of that law: Who participated in the process, who was credited with the work

and who was not, what kinds of ideas were valued (reductionistic—simple pressure-volume relationships) and what kinds of ideas were not (complex one that criticized the unrealistic and impractical situations in which pressure-volume only relationships were examined). I expected that this knowledge would empower the students to critique science—now that they knew the rest of the story!

I felt comfortable having the students listen to the story about Laura Bassi. I told the story with a few reasons in mind. First, I was looking for a way to be openly critical of some of the practices in science. We talked earlier in the semester about science having only men in it. But many times the students focused these conversations on the fact that women, during the early twentieth century were expected to work at home or other "female types of places" (not science) and that is why we never read about women in science. The story of Laura Bassi was my example of the superficiality of that argument. So I wanted to share the story with the class as a way to remind the students that there is more to this complicated story about why we read only about white European men in our text books. I wanted to suggest that Laura Bassi was very much "one of the men" in her work as a scientist—that she knew her science, was able to interpret the current research in her field, and was able to design and carry out "rigorous scientific experimentation." Yet, her work was still devalued. Was it because she was a woman? Was it because she tried to throw a wrench into the proclamations of the establishment because she refused to simplify unnecessarily (and unrealistically) the conditions for her work?

What my reflections help me to see is that I was still prescribing the science that the students were to learn. In the name of liberation, I was prescribing the critique of science they were to master. Even though I felt like I was trying to invite their lived experiences into shaping the science in our class, I was not creating many openings for the students to do so. As in the distillation discussion, I wanted to help students understand the ideology guiding the construction of scientific ideas and language of the gas laws. But I expected them to do so from the standpoint of my own experiences, my stories. I asked them to listen to the story of Laura Bassi,

but I did not ask them when their own experiences were not valued by science. I problematized Laura Bassi's gender, but I did not problematize our own. Furthermore, in allowing these subjectivities to control our own critique I did not allow any other kind of difference to also be problematized. In their absence, race and class were very much a part of our conversation. Perhaps that is why I encountered so many early problems urging the students to share experience which connected to and explained the prescribed science. My students' readings and interpretations of their own experiences were silenced and were disconnected from a liberatory science, because I was telling them how science is biased and unfair rather than allowing them to explore their own interactions with science to locate the bias.

In each of these examples, I was caught in a quandary: If I gave up my control as teacher scientist, would the students shape the science in a way that would mean a fundamental alteration of my (and the department's) original choices for what is important and useful in science class? Then again, by not responding to the students' ways of shaping their own science in class, was I implicitly suggesting that I value the science more than them, their ideas, values, and beliefs, and more than the kinds of interactions they can have with each other in class? By my actions in each of these situations, was I telling these students that western science is more important than they were?

Teaching as an ambivalent daughter

After the lessons on the gas laws concluded, I felt like the ambivalent daughter (Jacobs, 1994; de Beauvoir, 1959). Jacobs used the ambivalent daughter as a metaphor for "women's divided consciousness" (DuPlessis, 1980). The ambivalent daughter, according to Jacobs, is a woman who lives both with and against the patriarchal grain while doing both with some reluctance. In my attempts to teach chemistry from a feminist perspective, I spent a great deal of energy making sure the demands of an authoritative and patriarchal chemistry department were met. I also worked hard to ensure that the students would not accept that agenda uncritically. In retrospect, working to do both, I did neither well.

In one sense, I can say that I enacted most, if not all, of my feminist strategies. For example, to understand more fully the various gas laws, we examined them from a scientific and social-historical perspective. This process enabled us to develop a conceptual understanding of the scientific ideas behind the various gas laws. It also enabled us to examine the cultural and social mores which made such work possible and which did not allow the work of many women and minorities to receive credit (to this day). Thus, the social and cultural influences on the gas laws was acknowledged.

Yet, in another sense, none of my feminist goals were met. I felt as if I did little to challenge the traditional image of science, or to help students shake their feelings of oppression in science. Even though at the end of the unit the students were able to mathematically manipulate the gas laws with increasing success, they seemed artificially separated from our socially constructed scientific knowledge. It was not so much that the relationships between pressure, volume, amount and temperature remained abstract and untouchable, but that their place in our lives were uncertain or perhaps simply unwanted. Even though I felt the students understood the concepts, the historical development of that one concept, and a critique of history science, I still felt that my ultimate goal—to make science accessible and open to all (not oppressive)—was not even close to being met. I was confused because I thought that a feminist approach would help all students find a place in science.

My feelings of being pulled in two opposing directions is not new. I knew from the beginning that I would have problems enacting my agenda while still maintaining the mission of the chemistry department. Thinking about positionality brought this tension to the surface, and it gave me a language and a space to deal with this conflict. This tension was itself a "crossroads"—a site of multiple positions from which to rethink my science teaching and the students' science learning (Alcoff, 1988). Understanding that ambivalence becomes a "way of re-positioning ourselves" (Jacobs, 1994, p. 16), helped me recognize the reasons for my struggle between valuing western science or valuing my students. It was not whether I could or could not bring a feminist critique to class, because in either case the reality of western science is still

maintained. Rather, what was important was how (and if) I made room for the students' lived experiences to be a source of a science imagined in class. Could we find ways to make explicit our subjective experiences with and understandings of science in class as a multiple and shifting lens from which to reread science? For example, my agenda helps me to critique the patriarchy of science from the outside, but my privilege of being white and educated allowed me to critique race and class from the inside. We all needed to learn about each others' subjectivities in order to deconstruct science.

Jacobs captures this idea about ambivalence as a way of repositioning and imagining the world:

Coming to see things differently, we are able to make out possibilities for liberating collective action and for unprecedented personal growth, possibilities which a deceptive sexist social reality had heretofore concealed" (Bartky p. 21). At the crossroads, the personal and the political necessarily intermingle. By claiming—rather than meekly relinquishing—our divided consciousness, we retain our integrity as women committed both to living the contradictions in our lives and transforming debilitating patriarchal practices (p. 16).

Reflecting on this tension leads me to a fundamental question: Do I value the lived experiences and ways of interacting in the world that the students bring to class or do I value the methods and processes of western science? I believe that much can be learned from both and that there are sometimes driving connections between the two. But by choosing one way over the other (as I did in the class on the gas laws), I engaged in the politics of hierarchical dichotomies. I hierarchically placed the experiences of "real scientists" as more important than my students!!

To address this conflict, I find it helpful to think about my ultimate aim of the unit on the gas laws from a feminist liberatory perspective. Can that liberatory aim can be reconciled with the written goals of the chemistry department at the community college? I need to think harder about whether this is a unit about learning facts and theories about a particular area of science or whether it is about something else. The course was constructed (as evidenced by the text, the common syllabus, and department faculty) around learning facts and theories in

science²⁰. The focus, as emphasized by the department, is on "pure" scientific knowledge. Even in my own class, with my choice to introduce a feminist critique into learning the gas laws, the main emphasis was on learning (conceptually understanding) a prescribed scientific knowledge. What if I shifted the emphasis from learning a prescribed scientific knowledge to looking explicitly for ways and places that other ways of thinking and knowing intersect with the science? This idea connects to my belief that most important is the participation of all students and the recognition of their ways of knowing and doing rather than the recognition of the prescribed science. What if I genuinely allowed the students to revision chemistry through their own lives to promote this engagement. Of course this means that I would have to give up the authority I hold as scientist and teacher to define for the students what is important in science. Yet, this may help to shift the relations in our class so that the students' positionalities are more valued and central.

Thus, I have come to understand that despite my feminist intentions, I still maintained the authority of science over the authority of students. Even though I purposely tried to align myself with the students by sharing my frustrations in science as a female, I still held on to my role as teacher-scientist, always moving forward towards that "unadulterated body of knowledge". Even though I purposely tried to align with the students by sharing stories of other peoples' oppression in science or particular theoretical critiques of science, I still devalued their lived experiences in light of the experiences of science. Now that I know this, how will that play out in my teaching in the future in terms of what and how I teach?

²⁰The definition of learning is debatable and is clearly different across sections (it ranges from memorization to conceptual understanding). A good example is the discussion about the "cheat sheet" that we had over the course of several department meetings. There was a motion that the introductory chemistry teacher allow their students to bring to all exams a self designed 3x5 notecard filled with formulae and other important information. Some teachers thought that these "cheat sheets" would be helpful for students because that way they can spend their time learning how to manipulate the equations as well as develop a conceptual understanding of the science involved. Other teachers believed that part of learning science is learning the formula. Students would have the option of memorizing the formula or conceptually understanding them so that they could derive them on their own during an exam. After 3 department meetings, a vote was finally taken and the decision to use cheat sheets was defeated.

Looking forward to teaching the gas laws again

In this chapter, I explored how I introduce my position in the classroom and whether that leaves room for students to explore their own positions. But, I am left with many questions. What right I have, as a teacher, to bring my political agenda into the classroom with the expectation that students will (want to? need to?) take it seriously? Are my attempts to construct a more liberatory teaching and learning setting through the exploration of positionality an act on my part to force my own agenda "down their throats?"

Furthermore, what can be said about my agenda and my authority to impose that agenda, especially when I believe that the unwritten, unexamined, unchallenged agenda in science education is overwhelmingly patriarchal, white, middle class? What happens when students have learned to assume particular positions in patriarchal white society? In the distillation lab and in the class on the gas laws, I wanted the students to understand the role that dominant ideology plays in the construction of science. This focus seemed to me to be deeply connected to learning science. I do not think that the students saw this connection.

I need to reexamine my primary task. Education produces political people, and so, it is not teaching subject matter knowledge which is ultimately important as those in the dominant chunk of society would have us believe. Rather it is in helping to shape a "public sphere of citizens who are able to exercise power of their own lives and especially over the conditions of knowledge production and acquisition" (Giroux, 1991, p.50). I am again reminded of the work of Paulo Freire (1989/1970):

But almost always during the initial stage of struggle, the oppressed instead of striving for liberation, tend themselves to become oppressors or suboppressors. The very structure of their thought has been conditioned by the concrete, existential situation by which they were shaped. Their ideal is to be men [sic]; but for them, to be men [sic] is to be oppressors. This is their model of humanity (p. 29-30).

In reflecting on my teaching of the distillation lab and the gas laws in the spring, I developed new goals for my science teaching in the summer. Choosing science (as it is currently conceptualized and acted out) as the primary guiding task is just like encouraging the oppressed

to be like the oppressors in the name of liberation. If the ideal is to be scientists without critically rereading our own experiences in science, then the ideal is to teach students to oppress. As I planned to teaching the gas laws again in the summer, I looked for ways for the students and I to value our lived experiences and the knowledge we create from those experiences as we seek to make sense of the physical world. I looked for ways for us to reread critically our interactions with and in science as we search for a science imagined.

PART II. TRANSITIONS

Part II (Chapters 5, and 6) of my dissertation describes transitions in my thinking about positionality and feminist liberatory science education. During the summer I continued to reflect on what occurred in the spring through listening and transcribing tapes from class, by writing about the oral histories component of the course, and having a series of extended conversations with a small subset of students from the spring evening section. Through this process I began to wonder if the original intent for my dissertation failed to express the complexity of positionality. I take this opportunity to revisit my teaching and reflections in the spring from the vantage point of looking back with new knowledge about a more multifaceted understanding of positionality. In this set of three chapters I try to reread "what happened" during the spring with growing complexity.

Chapter 5 looks at excerpts of "oral histories" conducted by my students throughout the spring and summer semesters. I analyze these oral histories as a way to highlight how reflecting on my teaching and reflecting on the idea of positionality has helped me to explore events in my chemistry classes which offer hope for a feminist education. It also examines how the three themes developed across time in the oral histories in the spring semester and how these themes (elitism in science, human element, and political nature of science) wove their way into our relationships with the subject matter knowledge in class.

Chapter 6 explore a series of summer conversations with a small group of students from the spring and how they helped me to rethink classroom events. In this chapter I reflect on how these summer conversations helped me to see how I was using the agenda of western science to undergird my feminist teaching. My initial understanding of positionality did not allow me to realize this because I was looking only at positionality as something static—that positionality is an unchanging set of characteristics that one brings to the classroom. I was not looking at how different people's positionalities interacted with each other as they engaged in

relationships in the classroom or how the power differentials involved in teacher-student or scientist-nonscientist relationships shape and inform what we do. When my students helped me to see how I was defining my agenda through the eyes of Western science, it was a push for me to think about redefining the role of positionality in feminist liberatory education. In addition to looking at the positionalities brought to the classroom, I needed to look at the "moving relationships" that were created in the classroom.

CHAPTER 5

Creating spaces of radical resistance in science class:

Learning about ourselves through oral histories

bell hooks (1990) writes that choosing the margin as "a place of radical resistance" creates possibilities for disrupting hegemonic reality, because it offers a vantage point outside of mainstream culture from which to interpret the world. What does it mean to find or create a place of radical resistance in science class, and what does it mean to disrupt hegemonic reality? Will disrupting status quo reality help us to create new and personally relevant ways of thinking about ourselves in science, or will they leave us feeling more silenced than ever? What is required of teachers and students as gendered, classed, and ethnically diverse people if such radical vantage points are to be constructed in science class—inside the walls of the institutions of science and education?

In this chapter I explore my own and my students' attempts to find and create places of radical resistance in science class through "Oral Histories." The most empowering conversations in our classroom occurred not during discussion about chemistry or about feminist critiques of science but during our discussions of the oral history projects. These projects gave us to the chance to socially constructed ideas about science which valued and embodied the complex and contradictory locations of our lives. Discussing the lives of women (and men) in science who have been disillusioned in and unfairly treated by science as well as successful, gave us a language—some theoretical tools—with which to rethink and rewrite our own experiences in science. They gave a reason and a context in which to disrupt the neatly packaged hegemonic reality in and of science. The creation of these spaces pushed on the

boundaries of western science, and as a result, as a community, we were able to begin to decenter the traditional power arrangements in science. We were able to reposition ourselves in science. These attempts to create places of radical resistance influenced my personal reflections on positionality and its relationship to power, knowledge, and privilege in science class.

Oral Histories

Background

As a part of course requirements, students were asked to do an "Oral History Project", in which they were to have a conversation with a local community member to learn more about how science, and in particular, chemistry, has influenced her/his life in both personal and professional ways. The reason for introducing oral histories into chemistry class was to begin to make the practice of chemistry less abstract, to broaden the definition of science with which students come to class, to broaden the definition of chemistry practiced in class, and to connect the theory of the classroom to practice. The ways in which the oral histories influenced our conversations, decisions, and actions in science class were more complex than my original intent. Beyond the original goals, the oral histories helped us, as a class, to "stand up" to the institution of science by creating spaces from which to make positionality an issue in science, by making public our ideas about what it means to know, do, think, teach, and learn science (many of which were critical of traditional ideas about the nature and culture of science).

Several themes developed which enabled us to stand up to science: The human element, elitism in science, and the political nature of science.

Students were allowed to choose a candidate for their oral history, although a list was provided for them in cases where they felt unable to distinguish an "appropriate" member of

the community.²¹ Exceptions were made for a few students to present the work of a person based on library research rather than personal conversations. Most often students chose doctors, nurses, pharmacists, chemists, biologists, and engineers, but some students also chose jewelers, goldsmiths, highway construction workers, gas main excavators, teacher educators and fire marshals among other "non-science" professions. Before students interviewed their person, they were required to construct and share with me a list of ten to twenty questions they would like to ask their person. Student questions were to be drawn from questions or concerns they have about the nature of chemistry, how people use chemistry in their jobs, what excites, mystifies, angers, disappoints these people about chemistry, what is it like to be a woman or minority in chemistry (if applicable), and how these people would change the practice of chemistry if they could. Each day, at the start of class, a different student would share main ideas from their interviews/conversation. This presentation was then followed by class discussion²².

Shellie's Oral History: Reporting on the life of Lisa Karms, a woman biochemist and science educator

The fifth week of the semester, Shellie's turn came to share her oral history with the class. Shellie is a young white mother of two children, who has returned to school after a ten year absence. Currently she works as a receptionist for a community doctor in order to help her family "make ends meet." She has started a part-time (evening) program at the community college so that she can earn a degree in psychology and one day become a counselor. From the very first day of class, Shellie has been vocal about her dislike of and perceived inaptitude in

²¹I prepared the list to ensure that a range of perspective were represented. The list was biased so that marginalized perspectives in science were represented more than the mainstream. I included several feminist (and other critical) scientists on the list. It contained mainly women and several minorities. (Percentages of women and minorities that were well above the percentages of practicing women and minority scientists). Also, each person on my list agreed to participate.

²²Students were also required to write a 2-3 page paper on their oral history (most students just summarized questions and answers).

the study of chemistry, although she believes the school is probably justified in "making" her take the course as part of her plan of study.

Shellie was only the third student (out of fourteen) to present her oral history this semester²³. Her oral history project was on Lisa Karms²⁴, a local biochemist who does cancer research, and who also studies science education. Shellie began her presentation by informing us that before she began her project, she "dreaded" having to do an oral history project. She felt intimidated to talk with a person who was "much brighter in science" than she was. She confessed that her apprehension turned out to be unfounded, because the woman she interviewed was personable, down to earth—not at all like a scientist—and was also able to talk about the science she practiced in ways that Shellie did not find intimidating. Shellie then shared with the class that she actually enjoyed the oral history: "...we really only had only a little over an hour to talk and I could have talked with her the whole afternoon. It really went by very fast. But I did enjoy it and I think you guys [sic] will enjoy talking to your people." She added that talking with Lisa even made her "kind of excited about science."

The initial focus of Shellie's oral history presentation was a biographical portrait of Lisa. Shellie described Lisa's life growing up in a working class family in Michigan's upper peninsula, and the various influences on Lisa's decision to study biochemistry. She also described Lisa's cancer research. She talked about how Lisa fed mice low fat-controlled and high fat-controlled diets, and monitored the physical development of the mice for early signs of cancer. Shellie also expressed how tedious and slow Lisa believed her work to be, the frustrations Lisa felt as a scientist because she felt "like, if you have not gotten your years in or your time in you probably don't know as much as the rest of us," the dissatisfaction Lisa had with the lack of free time outside of science (if she wanted to be recognized as a competent and

²³Before Shellie, Tyrone shared his report on the pharmacist who works at the same place where he is employed as a custodian, and Dave shared his report on a fire safety manager who also works at the same place where he is employed as a line worker.

²⁴All names of oral history people who were interviewed (as opposed to those who were read about) are pseudonyms to protect identity.

dedicated scientist), and the self-consciousness Lisa felt as a "woman in white male-dominated science." Finally Shellie shared with the class Lisa's profound disillusionment with science.

As Shellie told the class,

One thing [Lisa] said when I really picked on her . . . she was very disillusioned with science. She said the hardest part for her was there didn't seem to be a wholistic kind of science, it was broken down into such small units that it didn't seem to have any humanness to it. What she is doing now, she said that she feels comfortable because she is looking at the whole. She is studying something that she feels is very useful.

Shellie then ended her presentation by repeating to the class how much she really did enjoy talking with Lisa and how she was excited for other members of the class to do their oral history.

Because Shellie was only the third person to share her oral history, there was no established routine for moving from the student's report into discussion and then into the subject matter. I hoped that the students would be so intrigued by the ideas presented in the oral histories that a whole class discussion would "naturally" follow, but as was the case with Tyrone's and Dave's presentation, the class sat in silence after the students finished their reports, I think, waiting for me to move on with the course.

So, after several minutes of silence I asked the class if there were any questions or comments. Shellie made provocative statements about the nature and institution of science, and I was surprised when my request was met with silence. Perhaps this was my imagination—my apprehension—but the silence following Shellie's presentation seemed different than the silence following Tyrone's or Dave's report. The students did not look in my direction when I asked for responses. This made me nervous because at least after Tyrone's report, after a little cajoling, the students wanted to know "what a pharmacist was," "how much chemistry a pharmacist needed to know" and "if a pharmacist mixed chemicals in the back of the pharmacy." Today the students appeared to not want to know anything.

I did not want to lose the wealth of emotion and critique presented in the report, so I used the students' silence as an opportunity to have them respond privately in their journals.

Angie: No one has any questions? [pause] I have a question for the class that I would like you to respond to in your journals. . . . the words that Lisa used were that she felt disillusioned in science. Shellie just shared with us that Lisa said that science did not seem to be a wholistic thing but it is broken down into units. I am very curious about that comment and I will write it on the board in a minute. What do you think about that comment and how do you think that it will affect you as you pursue your career in science or health? Think about that comment for the next few minutes and write down some thoughts in your journals. Respond to this comment in connection to some of your experiences in school or in your job, and in particular how it connects to this class. For me, I just want to try to think about what science is and how I can represent it in this classroom so it won't seem, you know, so alienating or so uhm cold, even though sometimes I think it is.

Shellie: You know one thing that I wanted to add, that I was quite excited about, since I have children, was that Lisa was saying that there was real interest in making science understandable. There are now, we talked about how chemistry is so difficult and why we couldn't make it easier and she did mention that she felt that a lot of the people that she worked with felt like they had to go through the tough knots, so you have to go through the tough knots. It wasn't easy for me and its not going to be easy for you. She said that there is a new wave that is going on now with a lot of books coming out with a lot of experiments that is really making chemistry something that is understandable to younger kids so that when they get older and they are doing their harder studying it will be easier. The whole concept makes sense. I think that is the hardest part. We have all these things that we are doing and you kind of wonder, how do we make sense of this all? So it was kind of exciting.

After Shellie's comment, I wrote on the board a phrase Shellie used in her report to which I wanted the students to respond in their journals (as best as I could remember it):

Lisa is very disillusioned with science. She said the hardest part was that there did not seem to be a wholistic science—it was broken down into small pieces so that there was no humanness to it.

I chose this phrase because it connected well with my own experiences as a chemist, and I thought it might also connect well with the students' experiences learning chemistry in school or experiencing science outside of school. I also considered the phrase a good starting point from which we could begin to critique the nature and institution of western science. I was not sure how students would respond, or even interpret Lisa's ideas as they were presented by Shellie, because I could not assume that they possessed either the vantage point of "living in science as a woman" as had Lisa or myself, or a knowledge and understanding of the major critiques of

western science. Yet, I felt this quote was appropriate because of the alienation in science many of the students expressed on the first day of class.

The silence surrounding the journal writing was broken by Shellie said out loud to me,

Shellie: Did I tell you that I made carbon dioxide candy last week?

Angie: Carbon dioxide candy?

Shellie: I was going to bring some to class.

Angie: What is carbon dioxide candy?

Shellie: It just kind of foams all over the pan and then you, then you, you don't have to, but you can put chocolate all over it.

Angie: Well, can we make that in here? If I brought a hot plate or something?

Shellie: Uhm hum, I think so.

Gene: That's a human element of science!

Shellie: Really! We all can relate to that!

Angie: What are the ingredients? And, why is it called carbon dioxide candy?

Shellie: It has vinegar and sugar and you just like mix it. I'll bring in the ingredients.

Angie: I'll bring in a hot plate.

Shellie: Wait a second, it has to get up to a temperature of 315 degrees.

Angie: I wonder if a hot plate can get that hot. I don't know?

Gene: Do you do it in the oven, or do you do it on the stove?

After this short interchange, Gene, Laurie, and Shellie moved their chairs together and began to plan how they would make carbon dioxide candy next class meeting. The other students quickly ended their own journal writing and began to talk with each other. At this point I wondered how I could begin a conversation with the students about the issues raised in Shellie's oral history. In many ways and at many levels, the conversation already started: There initially was silence. Then later, some of the students were discussing the possibility of making carbon dioxide candy in class as a way to incorporate the human element into science class. I had not explicitly asked the students to write about the human element in science,

although Shellie did describe Lisa as a biochemist whose disillusionment with science was partly rooted in the lack of the human element in science. The "human element" also was included in the quote I wrote on the board. Is the human element where the students located their own disillusionment with science or with school science? I needed to ask Gene, Shellie, and Laurie to describe what they meant when they indicated that in-class candy making brought the human element into science so that I could understand how they interpreted the scientific enterprise. I also wanted to learn more about what they meant by the human element so that I could try to position our classroom talk in a way that would help us to critique the science defined and prescribed for us in this class and in our lives. But first, I thought I would open the floor to the ideas the students just spent time thinking about in their journals.

After I asked the class if anyone wanted to share what they wrote, there was a short, silent pause. The students look around at each other. I was getting ready to ask Shellie, Laurie and Gene to talk about their decision to bring the human element into school science through candy-making when John nervously volunteered. John is an older white student who works full time during the week as a home health care provider who delivers oxygen equipment to people with respiratory ailments.

John: I will.

Angie: Okay, John.

John: (tentatively) I don't know if I wrote what you are looking for.

Angie: (emphatically) John, I am not looking for anything in particular! I just wondered what people were thinking about that comment.

John: Okay, well I've been dealing with respiratory therapy for the past four and a half years and it's all an interrelated thing. It's a human related thing, and anything technical it is more or less just in my head. But, in relating with the people, I eliminate the technical part and rely on a bedside manner, you know, the human element is everything. And the science part of it, it's really all in here (he gestures toward his head). It's just brought out in how I do my job, but it's never related to the people. Okay that's one part of it, but now as I was just thinking about it, I used to work in a chrome plate factory, and I worked as a lab assistant and that was a really neat job. The thing about it that was neat was that they used electrically charged probes down in a solution to chrome plate parts and stuff. And come to think about it up until recently, how much that relates

to what we are doing and how I used to mix chemicals in the lab, and we dealt with a lot of nasty stuff. Six months on the job and I quit. There was no human element, but, I got to learn how the electrical aspects of it works, chrome bonding to metal, and I don't really remember, it has been quite a while but it was a nasty job. It was dangerous.

John, too, has been drawn to the need for a human element in science. From previous class conversations, I know that John enjoys his work in home health care—he is in a Respiratory Therapy certification program at the community college so that he can take on more responsibility at work. Is the human element what he has found in his current job and what keeps him there? Was it the lack of the human element which drove him away from his work at the chrome plate factory? I was curious to learn more about how the human element is either included in, or missing from science, so that we can use this avenue to explore and critique our own connections to, and alienation from science.

Angie: John, you said that you leave the science part up here, and you rely on a bedside manner because it's all sort of the human element in your job. Do you find that you take that science part and sort of, do you talk about any of the technicalities with your patients? If you do, how do you weave in the human element?

John: I try to explain certain aspects if they ask, in layman's terms so to speak. You know, you can't get too technical there, but they really appreciate it, you setting them up, setting their minds at ease. Most of the people are elderly, and they need oxygen for their heart, and they don't understand how the machine brings oxygen.

Shellie: Are a lot of the older patients scared of the machines?

John: At first, they are afraid to lay down and go to sleep even though it is perfectly safe. Some people ask, they want to know what's going on, how is this really helping? And, what's going on with their lungs and their heart. And most people don't ask, they just want to make sure that you are there, that you are doing your job, and they appreciate your work.

Connecting people and their everyday struggles and activities to science, and using science to alleviate struggles seems to be what John means when he describes the need for a human element in science. It seems like John's idea of the human element refers to the ways in which science is used for and related to layfolk. Although I wanted to learn more about what John was thinking, I wanted to give the other students a chance to respond, and I wanted to hear from some women. Did Lisa's comment about being female in science help the women in the

course draw connections between their own personal experiences in science and any "disillusion" with science?

Angie: Does anybody want to respond to John, or to share what they wrote?
Laurie?

Laurie: Mine's not really what I wrote, but I just interviewed my person and he is a full professor and he does a lot of research. He is in charge of a collaborative research team, and I was really disillusioned in terms of the human element with some of the things that he said. He is doing research related to genes and cancer and things like that. I thought that would be rewarding enough, and that would come out in the interview, but he talked about the monetary aspects and that bothered me because he said that society does not place enough value on those things. He said we pay people in sports and performing arts, we have all this money, but we are not paying people in research, and that kind of bothered me.

Angie: So he believes he deserves a bigger salary for himself?

Laurie: Yah, that bothered me because what I thought what would come up in our conversation was the human aspects of his work, but it was more of the idea that this was valuable to society and you should pay us more. You hear sometimes that the doctors are only in it for the money, and then you interview somebody like this and it makes you wonder.

Gene: If you think about what scientists do, scientists try to solve problems to make life better for you and for me. I know that is debatable though, but what I want to point out is that sometimes the science that scientists do and science in the classroom can be different. Sometimes in class we don't do the experiments that scientists do, and so the human element can be removed easily. Unless we are using our hands and our minds like scientists while we are in class by exploring, doing some hands-on science, then it will be hard for the human element to be there.

In terms of the need for a human element in science, Laurie and John raise different questions than Gene does. Laurie and John appeared to be concerned with engaging in science for purposeful reasons, to make life better for people. In that sense, science is an intentional and powerful activity. Science shapes lives, and as such we need to make the human connections central to thinking and doing science. Laurie seemed bothered by the clinical researcher who wanted to do science for recognition and money. She appeared to want and expect a deeper and more personal human involvement and attachment in science and an overriding sense of caring about the ultimate uses of science. John seemed to be bothered by an indirect connection between science and human life (or at least "important" connections). I see these comments as very

powerful beginnings to a critique of science. These ideas are ideas that I wanted to try to help students think about more seriously.

Gene, on the other hand, possessed a different view of the human element in science, and this helped me understand his comment about the candy. He seemed to believe that the mere act of "doing" science (as opposed to talking science) makes the human connection, brings in the human element. It appeared that Gene supported more of a mainstream idea about the human element in school science—hands-on activities create a human science in schools. Laurie, and to some degree John, were more critical. They began to ask about motives for, as well as ethical implications of doing certain kinds of science.

After I learned about how the students were thinking about the human connection, I wanted to explore the reasons behind the need for their questions (why is science so humanless, so powerful anyway?) because some of these questions—like Laurie's and John's—involved the kinds of talk which is usually avoided or rationalized in science class. I began to see that the students came to this course with their own critiques of science and of school science. I wondered what it was about the experiences that Laurie and John and Gene brought to the course which helped them create the particular critique they did. I wondered if Laurie's experience as a woman and her job experiences and John's job experiences led them to be more critical of science than Gene. I hoped that by having oral histories of people whose ideas and work have traditionally been silenced in mainstream science, we would create a space for the experiences of all students to be a part of our developing vision of science.

Angie: Then does our talk about making the rock candy [sic] fit into this conversation? Would anyone like to comment?

Shellie: Well, when I talked with Lisa, she said that all the scientists that she talked with all had a different personality. To be in a laboratory, all alone with just these little mice, all these people are working by themselves. She said she has been in situations before where down here they will be working on an environmental project, and over here they are working on a genetics project, and its like this guy doesn't ask this guy about anything. She was saying that one guy wouldn't even borrow anything from the lab down the hall. Maybe there are different personalities which go into different professions. If you like to be alone, and think about things, then you go into science.

Angie: But should you have to be that way to go into science? You know, I think you raise an interesting point because when I was working in a lab on transition states of a particular reaction, there were other people in the country working on the same research, but we wouldn't talk to them. If we gave them our ideas, they might get the answer first.

Shellie: I know it is very competitive.

We ended our discussion by my sharing with the students how this competitive nature of science has influenced some of the work done in science in ways which discriminated against women. I told them the story about Watson and Crick and how their drive to determine the structure for DNA led them to "steal" Rosalind Franklin's work in crystallography. I also told them how Rosalind Franklin received little credit or recognition for her work, even though Watson and Crick had won the Nobel Prize.

Theme 1 - the human element

Shellie's presentation about the dilemmas and struggles in science experienced by Lisa appeared to be an authentic public acknowledgment (by a "real scientist") that science is not always good and not always right. Shellie's descriptions of the experiences of a practicing scientist also seemed to substantiate many of the students' experiences and feelings of disillusion in science and desires for exploring the need for a human element in science. The conversation surrounding Lisa Karms' experiences seemed to connect with most of the students at a deep and personal level, thereby allowing them to come forward with their own beginning critiques of science from the standpoint of their own experiences.

In this sense, the conversation about the oral history of Lisa Karms marked a turning point in my own thinking and teaching: Many of the students, like Laurie, Shellie, and John began to stand up to science—our muddled experiences as people who do not fit neatly into the mold of the mythical white middle class masculine scientist had something powerful to say to science. Our experiences outside of science both physically and ideologically as well as our experiences of having our lives partially inscribed for us as women and working class people

found ways to begin to transgress the imposition by science. As I learned later in the semester, our talk here—our talk of our personal lives and beliefs about science—carved a space for our own theories and visions for the world to be voiced and later to be used to critique science. I also began to understand the need to start a feminist critique of science based on the experiences of my students, not with the theoretical, abstract and often essentialistic literature. For example, throughout the first four weeks of the semester, the students and I only talked indirectly about feminist critiques of western science. In situations where we did begin to explore feminist critiques of western science, we did so only by looking at small pieces connected to specific ideas we were studying. I also tried to share with the students various "theoretical" elements of feminist critiques of science: Science is reductionistic, authoritarian, and falsely viewed as objective. It is intentionally removed from human experience and emotion as often as possible, because such connections diminish its objectivity. Furthermore, those in power in the institution of science have made the induction, advancement, and recognition of women and minorities in science difficult and often times impossible. Yet, every time I raised these issues, they seemed to hit a brick wall. I mean, my students, with the exception of Brian or Pete, never gave me trouble, never challenged my ideas as being far out, strident, or flat out wrong, yet they never seemed to connect with them or take them seriously either. (Pete and Brian always seemed to have reason to contradict my ideas critical of science. They always seemed to have evidence for why we all ought to believe in science the way it is. And, they always presented that evidence with a sureness that I could never mimic, a sureness that I never want to mimic.) I was unable to move the conversation beyond my own ideas, and I also never seemed to be able to move the conversation past the theoretical, abstract level—even when I provided examples of such critiques. In short, these sorts of actions and decisions which I promoted did not really provide the class with an opportunity to discuss critiques of science explicitly, or in connection with our lives. I had been talking and thinking about these critiques in a theoretical, abstract way, as if to suggest that bringing critiques of science and science education into class, without acting on them, would bring about feminist education, and would "liberate" my students.

Therefore the conversation following Shellie's oral history marked a beginning of a set of interesting conversations, and a change in my own thinking about feminist science education.

After this discussion, I remember feeling for the first time that the class began to question more seriously the status and role of science in society and schools as well as the status and role of women and the feminine in science. It also appeared that we began to use our own experiences in connection with Lisa's story, to form public critiques of western science. These emerging critiques of science were constructed around the theme of disillusion with science because of the lack of the human element.

After the first two oral history presentations, I was depressed because it seemed that all the students discussed seemingly apolitical issues: The kind of science the person practices, what the person does on a daily basis, and how the person enjoys science. At the beginning of the semester I hoped that the collection of oral histories would encompass a continuum of perspectives, so that perspectives which challenged our views would be expressed. After the first two reports, I was worried that this was not going to happen, and I wondered how I could intervene. The report on Lisa Karms, because it was different from the previous two reports in that it did not perpetuate a sacred and unproblematic positioning of science in our society, appeared to introduce new and critical ideas into the class's on-going conversation. For this reason, after Shellie's presentation, I chose what I considered to be one of the most provocative quotes and pushed the students to think about it. Also for this reason, I chose to respond to the ideas raised by the students which were critical of science to force these taboo issues to be recognized by the members of our class, including myself, even when it was uncomfortable. For example, this is why I, later in class, provided the students with the concrete example of Watson and Crick.

Looking back on this conversation, I can see that one reason why this conversation was a turning point for our class and for my thinking is that Lisa's disillusionment with science and her need to find a human piece to science created a space for us to speak critically of our own connections with or disconnections from science. Her experiences as a "real scientist" were not

the glorious and trouble free "I LOVE SCIENCE" experiences that were implied in the first two reports or through a lifetime of media sound bites. Lisa, a Michigan native, educated at a local university, working on a relevant research project for many students (cancer research), was candid about her critical stance towards science. Shellie, Laurie, Gene, and John (in class), and Tracy, Gwen, Tyrone, Dave, and Mary (later in their journals), were for the first time openly critical of their science experiences in a way that went beyond, "I don't like science," or "I can't do science." They wrote and talked about how the science prescribed for us did not match their own visions of themselves or the world.

Reflecting on this conversation, I also learned more about how "positionality" can contribute to liberatory education. As many of the students and I talked about ourselves and about science, we formulated new ideas about who we were in science class, what we knew and what we wanted to know, and where we fit. We found spaces in our conversation to value our lived experiences, even those which were not validated by traditional science. This kind of talking and thinking in science class works to help students construct new meaning and relationships with and in science.

Laurie's Oral History: Reporting on the life of Kurt Phillips, a representation of western science.

Laurie, a married woman in her thirties, presented her oral history during the class following Shellie's presentation. Laurie worked as a computer/data base administrator for a local medical research company. She was not completely happy in her current position: She felt she was not respected. For example, about one year before enrolling in this chemistry class, she almost lost her job because she was pregnant. She was told it would have been too expensive for the company to offer her a six week maternity leave. She was able to keep her job, because she agreed to a shortened maternity leave. Laurie, like Shellie, also started a part-time evening program at the community college. Her goal with this program was to

eventually attend optometry school, because she wanted to be able to work more closely with people.

Laurie did not enroll in our class until the third week of the semester. Her late enrollment was due to the fact that she originally enrolled, at the suggestion of her advisor, in the chemistry course a level ahead of the one I teach. After her first quiz in the course (where she received a slightly below average score), her teacher recommended to her that she drop to the introductory course. Since Laurie joined our course, she expressed an intense fear of the study of chemistry, and was quick to put down her efforts and abilities in chemistry.

Laurie introduced her oral history candidate, Kurt Phillips, (Dr. Phillips, as Laurie referred to him), by sharing his credentials with the class. Dr. Phillips, a clinical chemistry researcher and professor, with advanced degrees, spends eighty percent of his time in private research practice and twenty percent of his time as an Associate Adjunct professor at the local university. According to Laurie, Dr. Phillips, like most certified clinical researchers, has been through many years of schooling after college, including graduate school, and other specialization and certification programs.

The class had been "warned" about Dr. Phillips during the conversation which followed Shellie's report when Laurie shared with the class that she had been "disillusioned" with the clinical research practice after talking with Dr. Phillips. To her dismay, she learned that foremost on Dr. Phillips's mind was not helping humanity, but finding a salary which was commensurate with his perceived self-worth. So when Laurie brushed over Dr. Phillips's accomplishments in the medical research profession (for example, "the gene involved in severe mental retardation, he isolated") to focus on his attitude towards medicine, research, money, and the need for "more prestige in and respect for science," the class appeared ready. As Laurie told the class:

When I asked Dr. Phillips if there was anything he would change about chemistry, he said that he would increase the monetary compensation for professors of chemistry. Professors of chemistry often are directly involved in valuable research which can have a direct impact on health and human lives. He feels that society's values are warped as we reward professional athletes

and national performers and actors with millions of dollars in compensation for their professions.

And when I asked him if he felt if one needed an given aptitude for chemistry, he said that he did not feel that chemistry was at all a difficult subject. He did not elaborate but he gave me the subtle impression that he did not really understand why one would think chemistry is difficult as it is a "way of life" for him. He seemed so stuck on himself, so unaware that just because he may have some insight into chemistry, doesn't mean that everyone does. I would never dare tell him how hard this stuff is to comprehend sometimes...

...Finally, when I asked him what his greatest sacrifice was for having chosen chemistry as a career, he said that it was the lack of money during the period he was getting his doctorate degree in chemistry. Many of his peers were able to purchase thing he was not able to, during the time he was pursuing his Ph.D.

After Laurie finished, I asked the students to write in their journals their reaction to Laurie's report, because the ideas that Laurie shared about Dr. Phillips were in stark contrast to Shellie's report on Lisa Karms. For example, Lisa talked about needing to bring in the human element, and Dr. Phillips talked about needing to remove human bias. Lisa talked about finding a way to study science by looking across large systems, and Dr. Phillips talked about the importance of searching for new things at the molecular level (in connection with isolating genes). Lisa talked about how she understood that chemistry is a difficult topic, and how she has even had problems understanding it herself, while Dr. Phillips talked about how easy chemistry was and how he never had problems, even in high school. Lisa talked about how research required funding, and how the whole funding process reminded her of the political nature of science. Dr. Phillips also talked about how research required funding, but he also emphasized that he deserved more money than what he already made. Finally, Lisa shared frustrations about the difficulties she has had as a woman in the very male dominated profession, and Dr. Phillips talked about how "anyone" could do science if they put their mind to it and how the system is set up to ensure that only "quality" work survives. I wanted the students to take some time to process these ideas and draw connections between the two oral histories. Furthermore, because of the contrast there appeared to me the possibility that the oral history of Dr. Phillips, despite how frustrated it made me feel, could be used to help build a critique of science.

- Angie: Who would like to share their ideas? Laurie?
- Laurie: Like, I said, I did not really enjoy talking with Dr. Phillips. He seemed so stuck on himself. He seemed to care a whole lot about things that were very different from what I care about. As I said the other day, all he talked about was money, money, money, and it was as if nothing else in science mattered to him. Well he did mention some stuff related to the gene for mental retardation, but he kept coming back to the money thing. I guess, as much as I do not want to believe it, some people are in it for only the money.
- Shellie: He was so much different than Lisa Karms. I really enjoyed talking with Lisa, I would like to talk with her again.
- Angie: What do you mean, he was different, were there ideas that specifically stuck out to you?
- Shellie: The money, and how stuck on himself he was. Lisa seemed more interested in helping people. Not that Laurie's person didn't, he was just more concerned with his career.
- Gwen: That is the same sense I was making out of it. He was very career oriented. He wants to succeed in his career. Just what he said at the end, he wants money to buy the things his friends buy. It makes me wonder what is really driving him: his love for chemistry that he said he has had since high school or the money.

Similar to the student responses in the conversation following Shellie's presentation, Laurie, Gwen, and Shellie, appeared to be concerned with engaging in science for purposeful reasons. They all appeared to have difficulties with Dr. Phillips's attitude about money and prestige in science and the "elitism" connected to those ideas. For example, Shellie, Laurie and Gwen all agreed that this attitude was a "power issue," and a negative thing to have in science. In Shellie's presentation about Lisa Karms, I thought that perhaps the students were beginning to understand science as an intentional and powerful activity. I wondered how we could develop this notion of power so that it meant more than a "negative thing." I wanted the students to understand how power characterized relationships in science, and how it also characterized their personal relationships with each other and with science. I also wanted the students to understand how this notion of elitism was intimately connected to the power issue in science. In contrast, I also wanted the students to understand that power in science does not always have to be oppressive, that it could also be productive. For example, I thought that

Laurie and John began to raise this issue as they talked about using science for purposeful activities, versus using science for a high-powered, elitist career.

- Angie: Gwen, that is a very interesting question. I wonder how Kurt [Dr. Phillips] would answer, but I think I know how I would answer for him. What do people think? Let's hear from some people we haven't heard from yet. Mary?
- Mary: I was also surprised by what he had to say, but I agree that I think that doctors and chemists should get more respect. Just not millions of dollars. I think the sports people and actors are overpaid.
- Bret: If you think about it, everyone's job does a different function. People are willing to pay big bucks to see a football game or to go to a concert, so you can't say they don't deserve the money, we give them the money.
- Angie: Let's get back to Kurt Phillips. What do people think?
- Tracy: I am glad that I did not interview him. I was intimidated to interview my person, but she turned out to be really cool, and to make me feel at ease talking with her and about her work. I think if I interviewed the person you did, Laurie, I would still feel intimidated when I left. He does not do a good job making his work accessible to people who do not like science like me. It seems like all he cares about is keeping his reputation, you know with the money, and talking in ways that make you feel dumb.
- Laurie: I felt dumb.
- Dave: Laurie, don't feel dumb, you understood everything he said, then shared it with us. You did a good job.
- Gene: Yah Laurie.
- Gwen: God, that guy is a jerk!
- Shellie: No kidding!
- Angie: I agree, you shouldn't feel dumb, but Laurie, I think I know what you are saying. That is one thing that really bothers me about science. How elitist people in science can be. He just talked and talked and talked about how good he was and about how he deserved more money, about how he isolated the gene for mental retardation, as if he had done it alone, and about how easy chemistry is. I have never found chemistry all that easy myself! Why do people in science have to talk that way, so that those people who aren't in science or who are trying to get into science feel dumb. Somehow I bet he had to study hard for a Ph.D. in chemistry.

I felt very angry that Dr. Phillips's actions and attitudes made Laurie "feel dumb."

That was the last thing that I wanted to have happen as a result of the oral histories. I was encouraged by the response she received from the class as a result of her comments. I was also

afraid that this was turning into a "complaint session" instead of a productive critique. Maybe what the students needed was a place in science to express those feelings. Even though it did not feel productive to me, it may have been helping the students to work through some issues and feelings. For example, by having a place to talk about "feeling dumb" students began to think through the experiences they have had in science which have made them feel dumb. It may be that as I believed was the case with Laurie, the students recognized that feeling dumb was not the result of intellectual inability, but rather the elitist attitude of the institution of science.

Laurie: That was just the way it was in the 151 class I dropped before taking this course.

Angie: What do you mean?

Laurie: The first day of class, the teacher took out the six page handout and told the class they had to have it memorized for a quiz the week after, because if they couldn't do that then they would never make it through the course. I took one look at that handout and knew I should have dropped the class then and there. But it still makes me nervous because I have to take that course next semester.

Theme 2 - Elitism

As with Shellie's report on Lisa Karms, the theme of personal (dis)connections and disillusion with science emerged in Laurie's report. Looking back on this conversation, I think that the development of the theme of elitism was powerful in this class session for two reasons. First, several of the students—primarily the women students—worked through different aspects of elitism in science in a way that led me to believe that they were beginning to construct their own informed critiques of science—how it made many of us feel dumb and how it shaped the "power" issue in science. Second, our talk about elitism allowed many of the students to continue to build their critique of science through a new vantage point: The voice of western science. The Lisa Karms oral history provided students with a space to build a critique of science through connections between Lisa's experiences in science (which I believe to represent a stance critical of western science) and their own experiences. In the conversation following

Laurie's presentation on Dr. Phillips, the students had a new space from which to continue to work on their emerging ideas through disconnections between Dr. Phillips's experiences in science (which I believe to represent a living image of western science) and their own experiences. Many of the students were able to begin drawing stronger connections between their own experiences and the image of science constructed through the oral histories. These two ideas became important because this kind of thinking and conversation helped the students to rethink their own experiences in science. This was particularly evident by the comment that Laurie makes near the end of the conversation, when she described her experiences in Chemistry 151, in light of having felt "dumb" in front of Dr. Phillips.

As the teacher I was able to learn a great deal about my students through these discussions. Because this group of students I taught were primarily working class, I wondered if that brought out the issue of elitism more than if these students experienced lives full of financial and educational privilege. Science is esteemed in our society; it is an endeavor that "requires" (and receives) years of labor and millions of dollars to carry out. These can both be access barriers for many people. I wonder if this is why Laurie, Shellie, Tracy, and John connected more passionately with this theme than did Gene or Bret. I also wonder if Mary supported a certain degree of elitism because her life history as a white working class woman taught her to unquestionably respect power hierarchies. I know that these explanations for the students' feelings are contradictory and do not capture the complexity of the situation.

In the process of building a critique of science, I began to recognize the multiple and contradictory experiences students bring to class. Experiences that each student has with science cannot be labeled or totalized without losing its personal or cultural relevance. For example, it was easy for me to see Laurie at the beginning of the semester as a woman who did not like science and to impose on her my own notion of what it means to be female or in science. In reflection I can see that her relationship with science is far more complex, interactive and shifting; far less essentialistic. Laurie's initial dumb feeling was not grounded solely in her

experience as a woman or as a working class person, but rather an artifact of her way of thinking about the world.

Having to think through critiques of science from the standpoint of western science (Dr. Phillips) also helped me, as the teacher, understand and appreciate the struggles endemic to teaching science for all. I gained new insight into my students' struggles with science as women and working class students. For example, Dr. Phillips held the attitude that anyone can do science if they tried hard enough and that only quality work survived the rigorous testing of science. But our critique of that (based on the comments in the previous oral history made by Lisa Karms, as well as the emerging notion of an elitist attitude in science) helped us to see that was not true. Laurie said that Dr. Phillips made her feel dumb, but I believe that our developing critique helped her to rethink her feelings about her own intelligence and the scientific mask of elitism.

Tracy's oral report: Reporting on the life of Patti Ricker, woman scientist and teacher educator

Tracy, a white woman in her late twenties, chose to interview Patti Ricker because of Patti's background in psychology. Tracy, who works as a secretary for a government agency, attends the community college part time in the evening to study psychology. Her goal is to transfer to the local state university and study social work. Tracy's interest in social work is a large part of her life. When she is not at work, in class, or studying, she is helping out at a community crisis center where she works directly with rape and other domestic crime victims. Her desire to work in the social justice and social action sector stems from her own experiences of being oppressed by our society. Tracy said that she had to deal with a great deal of prejudice in her personal and professional life. Although she said that this is not the reason behind her decision to enter social work, she believes it provides her with a great deal of insight into understanding the nature of oppression.

Tracy, like Shellie and Laurie, expressed a dislike for science in general, and chemistry in particular, although she revealed some interest in how the brain functions and how that

connects to who we are as people. Tracy claimed that her real interest was in psychology, and "psychology is not science." In a previous class meeting, she shared that outside of having to take this chemistry class for her program of study, she "never thinks about science" except "little bits and pieces here and there." Tracy said that she would not have taken this course if it were not required, and that she had not taken a science class since tenth grade biology (which, as she reminded me in an interview, was over ten years ago).

Tracy's presentation occurred the week after Laurie's presentation on Dr. Phillips (there was a presentation on a chemical engineer in between). In her oral history presentation, Tracy shared with the class Patti Ricker's experience as a scientist, an educator, and a woman in science. She began her presentation by sharing with the class a chronology of Patti's career: Her move from psychology to experimental psychology in her masters program, to neuroendocrinology in her doctoral program and postdoctoral research, to teacher education and concern with women's and girl's achievement in science as a full time assistant professor with a joint appointment in science and education at the local university. Tracy then shared with the class that Patti made the last career switch primarily because of her experiences as a woman in science. First, Tracy suggested that Patti was interested in helping teachers think beyond traditional science teaching practices because these practices often discourage girls from entering science. Second, she suggested that Patti also chose to move into science education because of the difficulties she had to face:

When I asked her what difficulties she faced being a woman in a male dominated field, she said that really she was in two different fields—science and science education. As far as being a woman in science is concerned, she said that it was difficult to be woman in science and that is one reason why she decided to go partly into science education. She said that she became more and more uncomfortable with the traditional way of science, whether it was in the research, the questions, the experimental method. She even began to question her own ethics with her animal research. She wasn't excited about doing the research, publishing the papers, and getting the grants like she was supposed to do. That was how success was measured. Also, she felt she wasn't taken seriously as some of her male counterparts, as though women were less capable in this field. She felt that she was not as supported as men were in her position. But she was quick to add that this was only her experience, not the experience of every woman in science. But that these experiences were from graduate and postdoctoral work at [two different large state universities].

I also asked her if she ever regretted going into this field because of these difficulties. She said that sometimes she did. She has thought about going into medicine, but as far as the gender issues, she didn't think that it would be any different. She doesn't regret where she is now. She is very happy where she is, and she may not have ended up there if she had not had the previous experiences. She said she would have been happier if her route had been paved a little more by other people.

Tracy then shared with the class Patti's vision for science. She suggested that there are many things that Patti would change about science if she could. For example,

When I asked her what she would change about science if she could, she said that she would change the elitist attitude that there is only one right way of doing things and that she wishes science would more seriously entertain more alternative ways about how the world works. She said that all useful research should be recognized even if it is coming from a different perspective than what we are used to. If it's legitimate research, it shouldn't be disregarded just because it is nontraditional. This goes along I think with some of the things that Angie has talked about this semester.

Tracy concluded her presentation on Patti by sharing with the class that Patti's most rewarding experience in science has been in the education sector. Her reasons for this were that it is difficult for women in science to receive funding and that a great deal of money is wasted on insignificant research. For example, Patti believed that "The governments spends thousands and thousands of dollars on research that isn't meaningful, and it's sometime hard for women to get fair funding. It's sort of the old bureaucratic way. " Tracy said Patti believed that science education was often times more useful because it involved "showing someone how to look at the world, ways of teaching and learning by using science has more personal value to her. It gives her a sense of having more of an impact on a person's life."

At the end of Tracy's presentation, I asked the class to respond with any questions or comments. Tracy's oral history of Patti Ricker presented the students with several ideas which could be rather unsettling. After all, Tracy shared with the class that Patti believes science to be inequitable, particularly to women, and that science claims, unjustifiably, a position of authority in our society. Not only did Patti's ideas about and experiences in science represent a perspective I deeply wanted the students to explore, but also Tracy's presentation of these ideas

placed them in our laps. If we did not talk about them now, then I feared we would be making a very strong statement that these ideas did not count.

Angie: (breaking the silence) Questions or comments?

Laurie: What did she mean by the old bureaucratic way?

Tracy: I think that she was just referring to the fact that for women in that field it is going to be hard sometimes, and that it is a business out there, hard to get funding. That was my impression.

Although Laurie started our conversation with an interesting question, it was followed by a long and very uncomfortable silence (discomfort on my part anyway). Were the students afraid to talk about these ideas because their reactions might challenge an institution they have been taught to worship and in some cases fear? Or were they reluctant to talk because they felt threatened themselves? In any case, Tracy's response to Laurie's question presented the students with provocative ideas—women are treated unfairly and science is a business.

Angie: Somebody has to have some reaction to that!

Tracy: Well, I really enjoyed talking with Patti. She was really interesting to talk to. At first I thought that I did not want to go talk to a professor and I was very nervous, but she was very personable. She turned her computer on and popped in her CD. It was nice.

Shellie: She sounds very interesting.

Angie: Why do you say that?

Shellie: Oh, I don't know, she reminds me of the person I interviewed. Very smart, very personable scientist. Very different image of a scientist than I usually think.

Although Shellie's and Tracy's comments were met with another uncomfortable silence, they began to question their own vision of what is science and who can do science. Shellie and Tracy (as well as Lisa Karms and Patti Ricker) made it evident that they felt a power relationship between themselves and science (or the scientist) where the scientist holds the more powerful position in the relationship. Yet, both of these women, after conducting an oral history project on women scientists who themselves were trying to challenge the traditional social mores in

the institution of science, were able to begin to critique Shellie's and Tracy's own ideas and experiences in science.

- Angie: Are there any reactions to that? Has anybody had any similar experiences?
- Gene: Very similar, interviewing. My person was very personable and shared similar ideas.
- Angie: Oh, I mean did you have any similar experiences that Patti was talking about?
- Shellie: Experiences like Patti's?
- Laurie: In science?

The students laughed at Laurie's comment. I was not sure why; I think it was because they all felt they had no "real" experiences in science. So, I suggested to the class that they could talk about their experiences in general.

- Laurie: I guess I am wondering about science and technology. If you compare what people get money to do research for and the kinds of results they publish.
- Angie: I have heard horror stories about that when I worked in business, but I am curious about what you think.
- Tracy: But I wonder who gets the money to begin with.
- Laurie: Aren't there norms? I guess it was my impression that there were norms.
- Angie: Do you mean in business or in science?
- Bret: I am sure that money is distributed fairly in science because it has to be. Isn't it regulated? There are more men in science so it just seems like men get more money, when really that is not the case.
- Laurie: Aren't women respected? I thought women were respected, at least as doctors.
- Tracy: Women might be respected as doctors, but they still aren't doing as well in business. I work for doctors and the majority of people are mostly white men. There are very few women doctors in the higher positions. We are all the secretaries. There is very few women who are recognized at my work.

Before this conversation, there seemed to have been the assumption among the students that money was distributed fairly within the sciences across projects and people, regardless of position, gender, or anything else. Patti's idea about finding funding and science as a business

appeared to have helped students question these assumptions that they have about the practice of science. Both Laurie and Tracy raised the question of the sources and distribution of funding in science. I found this conversation exciting, yet also challenging. It was not until I personally worked in industry that I really understood how much science was like a business, and how biased and political the funding process is. For these students to begin to explore this issue in introductory chemistry gave me hope that we could draw on this discussion to inform future critiques of science—namely, how funding determines the nature and content of particular research projects and the resulting knowledge.

I also felt challenged by this conversation. On one level, there seemed to be disagreement brewing between Bret's ideas and Tracy's ideas (as well as the ideas of Patti Ricker). Bret, an outspoken student, supported the mainstream perspective, and the perspective that many of us desperately wanted to believe, that the funding process in science is equitable, that is does not hold different standards for different people. I wondered: If I, myself, completely disagree with Bret, am I valuing his ideas? On another level, how was I supposed to help students make sense of a science which is, at times, unfair in its practice?

After this short exchange among the students about the funding process in chemistry, Shellie, very thoughtfully, began to draw parallels for the class between the various oral histories thus far in the semester:

Shellie: I find this so interesting. Since we have started these oral reports in class it seems like almost all of the women who have been interviewed with the exception of the engineer who was very positive, it seems like most of us have come back with a painted or colored picture that science is this disillusionary and that the men are the dominant force, and I am just wondering how the guys in here are feeling about all this stuff we are saying.

Shellie's comment was met with laughter from both Gene and John, yet her thinking so intensely defined for us both the critique of science we were building across the semester (science as disillusionary) as well as the immediate mainstream passionate response (but what about the men?). Critiques of science are not easy. We have all been socialized, to some degree, into the mainstream. We learn to play certain roles just because of where we are born, when we are

born, the race and gender into which we are born. The practice of science has grown out of this society, just as it helps cultivate this society. Many female scientists, because of their gendered position as women, share similar experiences in science. Likewise, male scientists, because of their gendered position as men, have similar experiences in science. As a science teacher, this was an issue I wanted to pursue with the students. How could I help students work through this argument, to take responsibility for this situation through recognition of positions of privilege, without blaming the individual men in the class for this situation (which I think is the typical defensive response) and without essentializing gender roles. I also wondered if there were ways to push our thinking beyond gender.

As I anticipated, Shellie's question provoked a long and intense exchange between the students and me about gender, power and science:

Dave: [directed right at Angie] Why do you think that it is? Is it the men's or the women's fault? Why do you think it is?

Shellie: After all, this is the 90's.

Dave's and Shellie's comment were followed by silence. (People were waiting for me to answer, I think). So, I turned to Dave and asked him if he wanted to answer his question himself to see how the women would respond. My choice to do this was intentional. I was irritated that he would invoke his male privilege and use my teacher authority to force me to polarize our debate. I also felt like he was taking the "hot potato" that Shellie threw in his lap, and threw it at me. I wanted Dave to think about his own feelings and experiences, so I turned his questions back at him. The students laughed at my response, and Dave, rather defensively replied that he "just asked the question!" and effectively silenced our discussion on the difficult topic. So, I turned to the class and asked if anyone wanted to respond:

John: I'll try. I did not realize that things were really behind. My boss is a female and she is head of the respiratory department. Her right hand person is a female. And, the boss in the branch that I work out of is female. So, I don't know what I think.

Dave: I see the same thing where I work too. There are a lot of female superintendents, level eights and classifieds.

Gwen: I think it is changing but it has been a recent change. I have a sister, for example, who is four years older and she was a senior in high school and had a final in physics and it was a curved grade and she tied with a male. He received an A and she received a B, because quote unquote, it is more important for a boy to do well in school.

Angie: How old is she?

Gwen: Well, this was 20 years ago and there can only be so much changing that can be evolved because if you think about how we get our ideas of how we socialize together as men and women, a lot of them from our parents. Twenty years ago is a generation. All right now a lot of the parents from that time, that raised that particular person and that mentality of the time, they are still grandparents and it's not that far enough evolved to be a big enough change. In time it will be but also another factor that you have to look into to is there is some research on how men and women excel mentally in their abilities. Men sometimes, but not always do better in scientific and analytic reasoning, and women do better on verbal things. That's due to in part how we are socialized with our parents—how they treat us. My highest thing I remember when I took a test for aptitudes, my highest thing was technical ability and it bores me to death! And you know that it is a very male-dominated field. It bores me because I think of the way of the things I am interested in. I am more into the verbal things. The hair and make-up things. The more female-dominated things and I think that was how I was raised. My mind is best for a male dominated field, but as soon as you begin to talk about it, I snooze. I'm not interested. So I think that with time it will get better, but I don't think there is a blame or a fault. It's just socialization and how it is evolving.

Dave: There is research in science education that says that women in science and math classes do not get as much attention and achieve as much. They are trying to equal that out, and I really don't know what they are doing or saying.

Angie: I know what they are saying. Men receive more attention than women do and that boys receive more attention than girls. And the types of responses that boys get from teachers are different that the types of responses girls get. Boys get intellectual criticism. You know you can work harder. Girls get attention or physical appearance on appearance of school work. You know your homework is messy or your dress looks nice today. The boys receive 70% of the teachers time and girls receive 30% on average. So that is what some of the research that you are referring to has shown.

Jerry: But aren't there more women teachers?

Angie: In elementary school its around 80% women. It's primarily women, but it doesn't matter—women and men are taught the same thing—to give boys more attention. It's like Patti said with her socialization thing. And, boys are taught to expect more attention. I know I probably do the same thing even though I am aware of the research.

I have had experiences in college and that wasn't too long ago that are similar. In analytical chemistry I was having trouble with a problem set

and so I went for help and the first ten minutes the professor spent criticizing how sloppy my problem sets were. He said I was doing a disservice to myself. He also said that he could tell by my handwriting that I was stubborn [students laugh] because I was of Italian heritage, and that I needed to work on my hand writing if I wanted to get anywhere in life. I don't know what he said to my male counterparts. He might have been just as insensitive I didn't ask. And then I had another professor who I cried in front of because I was so frustrated about my inability to solve a particular chemistry problem and he got mad and said he never had problems like this until women came to the university. I went to a university that up until 1970 was all male. I went to Notre Dame, but at the time I went, there was 75% men, 25% women. Now its 50-50.

Uh, well you can see these emotions are deep inside me. So I think that the experiences of these women are real. I am not blaming the men in this classroom, but I think there is an issue here.

The students all start talking at once, so I tried to bring the conversation back together by tying some of the students' ideas into my own experiences.

Angie: It's so interesting how these socialized roles play out in everything we do. Right now I find myself cooking more than I ever thought I would. And I never questioned it. It wasn't until this past year when my husband and I started questioning why we do what we do at home. I have been taught that is what you do and so I didn't ever seriously question it. I mean I questioned it, but not seriously.

Dave: Things will change there because you took the initiative. I remember when I was in high school, the guy always picked up the girl, but now they fight to see who drives. I wanted my wife to drive and she said no you drive, and I just as soon she drive. I also think that this has worked against men too, you know that good old boys network. When a man gets divorced, and I hope I never get divorced, when the judge is standing there and goes to give custody of the children, the mother always gets the children. He's been raised that the women raises the kid and that who gets the kids. And I think the more and more you get female judges, the more and more men will get custody of the children because they will say, you know I know some real bad mothers. So I think that this works against the man too. If you look at other societies like Mexico or Spain or Saudi Arabia or Israel or other countries, we are so far ahead, not that we need to stop here, but look at all the accomplishments we've made.

Shellie: That's true.

Gwen: And that's why when you said you need to make decisions. If you ever have a family, these are things that are really small, but they are going to influence the mentality of the children and that will carry on with the children and that is what I mean by generation changes. You can't expect everyone to expect that all the sudden we are going to live in a perfect society.

Dave: I work with some very successful women now, who work because they have to but wish that they could stay home and raise the kids. They wish they had that kind of opportunity...

Dave was momentarily interrupted as Shellie and Laurie, both working mothers, laughed.

...And, some women would say that is their goal, and that is hard. I know if I could stay home and raise the kids. I've seen professional women who wish they could do that.

Shellie: I've done that for ten years. Now I am trying to take classes and work because society forces a woman to work. My family needs two incomes. Its not feasible anymore. It's a lot tougher to go out to the work force when you are not ready.

Angie: I just read this thing the other day and they said that women or men, whoever stays home between the daycare and the housecleaning, is worth about \$90,000 dollars a year. That is if you paid someone to do all that work for you. Hopefully their spouse appreciates it, and some are very appreciative and in some instances it is just assumed that the spouse will do all the work.

Shellie: It's become a very demanding occupation.

Angie: It has and...

Shellie: It should be a personal choice, you know though some people will stay home and watch soap operas.

Angie: Gwen were you going to say something?

Gwen: No, I could talk forever about this

In this last exchange, the students seemed to be trying to make sense of what they were hearing about women and science from their own experiences in science or with other women. At first, it appeared to me that the men (John and Dave) attempted to diminish the argument by sharing with the class experiences they had where women appear to be successful (although John seems to be more reflective and less defensive in his story). I was encouraged with Gwen's response. She acknowledged the advances the women have made with guarded optimism, and provided the class with a sophisticated argument (socialization processes) for why things are they way they are. This provided the students with another venue to rethink their experiences in science.

Theme 3 - Politics of science

The conversation following Tracy's oral history on Patti Ricker pushed our thinking on the political nature of science, in particular how this shapes funding in science and the experiences of women. Because Tracy placed an emphasis on Patti's experience as a woman in science and the discrimination endemic to her practice in science, it forced the members of the class to rethink the disillusionment with science we talked about in connection to the human element and elitism we talked about two weeks prior.

The messages about science and who can do science were intensified in Tracy's report, because several of the students began to draw connections across oral histories. Just as Shellie shared with the class Lisa's disillusion with science and the elitist attitude that Lisa confronted with science, Tracy shared Patti's dilemmas. These two oral history projects created a space for us to seriously re-consider our own experiences in a highly political science. Because these connections had been made and because the notion of disillusion and elitism were in such stark contradiction to the experiences of Dr. Phillips, the students also seemed to have the chance to rethink their own ideas about equity in science. Dave and John talked about the women with whom they work and how they felt things were fair. Yet, I believe that through the course of our conversation, the fairness of the situation was questioned through Shellie's experience as a working mother and Gwen's ideas about socialization. Science, at least in our class, could no longer be an objective, detached, impersonal and unemotional endeavor because through exploring ourselves through the oral histories of Karms and Phillips we altered conceptions of our actions and beliefs within the social contexts in which they were constructed.

Gene's oral history on Karen Ross: A science educator and biologist

Gene's oral history project was on Karen Ross, a science education professor at the local state university. He chose Karen from a list I provided the students because he wanted someone who "was interesting, thoughtful, and had different kinds of ideas." I recommended that he talk with Karen Ross not only because she fit his description but also because she is a science

educator. Gene, who is white, in his late fifties and a former football player in the National Football League, was studying chemistry to become a certified physical science teacher. Although not new to education—he had been a physical education teacher for nearly twenty years—he was new to science teaching. He was in his first year teaching physical science to urban ninth graders.

Unlike many of the students in this course, Gene admitted that he likes science. As he told me in an interview at the end of the semester, he likes science "at its core". That is, he likes to observe and to figure things out. He likes to think through situations, "to use his intellect", and not just to do something because someone told him to. And, he would like his own science students at the high school to develop those same qualities.

Gene introduced his oral history report by sharing with the class a biographical sketch of Karen Ross. He told us that Karen first became interested in science when she was young through "the outdoors stuff" and through the influence of a "chemistry family." He told us that Karen explored science as a high school and college student not because of particular employment opportunities, but because of the many options it provided: With a science background Karen could pursue careers in forestry and marine biology as well as think more deeply about the kinds of things which made her wonder, such as the "complex and intriguing chemistry in a leaf."

Gene then shifted focus to share with us how Karen used science in her profession. This piece of Gene's presentation opened up a complex web of ideas about the nature of science, education, and issues of equity. Gene relayed how Karen has experienced discrimination in science because of her gender and in science education because of her "female" perspective:

Karen also said that being a woman was a big reason she went into education. First when she was interviewing for a job which was environmentally oriented, she experienced discouragement through sex discrimination. Many potential employers told her that they would not hire a woman because she would get pregnant and leave. In her personal life, she wanted to get married. She assumed she had to get a job to support her husband so he could get his Ph.D. in Biochemistry. As a woman, education was a natural path and so was teaching science to support her marriage. Until this year she was the only woman on the [university] staff in the science education faculty. What was interesting about

this is her concept of the nature connection with science she felt that particular concept, she had to hide. It wasn't scientific enough. She felt like it was too feminine. Her scientific measure of science nature connection was too feminine for approval from her peers.

He also relayed how Karen worked to demystify the elitism of science with her teacher education students, practicing elementary school teachers, and elementary school students:

I also asked Karen how she used science in her profession. As a teacher educator, Karen works with teachers in the elementary schools in Andover to improve the elementary science teachers' perspective and convince them that science can be understood by or work toward and understanding a connection of science with the students...Karen's feels good that she has helped students overcome their lack of confidence in the ability to learn science, especially those tagged as not good in school...A major goal of hers is to impact the national science education community, to develop ways of connecting with kids and pull them into something they are resisting initially, and to call more attention to it.

Gene then shared with the class ideas critical of science which Karen believed were important:

Elitism in science, the political nature of science, and the need for a human element in science:

I asked her what she would change about science or chemistry today and she gave some very interesting answers. First thing she said she would change the political structure of science. She talked about the good old boy network. Science seems to be regimented, redundant, and a word that she used that came up the other day was elitist, which meant only a select few can do it, and that it could only be done a certain way. It was accepted to do only science all the time and no room for kids or raising a family, and that science and chemistry are too hung up on tradition. Science should be less removed from the masses as it is. She hates it when people think they can't do it or understand it, and the scientist reinforces that perception. [short comment inaudible, something about scientists]. If you are a scientist you have a responsibility of communicating to a larger audience. Scientists need to let their uncertainty show more and that they shouldn't be so elitist or authoritative. Sometimes scientists talk a big game, but they are really not so sure. They need to be more honest with those who look up to them.

How would you want science to make the world a better place? She said she wished it could make the world a more human and gentler place, to open your eyes to what we do to nature and to ourselves. She said we need to be respectful of the power of knowledge, and being conservative in using scientific knowledge and being aware of the intrigue and excitement.

After Gene clarified that Karen, had been the only female tenure track faculty member in science education at the local university until a year ago, Shellie began the conversation by asking Gene to talk more about what Karen said "that had to do with the feminine."

- Shellie: I think I missed out on, you were talking about something that had to do with feminine, near the beginning?
- Gene: Yah, she felt that, she felt that her views were too feminine about the connection with nature and the natural connection between science, chemistry and nature and so forth which was something that apparently wasn't masculine enough for her peers.
- Mary: Was she rejected?
- Gene: No, she kind of hid it. They kind of, they kind of, she kind of hid it.
- Shellie: (persistently) What did she mean by too feminine, did she say?
- Gene: No, I just kind of think of the mother nature kind of thing and she felt that the connection between the natural, the chemistry and science was not the type of attitude that was held by her peers and professionals.

After Gene described how Karen's thinking was not appreciated by her former department, Gwen, in a light hearted, yet serious voice, suggested that Karen's marginalized perspective is much needed on the chemistry committee at the community college. Many of the students laughed, yet Shellie took Gwen's comments rather seriously and suggested that Karen "tutor the people on the chemistry committee." Although as a class we did not spend a great deal of time working through Karen's "mother nature kind of thing," Gwen and Shellie seemed to connect to the idea immediately and publicly stated that they thought it would be good for our chemistry program. I wondered if it was the nature approach or its explicit connection to the feminine which intrigued Gwen and Shellie.

When I asked the class for responses or further comments, as I usually do when there is a silent pause after what I consider to be rather provocative comments, Tracy extended the connections between the lives of the women scientists which were made in the last class:

- Tracy: She said a lot of the same things that Patti Ricker did, science and being a woman.
- Gene: Yah.
- Shellie: That was a lot of what I noticed too.
- Gene: Yah, I connected that too.

Again I was excited that the students were drawing connections between the lives of the women shared in our class through the oral histories. To challenge superficial connections and to encourage them to be critical of the practices in science which promoted the commonalities in the lives of the women, I reminded the class of Laurie's oral history project on Dr. Phillips:

Angie: But sounds a lot different than the person you did, Laurie. You said that Karen would change the political structure of science because it was too elitist and that knowledge is power. And, Laurie, I was just thinking about your scientist and I can't remember his name [Kurt Phillips], and he said that he should make as much money as the sports players and sounds like he's helping to make that elitist status of scientists.

Gene: [Karen] also said that science perpetuates that by saying you aren't smart enough and that the science department is also saying to people you aren't smart enough, we don't want you. How can you ignore all these things about science when they are real? If you feel like you understand pretty good, and then they tell you that, then you, you can't.

Gene's comment went right to my heart. I struggled with ways to make science class more liberating so that students would not feel oppressed by science. His comment suggested to me that after so many years of schooling and so many years of participating in society, he understood that the elitist practices in science have not changed. He understood that unless he participated on their terms to their expectations, he would still be considered a failure in the eyes of science. I felt a bitter-sweet hopefulness knowing that Gene had taken some of the critiques of science to make sense of his own "failed participation" in science.

Yet, I could not lose this opportunity to push on Gene's comment. I believed (like I felt that Gene was beginning to argue) that the practices of the institution of science and science education can serve to perpetuate the elitist status of science through the ways in which it chooses to express who can or cannot do science. So I told the class that "I feel that way with this course and the way that they have designed it. They try to make so that many students do poorly or fail. You have to have an average exam score of 70, you have to make sure you have a 30% fail or drop rate. You have to have five exams and you have to cover 17 chapters in 15 weeks. Who cares if you understand the material or can find ways to use it or make sense of it in your lives?"

Gwen responded to my comment immediately by sharing with the class that she had been talking with someone in another section and found out that they were "two chapters ahead of us." Shellie appeared to be disturbed by this comment:

Shellie: We are way behind, aren't we? You work so hard to get through this stuff on time, what are you going to do?

Angie: You are all very smart people, don't be fooled by the department's requirements. I want you to have a conceptual understanding of the material we talk about, and I just don't want to lecture just to say that we got through the material. It's not fair to you, and besides I just don't think that I could do that. I would rather have you understand some of it, then pretend to cover all the material and understand much less. But to get back to your oral history report Gene, you said that Karen said that scientists sometimes try to, uhm they have this attitude that they are smart, and if they scare some people away then that's okay, they just can't cut it. It's like, if you can't keep up, it's your problem.

Gene: I think that's traditional in science classes. Thinking back to my freshman year at Michigan, we had a freshman science class, and there were about a thousand people in the lecture hall, and the prof, I remember he looked at us and said, on the first day, look to your right and look to your left, you won't see these people come next semester. Over half of you won't make it to the second semester because you'll drop or your grades won't make it.

Angie: Oh no!

Gwen: I would have dropped right then and there!

Gene: Well, I know, everyone's jaw dropped.

Angie: Was it true?

Gene: Yah

Angie: Were you in there the next semester?

Gene: Yah, I was in there. Over 50% dropped though.

Gene's comment about his own science education was all too similar to what is advocated by the chemistry department at GCC. Although the department seemed outwardly and even genuinely concerned with helping as many people through science as possible, there also seemed to be this unspoken glory in the fact that our introductory chemistry course was known around GCC as "the hardest course on campus," and that over one-third of the students dropped the course before mid semester. These statistics, along with Gene's experience, and my

personal experiences in science, all highlighted the elitist attitude in science that shapes how science gets played out in classrooms. So far, in the course of our oral histories this semester, the students and I began to uncover some of the qualities of science which have silenced some of us:

The disillusion due to elitism, the lack of the human element, and the political nature of science. Yet, these ideas, although intimately connected to our own personal lives, always seemed slightly disconnected from the chemistry we learned in class. Now, as Gene replayed his own learning experiences in college science, I felt that we created a space to critically reread our experiences in the course we all sat in that room for.

Angie: Well, CHEM 125 has about a forty percent drop rate, but I heard that the department is going to try some things to bring the drop rate down

Gwen: (interrupting). Oh, I believe that!

Shellie: They may say they are, but the way the course is set up right now, it is a very difficult course.

Gwen: I had [a different prof] last semester and I dropped the course and let me tell you why. When I got my first exam back, I got a sixty percent and he suggested that I drop the course unless I wanted to be in for a big struggle for the rest of the semester. So, I listened to him and I dropped the course. Now I wonder why did I drop the course because it wasn't like I did anything between now and then to get more ready, and here I am taking the course again, and I am doing fine. But he told me to drop the course.

Angie: Oh no. Let me see do I have those statistics with me? I only have the statistics for CHEM 125 because that is the only course I teach. Let's see, here it is. Last year across all the sections there was a forty-six percent drop rate. Out of the fifty four percent of the students who stayed in the course, guess how many people get zero points.

Pete: Zero points?

Angie: Zero point zero. F.

Shellie: A zero?

Gene: Out of the people who stay on?

Angie: Out of the people who do not drop the course, guess how many get zeros. Let's say we had 100 people lined up. Forty six dropped the course, 54 are left. Out the these people who are left, guess how many failed the course.

Gwen: Seventy five percent?

Angie: No, it's not that bad. Twenty nine percent. That's almost a third of the people who are left, let's see a third of 54 is nearly 17 more people. That means that out of the one hundred people who started the course, one hundred minus forty six minus seventeen is about 37. Thirty-seven people pass. That's only a little bit more than two thirds, no wait, one third of the people who sign up for the course, make it to the end with a passing grade. My question is, how can they justify that? Talk about keeping that elitist attitude!

I spoke very passionately at this point in the conversation. I was angry and exasperated. How could an organization (GCC) committed to the education of community learners, many of whom have been alienated from the schooling process, work so hard to keep them alienated? How could an institution (science) created to "better" society work so hard to keep so many people out? There were many forces at play which tried to keep us in our places and I wanted to work against those forces. I wanted the students to use their experience of our class, their other science classes, and the developing critiques of science which we were gleaned from the oral histories to make sense of policies and practices of the course in which they were enrolled.

Sue: What about the other teachers? Couldn't they realize if you were doing that bad, that it might not always be the student?

Angie: I don't know, but I do know that a few weeks ago, another teacher asked me what the average was for exam 3, and I said 75. And he said, your kidding me, mine was a 50!

Laurie: Sounds like he was proud of that.

Angie: He seemed to be proud of that. And, then when I had a meeting with the department chair and he wanted to know my exam averages and I said a 75, he told me I needed to work harder at making sure the exam average was not higher than a 70. This is not acceptable to me.

Shellie: I had another chemistry teacher tell me that if you have a three point on your first test, you better get out.

Angie: I know. These are the messages that I am getting and these are the messages that you are getting. This sounds like the elitist attitude.

Kristin: Do you think they do it to get the money?

Laurie: They make a lot of money. If you think about it, they make a lot of money. They are doing it for financial reasons.

- Angie: I never thought about that, I just know that when I found out, I could hardly believe it and I am really embarrassed by it.
- Shellie: Do you find yourself getting discouraged when you bump up against that regularly? Or do you get more motivated to make some changes?
- Angie: What motivates me is to get my dissertation done and get a position where I have some authority to make changes. No really, I want to try to make changes, but I feel like I am in a powerless position as far as the hierarchy at the school is concerned. I have to sign a contract every semester, and if they don't want to offer me a contract next semester, they don't have to. But, I am not going to do everything they want for job security, that sort of defeats the purpose. I feel pretty powerless with them, and I also feel like I am taking a risk when I do not follow the rules of the department in this course.
- Gene: Policy always gets in the way. I am telling you. If it wasn't for all these politics we'd be moving ahead a lot faster.
- Tracy: We need to do something together then because there have been many classes where I did not learn anything. All the teacher did was lecture and they didn't care if you learned. And that means a lot to me personally that you do care. If we are going to pay for this course than I would rather learn something rather than just plow through everything just to say that we finished.
- Angie: Well I feel like we are plowing through and I apologize for that. (sighing) Well, anyway, (a few loud sighs and laughs from the class) sorry that you had to listen to my frustrations.
- Shellie: Hey, we did it together!

Shellie's comment was so very important here. I knew in the last ten minutes of class conversation that I spoke passionately about the unwritten policies of the chemistry department. I felt like the students were part of this conversation, but I wondered if I went overboard. I wondered if my passion silenced them. I wondered if I was just on another soap box and my students were patiently waiting for me to get off so that we could get back to chemistry. I wondered if the comments the students made were to please me rather than sincere searching on their part. I know that Shellie's comment does not speak for the whole class, but her comment, of "we did it together" followed by a general nodding by the class implied some sort of solidarity. We formed some sort of community of resistance.

After a few deep breaths and a couple moments of silence, Dave continued the conversation by suggesting that there were other ways that the elitism played out in science

against women: The number of women's bathrooms in the science buildings. I agreed with Dave, and shared with the students more of my own stories of being bathroomless in science buildings. I told them about how I was rebuked by the chemistry department at the local state university for suggesting that they spend a small portion of the seven million dollar renovation grant to install a few women's bathrooms. Tracy responded to my story by suggesting to the class that we not put up with the unfair decisions, and that we start a letter campaign to let these people know how we feel. A few people nodded in agreement, and we drifted off to the subject matter stuff.

The three themes revisited

The conversation following Gene's report marked what I consider to be second turning point for our class because we used our developing critiques to begin to rewrite our science education. Throughout the conversation we continued to build our critique of science through the themes of elitism, of science lacking the human element, and of the political nature of science. Yet, our critique seemed to grow in intensity and complexity. With each new oral history conversation the same set of contradictory ideas about science emerged. They reinforced the notion that neither our lives, nor the lives of the people represented through the oral histories were isolated cases, and provided growing support for more and more students to talk out about their own less than satisfactory experiences in science. It was not that our experiences were identical. Quite the contrary. It was more that there was an evasive yet nevertheless present set of power arrangements in science which generated an equally evasive yet present set of artifacts—elitism and ahumanism.

For example, Gwen shared her experiences in the introductory chemistry class that she dropped a semester earlier, because the professor did not want (have time? believe it was not important?) to consider the needs of the students. Gene talked about the "elitist" attitude of a science teacher he had in college several years earlier. Shellie expressed frustration about the

"weeding out" process in science and wondered why everyone couldn't be scientists if they wanted²⁵.

We then used our developing critique to begin to deconstruct our own situations at GCC and to begin to build our own science education. The students were not aware of the high drop rate for the course. What they did know about the course was mainly learned through hearsay: It was the supposed to be the toughest course on campus and that if you could not score at least a 3.0 on the first quiz then you are doomed to fail. We spoke about the practices in the chemistry department that made some of us feel inadequate as students and teachers. This process of deconstructing the practices in the department began a process in which we began to rewrite our own science education.

Positionality and the oral histories: Rereading the oral histories conversations again!

I suggested in this section that our talk of the human element in science pushed on our vision of what science is and who we could be in science. I believe that Shellie's telling of the story here is very important. As a mother of two children in a family where gender roles appear to have been traditionally employed (Shellie is the primary care giver of the children), I believe that in her presentation to the class she emphasized the issue of the human element and Lori's own disconnection with science because it lacked that dimension. I believe that Shellie's experiences as a woman and caregiver in our society and in her family make that issue a powerful force in her life. I also believe that this is complexified by her location in the working class where the jobs she holds are service oriented: She currently works as a receptionist for a local town doctor. I am not suggesting that Shellie's own perception of what is

²⁵This is an interesting comment because it contradicts the egalitarian idea promoted by current reform agendas in science education that every can do science or become a scientist if they put their minds to it and work hard enough. I believe that Shellie's comment was contradictory not in that there were people who couldn't do science because they weren't capable of it, but that science is too prescribed in its intent and procedures that it is unaccepting of many people.

important for her life is solely a function of gender and class. However, I am suggesting that the roles she plays because of her locations as working class and female have specific messages for what she ought to care about. They also have specific messages for what others ought to care about—like scientists. This was very evident in her self-definition of science and her perceived place in that definition. She shared in previous classes that she does not like science because she does not like doing calculations and that she does not like thinking about ideas that "are way out there." She also felt that Lisa Karms was "not at all like a scientist." I wonder now, in retrospect, if it was Lisa's gender, Lisa's background growing up in working class communities, Lisa's articulation of what ought to be considered important in science, or some combination of these particulars which led Shellie to her claim that Lisa was not at all like a scientist.

I ask myself, what if Bret or even Gene or John told this story? What ideas might they focus on in their telling? Reflecting on what they shared with the class leads me to think that at this point in the semester, it would have been something very different. For example, Gene also connected to Lisa's comment about the human element in science, but he did so in a much different way: His own articulation of the need for the human element during our conversation was in reference to the way science is talked about in school, rather than the way it was practiced or in its ultimate goals and purposes. I know that Gene feels comfortable with science "at its core" because he told me he did. I question if Gene, as an older white man who has had a successful career in football, has had to deal with the human element and the care giving in his own life as Shellie has had to both because of their careers and gender.

Laurie's telling of the story of Dr. Phillips expresses similar dynamics. Laurie, clearly in her written report focuses on a variety of issues from the scientific research and gene isolation to the education required by research scientists. Yet, her presentation focuses primarily on how Dr. Phillips was "so much different than Lisa Karms" and how he was concerned with making money rather than helping humanity. Laurie's situation offers an interesting opportunity to understand how her positioning in this conversation shape the meaning which she took from it

and what she chose to share with the class. Because her project is about a person who embodies an aspect of science our group began to critique two days earlier, there also the complicating factor of how did the previous conversations also position Laurie in her telling of the story?

Laurie, like Shellie, is a working class mother: She works as an office assistant at a local medical research clinic, and also has primary child care responsibilities for her son. Laurie's situation is more complicated than what this lets on. When she was pregnant with her son, she almost lost her job at the medical research clinic because a six week maternity leave was not an acceptable practice because it was too expensive for the company. This reading suggests to me that Laurie, as a working class mother, had reason to be angry when her company gave her no support for her impending motherhood. She also had reason to be angry when Dr. Phillips, one of the doctors at the research clinic where she works suggested that he ought to be paid a great deal more.

The dynamics of our conversation following Laurie's telling of the story is equally revealing. Again Gwen, Shellie, and Tracy are also critical of the elitist attitude that Dr. Phillip's seems to have and the adverse impact that has on the possibilities for an philanthropic science. Yet Bret, one of the few "professionals"—a hotel chef—supports this stance suggesting that people should make what people are willing to pay for. Class and gender seem to be a salient issues here. Gwen, Shellie, Laurie and Tracy are all working class women in traditionally low paying service positions—cosmetologist, receptionist, office assistant, secretary. They leave work tired to take care of children or victims of violence. Gene, who had been so vocal about the human element in science, hardly engaged in the conversation at all, except to tell Laurie, in concert with Dave, that she was not dumb.

This causes me to read gender and class dynamics into the telling of Lisa Karms and Dr. Phillips oral histories. For example, the ideas expressed by Laurie, Tracy, Mary and Gwen in our conversations and in their journals were equally as critical of science as was Shellie, and all of these women share lives as working class women. However, I feel that I must address the complexities of the situation before I can continue. For example, what about John who also

latched on the human element in ways which I believed questioned the political intent of science? Or, what about Sue who did not? What about Mary who agreed with Dr. Phillips that the medical professions demands more respect? As poststructural theorists argue, identities are shifting and are located within power arrangements (Foucault, 1980). Therefore, to label my students as female or male, as working class or educationally privileged, brings a sense of stability into identity, relationships, and sense-making, which does not exist. But, I do not believe that this is reason to ignore the significance of the discourses and practices traditionally a part of our lives and the influence they have on our perceptions of science and education as well as what it means to engage in these activities meaningfully or "successfully."

With this said, I want to problematize our conversation around the Lisa Karms oral history even further: What about me? How did my own reading of what the students said to each other and to me guide the telling of the story and the conversation which followed? I think that my choice to begin our conversation focused on the statement about the disillusionment and the human element rather than the mice experiments, Lisa's education, or even to push the students further to pick their own line of conversation (remember when the students had no questions, I asked them to think about the human element statement in their journals), speaks to the issue of the influence my own positioning had on our conversation.

So why is any of this important? Meanings about science and who we can be in science are enforced in the contexts of power relationships in science class and other locations. From Shellie's and Laurie's perspective, science does not connect well with their classed and gendered identity. Marginalized in their experiences as mothers and office assistants in the medical professions, these women practiced their gendered and classed resistance in class through our discussion around their oral history projects. These women also clearly received the support of me, a woman feminist teacher, eager to problematize issues of positionality in science class. I believe this had political and personal meaning. However, these kinds of oppositions expressed by several of the women and some men were constantly tempered by other

members of the class, like Bret and sometimes Mary or Sue who would promote the traditional stance of science in our society.

Reflections on the oral histories

As women share stories of their own lives, a common experience of oppression and of resistance is recognized. This politicizing gives women the courage to persist in resistance, recognizing that their difficulties have not only an individual basis but also a social and political basis as well. Fear of moving beyond accepted definitions of behavior is not definitely allayed, but the experience of self-affirmation and hope that comes from the affirmation and community of sisterhood gives courage and enables creative resistance (Welch as cited in Magda Lewis, 1993).

Reflecting on my teaching in the spring semester I can see that our most empowering conversations and actions occurred not while we were studying chemistry and not while we were critiquing the chemistry, as I tried to have my students do throughout the semester. Rather the most empowering conversations occurred when we discussed the oral history projects. In our conversations about the various oral history projects shared in this paper, we had the chance to problematize what is acceptable in science by valuing our contradictory lived experiences. Discussing the lives of women and men in science who have been disillusioned and unfairly treated as well as successful in science helped us to rethink and rewrite our own experiences in science. They gave a reason and a context by which to disrupt the hegemonic reality in and of science.

I believe that we formed our own creative community of resistance. Although I began the semester hoping to work through the oppression that many women studying science experience because of the domineering patriarchal structure of science, I learned by listening to my students that the patriarchal structure is inextricably bound up in its capitalistic agenda as well. I believe that this helped us all dig into our experiences to find memories of oppression in science. Understanding and critiquing our own and each others stories helped build solidarity.

Reflecting on the oral history conversations has taught me a great deal about feminist liberatory education and about issues of ambivalence. These oral histories helped students to reread their lived experiences in science critically, something which I had not been able to do (well) in learning or teaching the chemistry subject matter. The oral histories, much more so than the official subject matter knowledge, served as a source of critical revisioning in science.

One reason for the power of the oral histories was that they were not bounded, unlike exploration of subject matter. When we talked about atomic theory, there was the unwritten and unspoken rule, followed implicitly by me, that despite anything else the students and I did (such as critiques or revisioning), we would eventually cover. This was assumed to be primary to our learning of chemistry. With the oral histories, we had more freedom to explore issues that connected with our personal needs and experiences. When we talked about the experiences of Patti Ricker, Lisa Karms or Karen Ross, for example, there was no set expectation for what we would cover. There was no department chair and no text book telling us what we had to say and what we had to learn in order to be considered knowledgeable in those particular areas. There was a freedom to talk about the lives of these women (and men) in ways which meant something to us because they connected with our experiences in and out of science, not because they connected with the text book.

Another reason for the power of the oral histories was that they enabled us to create spaces of radical resistance that informed our efforts to rethink science. They allowed us to share our own identities and experiences in science rather than remain "voiceless" as many students feel is expected in the sciences. Through conversations surrounding the oral histories projects, we created a context in which to reveal aspects of ourselves—who we are as learners of science, as gendered, raced, and classed people—that we might not have been able to do in the context of science. Sharon Welch (1985) writes that "the disclosure of suppressed systems is part of an insurrection of the subjugated knowledges" (p. 74.). I believe that the oral histories created a space for the disclosure of the complexity of our lives which is delegitimized by

science. Our connection to the oral histories through valuing our own life histories allowed us to begin to critique and revolt against the subjugated knowledges of science.

For example, Laurie and John connected with Lisa Karms' disillusion with the lack of the human element in science. Through articulating experiences in their own lives where they encountered a need for the human element in science, each in her or his own way was able to uncover partially how the institutions of science and education work to suppress the human element in science. On another occasion, the students, led by Gene, Gwen and Laurie, taught me to see how the department works in tandem with the science community to perpetuate elitism in science. Through their courage and their own political resistance, they also helped me to act on my developing beliefs.

Finally, the oral histories gave us a language to reread our experiences in and out of science. In this process of re-articulating our experiences, we were able to challenge and change our relationships with science. By constructing spaces in which we made public our nontraditional science ideas, we were able to push on the boundaries of western science. As a result, as a community, we were able to begin to decenter the traditional power arrangements in science. We were able to begin to define our own science and our own relationship with that science.

Traditional relationships between students and science are hierarchical where science holds most of the authority and prestige. Students' ideas, values, experiences, and feelings are not valued. This was reflected in the departmental course design—a syllabus created by the department two years prior which defined what the students needed to know in chemistry and when. The students had no input. I had no input. For example, When I talked with the department chair about revising the introductory chemistry course syllabus for the fall, he made it very clear to me that all students in all sections of the course were responsible to learn the objectives that were listed in the course syllabus. The authority of the department chair and of science were telling me what I needed to teach, what the students needed to learn, and how they needed to learn it, without even an inkling of who these students were and the

multiple and oftentimes contradictory experiences they bring to the course. The department, although superficially concerned, appeared to pride itself in the fact that their course developed the reputation as one of the most difficult courses on campus. Even when we (as a department) talk about what we are going to do to improve the drop out rate, all of the blame is placed on the student—they do not have the math, the reading, the study skills, the motivation. For example, there is a grant at GCC to establish reading levels for all students. The students will be required to attain a specific reading level before they are allowed to take certain classes. Chemistry 125 has been selected by the college as one of the courses to pilot this restriction (no doubt because of the drop out rate). The reading level of all chemistry students is being tested and many of the teachers are viewing this as the way to improve student performance. (The assumption is that if the students learn how to read better, they will do better in class. This implies that the onus for change is solely on the student.) The department chair also decided to set the reading standards low so that enrollment would not be affected in the introductory chemistry course. At our most recent department meeting, one teacher complained that students were not studying hard enough so it is more than reading that is the issue. No one ever mentions that it might be their teaching, the structure of the course, or the nature and political intent of science education! The last time I tried to suggest that we look at our teaching by suggesting that some of the things that I was doing in my class were not working that well, all I got was "answers" from a few teachers of what I could do to improve my teaching. Actually, it was nice to get advice, but I felt like no one else wanted to talk about their problems. I also felt incompetent, like admitting that I was the only incompetent teacher. Maybe I am! Strangely enough, my students are the only people at GCC with whom I can have a candid conversation about my concerns with department requirements, my actions as teacher, and their actions and needs as students.

The oral histories of Karen Ross, Patti Ricker, and Lisa Karms and their struggles to have their ideas valued in science gave the students and me a space and language to rethink our own interactions with science. Laurie and Gwen both talked about their chemistry classes that

they were asked by their teachers to drop because of their slightly below average performance on their first exam. Shellie and Tracy wrote about their experiences in high school of having to dissect frogs and do other sorts of compromising activities (activities which they did not want to do) and how those experiences played a role in their decisions to boycott science for fifteen and ten years respectively. Gene talked about his own experiences in college science where the professor promised the class that only half of the enrolled students would (could) return for a second semester. As students bring more and more of their lived experiences into science class, the dynamic of their relationships with science changes because they are able to interrogate what they know about science through new lenses.

*Moments of Political Resistance in the Teaching and Learning of Chemistry:
Connecting Chemistry and Oral Histories*

The emergence and reemergence of the theme about the political nature of science and the influence this had on the marginalization of women in science in other oral history projects and in other chemistry units throughout the semester had a profound influence on the rest of the course. For example, it pushed me to work harder to find the silenced experiences of women in chemistry. I was minimally successful in this endeavor, but I did find a few stories to share and a reason or purpose to share them (other than my own personal desire to work towards equity in the sciences). Consequently, some students like John, Gwen, Gene and Tracy began to notice more often the absence of women in our text and began to request (of me and of themselves) a more complete picture of chemistry. In the gas laws story, Shellie again drew connections between the work of Boyle and the work of Rutherford. Gwen, on numerous occasions, suggested that it was an unfair practice for the chemistry department to require students to buy books that were historically inaccurate and unfair. Tracy, in her journal and in personal conversations, stressed that one of the things that she became most aware of was the lack of women in our text book. Every time I told a new story about a woman not present in the text, John reminded me that I ought to consider writing a new chemistry text book that was "more fair to the women." Even

Dave admitted that we needed to do more to make the stories of the women heard, especially since he has two daughters about to enter public school.

As the oral histories progressed across the semester, so did the complexity and subtlety of the critiques emerging from our conversations, which worked their way into our study of chemistry. By the time the unit on the gas laws arrived, we already worked our way through the oral histories of Lisa Karms, Dr. Phillips, and Patti Ricker among several other oral histories (including that of a female chemical engineer, pharmacist, and biologist and a male fire marshal, goldsmith, and pharmacist). As we located instances of "missing women and minorities" as well as the discrimination that they feel, some of us began to reread our own experiences in science. We began to critique the practices of the department as a place where learning chemistry knowledge and learning the institutions of science and education crossed. As the conversation around the oral histories became more complex, the interactions between the oral histories and our learning of chemistry became more complex. This was particularly the case towards the end of the semester, when we collectively decided to engage in "acts of political resistance" by throwing out the department's requirements for the course and rewriting our own²⁶.

Welch writes that moments of resistance are "an affirmation of an identity that is different from that imposed by the dominant patriarchal social structures. . . [they] are a declaration of the possibility of freedom and justice." (p. 42). I believe that our "moments of resistance" in science class served to shift our relationships within the power relationships arranged by the dominant patriarchal social structures of science and education. Because we experienced ourselves and our ideas about science differently, we were able to construct new relationships with and in science.

²⁶For a discussion of this class session, refer to Appendix E.

Looking ahead: A conversation about how the oral histories project influenced our thinking about science

In this section I present a semi-fictitious conversation between my students from the spring and summer semester and me about their analyses of the impact of the oral histories on their learning of chemistry. The conversation that follows did not happen the way it is presented below. Rather it is a conversation constructed by me using quotes from student journals, class conversations and interviews with the students where they spoke or wrote about the oral histories projects during the course of their semester in class with me (spring semester students and summer semester students). I have taken liberties in turning my students' and my own oral and written statements into a conversation. I have also offered similar liberties to a few former students to edit their own comments (those who continued to engage in conversation with me over the summer). In this process, some of the quotations have been edited in order to make the comments sound more like a conversation. Although the editing process changes the students' statements, I have tried to keep intact the intent of the student comment. I have tried only to draw connections across student ideas and class conversations. My purpose for doing this is to draw out several themes and ideas that the oral histories raised for us to think about in our chemistry class.

The decision to construct a semi-fictitious conversation is inherently problematic—the conversation is constructed around ideas that "I am hearing." My very act of authoring the order of ideas and exactly what students say is bound by my own biases. Although I have tried to include many statements made by students which are in opposition to the dreams I have for my students, they are still the statements that I hear.

Furthermore, the very act of constructing this conversation from students ideas recorded in journal entries and in interview, immediately changes the dynamics of the conversation. In their journals and interviews the students were writing to themselves and to me, not to the rest of the class. Many ideas raised by the students in their journals may have been particularly difficult for the students to express publicly, especially given the uncomfortable power

arrangements marked by race, class and gender in our class, science and society. In light of these two problems, I have included in Appendix C, the verbatim student quotes and journal entries that I used in this conversation.

My reasons for constructing the conversation this way are threefold. Although student comments did happen in a chronological fashion, things that were said and written late in the semester informed a thought made at the beginning and shed new light on it. Also, conversations in one class (in my own mind) gave me new ideas and insights to take to the next class. For example, last spring when I was teaching an afternoon and an evening section, I constantly brought new ideas and insights gleaned from one section into the next. Similarly in the summer when I was teaching the evening section, I was engaged in a series of conversations with former students which informed my summer semester teaching practice. Another reason is that I want to give weight to voices which are often silenced by the active power relationships in science and education. As the author of this text I decide what to include. Often I sit alone at my desk at home or at school, reading transcripts, typing on the computer, cutting and pasting from file to file. Although I am positioned within the hierarchy of science and education, as female, white, scientist, educator, feminist, and have learned to ignore (and am struggling to unlearn this practice) how my oppression and privilege shape what I say, and when and how I say it, I still have the freedom of constructing this text away from those who intimidate me. Yet, the classroom is another story. Even when the students and I talk critically about our experiences, there are things that the students write about in their journals, that they tell me before and after class, away from public conversation, that we both know, they would never say in class (either because it was too close to the beginning of the semester and a safe enough space did not exist for radical and marginalized ideas to be voiced, or because the power arrangements in the class are too visible, too painful to confront, no matter how safe our communities outwardly appears to be). I wanted to help break these power arrangements by allowing some of these ideas to be heard.

In this conversation, the same themes are raised as in the earlier conversations (human element, elitism, and the political nature of science). However, I felt raising these themes again in this text is important for several reasons. First, they are raised by students whose voices were not heard in the earlier stories either because they were quiet in class or because they were member of a different class than the one described in this chapter, and the same ideas were raised in other sections. Second, in this conversation the students talked more openly about the contradictions I have created for them. That is, they came to my class to learn traditional chemistry because that is what they are told they need. Yet, I came to them not willing to give them traditional chemistry. Some students talked we me personally through journals or before class about their concerns if how much time the oral histories took from "learning chemistry." Finally, I chose to create this conversation to show how the oral histories helped the students not just to critique science but also to explore the pervasiveness of science in our society in terms of how it is "all over the place." I do not think this idea came up as much in the earlier conversations I wrote about, but it obviously influenced them in their journal writing.

Cast of Characters

In order of appearance:

Angie: Me. The teacher. I am a white middle class feminist who has not always been middle class or a self-named feminist and who is trying to construct a feminist liberatory science teaching and learning setting with her students. It was my idea to have the students do the oral histories projects, to have them talk about them in class and write about them in their notes. I am also the person crafting the conversation which follows.

Tammy: She is student from the summer semester, and a young white full time student majoring in physical therapy, who is returning to school at the insistence of her newly wed husband after five years of working as an office assistant.

Shellie: She is a student from the spring evening section, and is a white married mother of two elementary aged children. She works during the day as an office assistant and just started back to school part time after fourteen years, to earn a degree in psychology. She thinks at the rate she is going, she might be done by the "time she reaches menopause."

Holia: She is a student from the summer semester, and is a single young Middle Eastern mother, who tries hard to split her time between school, her two year old son, and work. She often comes to class with a can of Coke and a candy bar in order to "stay awake", because she gets, at most, "four hours of sleep a night."

Pete: He is a white, student from the spring evening section, and is the youngest student in the class—he is a high school senior from one of the suburbs who wants to get a "head start" on college. He has already been accepted into his first choice college, a branch of the state university system in the northern part of the state.

Bret: He is a white male student from the spring evening section, and is attending the community college to prepare for a career in engineering. This is a big switch from his last career of eight years as a hotel chef.

Sandy: She is a student from the spring afternoon section, and is a white single mother who works full time as a secretary. She is taking this class because she wants to eventually earn a degree in occupational therapy.

Tim: He is a white student from the summer semester, and is the youngest student in the summer section. Just graduated from one of the city's high schools, Tim wants to get ahead in his course work at the community college. He (and his parents) believe that attending the community college will "help him to get his life back on track."

Gloria: She is a student from the summer semester is Latina and is in her late twenties. Although quiet, she is very strong willed. She consistently and quietly puts up with sexual harassment in her job digging gas mains for the local gas and electric company.

Juan: He is a student from the summer semester is Latino and also is in his late twenties. Juan comes to class very tired because he spends all day mixing concrete and asphalt mixtures.

He often comes to class with intense headaches because the noxious solvent mixtures used in the concrete and asphalt mixtures.

Bill: He is a student from the summer semester and is outspoken, white, and middle aged. He has spent the last decade as a home health provider in his job "hooking up people to home respirators." He is attending the community college in the evenings to "learn the basics" so that he can apply to the undergraduate program in physician assistance at a local state university.

Rico: He is a student from the summer semester who left a large family in South America only one year ago to attend school in the United States. He is attending the community college in part because he needs to work on his English language skills, but also in part because he does not yet have the money to attend a larger university. Although struggling with his oral English at times (his written is better than many of the "English as a first language" students), Rico is quite outspoken with his ideas about science. He also helped me (the teacher) learn a bit of colloquial Spanish during break some days.

Lisa: She is a student from the spring afternoon section, and is a single white mother. She is on a financial aid based scholarship from the Women's Resource Center to study medical research at the community college.

DeShawn: She is a student from the spring afternoon section, and is a young Black student. She is studying literature and would like to focus on Black Literature. She is taking this course to meet the college's science requirement.

Linda: She is an older white student with a masters in public affairs from the summer semester. She is taking this course to help prepare for veterinary school.

Janine: She is a young (traditional aged) white, single and full time student from the spring afternoon section.

Ron: He is a (traditional aged) white, single and full time student from the spring afternoon section. He is very open with his opinions in class. He appeared to work hard to uphold a traditional image of science, and to undermine my authority.

Ann: She is a young, quiet, white, working-class woman and an Occupational Therapy major from the spring afternoon section.

Becky: She is a student from the summer, and is a white single mother who works full time in a local super discount store. She is taking this class because she wants to eventually earn a degree in physical therapy.

Karen: She is a student from the summer, and is recently married. She works part time as a beautician. She is taking this class because "her husband thinks it will be good for her" and because she wants to eventually earn a degree in physical therapy. She is best friends with Kelly.

Kelly: She is a student from the summer, and is a white female who works part time as a camp counselor. She is taking this class because she wants to eventually earn a degree in physical therapy. She is best friends with Karen.

Gene: He is a middle aged white man, high school general science teacher and football coach from the spring semester evening class. He speaks freely and openly in class, and likes science "at its core."

Julianna: She is Latina, and a single mother from the spring afternoon section. A very quiet person, she is returning to school, after nearly ten years away.

Tracy: She is a single and white and in her late twenties from the spring evening section. She actively boycotted formal science for a decade. She is taking this class because it is a required "hoop" on her path to social work.

Conversation

Angie: Does anyone feel ready to share their ideas with the group?

Tammy: Well for me, I never realized or actually thought about science as being all around me. From the road I drive on to the entertainment of fireworks enjoyed on July 4th.

Shellie: Tammy, I never thought about the connection between my life and chemistry either. Through the oral histories, I found there are a lot of people out there doing chemistry, thinking of ways to improve our world,

and those who are concerned with making our lives safer. As for me, I now know chemistry and science is so much a part of my life in ways I never knew. I found all of the reports fascinating.

- Tammy: I know, I now find myself looking at my surroundings and trying to relate at least five items in each room of my house to science. I've read the labels on house cleaners and my make-up and I understood some of it. It's fascinating, and being able to relate science to so many practical things makes me want to learn more.
- Peter: I agree. The reports made me think more about how chemistry is all around and that many people use it in different ways. But, I have to say that they haven't really shaped my beliefs about science. I already know that it is a tough field and you have to work hard at it. I already know that to be a successful scientist you have to work long hours in the lab. That's why I am not going into science.
- Bret: Yah, the reports have given me a better idea of how chemistry has a role in the different careers. I don't think that the reports have reshaped my scientific beliefs at all. I don't think that science is any different than any other part of life, it has its ups and downs. It was fun hearing what people had to say, but so what, it's like that all over life.
- Sandy: Bret I agree that all of life has its ups and downs, but I don't know, there is something all together different here. The projects have made me think more about science. At first I thought that the reports were a waste of time. We could have used that time to learn more chemistry, but then I began to think about some of the things we talked about. I didn't realize the political elite that takes place in science before this class. From the oral reports, it seems things are starting to improve some places as new, younger minds (and women) enter the field.
- Tim: It's kind of strange, I mean I don't know why it's taken so long for people to accept women in science. It makes me feel better now that more and more females are getting into chemistry and taking credit for their work. It makes me wonder why women were pushed away. I say that if it is an advancement, it doesn't matter who done it.
- Tammy: Tim, it makes me happy too, but I wonder if things are really getting better. I am really discouraged by the reports of the women in science who have been interviewed. I don't desire to make Chemistry or Biology my career choice but it's sickening to think about how many good things may not be happening because women are still not being taken seriously in this field.
- Gloria: It's mixed I think, at least in my situation. It's scary to hear how much sexual discrimination against women there is in the field of chemistry. At least in the company I work for, and I don't do chemistry there, I have seen some small changes of acceptance of women. Several of the men in my department swore they would never work with women on their crew. These men are still going from the rules of the "olde school". After working with several competent women, many of these attitudes are changing.

- Juan: Even if they are getting better, what's worse is that I was not even aware of the discrimination. My awareness was increased greatly but after hearing Megan's report, my notion of clean, smooth running, equal opportunity X Laboratory was changed drastically. I hope that change in discriminatory attitude happens in the sciences for minorities and women.
- Bill: You know this just brings up the point that money is the driving force behind everything including science. Just like the chemotherapy nurse said: Research information cannot afford to be shared. The focus in medicine is always on economics for survival in the current science climate. Certainly I can't think of a report where it was not mentioned.
- Rico: It goes back to Dow Chemical. Big corporations will decide the roads that science will lead.
- Juan: And not just the road for science research, but the road for the opportunities for minorities and women.
- Lisa: Big businesses, hospitals, it's all politics. Julianna's report about the doctor who studied the animal's eye really got me curious about just how much science is unknown because of politics. I think I believe science is much more political now than before I started the class. I don't think that years of research should be put on hold because the government decides that it isn't important enough to give money to anyone.
- DeShawn: It sounds like mostly they don't give money to minorities or to women who need science or want to learn science.
- Juan: It really makes me wonder about what kinds of chances minorities have in science just to have access to science. When my mother had cancer it took forever before she could get the medicine she needed. She would not have had to go through all that pain.
- Linda: It's just like my friend I interviewed. She was promised that job at that chemical company and when they moved they took the job away and kept her husband. They never did find her another job.
- John: This is interesting and all, but can't we cut this out, or we will never get through everything we need, all of the chemistry, before we take 151.
- Shellie: I am so torn. I really need to learn the material because I have to take 151, and I am so far behind everyone else. I have never had chemistry and I haven't been to school in 15 years. But I can't help but think about what Lisa, the biochemist told me when I interviewed her. She said the hardest part for her was there didn't seem to be a holistic kind of science, it was broken down into such small units that it didn't seem to have any humanness to it. What she is doing now, she said that she feels comfortable because she is looking at the whole. She wants to help try to change the approach to science. I'm like Linda, I don't want to be in science class if I can't connect to it.
- Janine: The oral histories helped me connect more in class because they gave you real people who use chemistry everyday. Not like people you read about

in a chemistry book like Bohr or Dalton. The people from the reports seem more real. I don't think that I would want to learn this stuff without having the chance to see how it plays out in real life. It would get too boring.

Ron: I totally disagree with you. If you want oral reports in CHEM 125 make the students explain concepts to the class with example of experiments and research, instead of tidbits of information on dead witches, wizards, monsters and alchemists. These oral reports only increased my cynicism towards feminism because of the high woman content of choice.

Angie: Ron, I am curious as to why you don't think learning about witches, wizards, monsters and alchemists is chemistry? Also you alluded to a cynicism towards feminism because of the high women content of choice. Would have you developed a cynicism towards masculinity if it had a high male content? Why is the large number of women problematic for you? Ron, another idea I find curious is that at the beginning of the semester I intentionally put more women on the list than men to get a reaction from the class. No one said anything to me at all—until now. But, there was also another reason why I did that. There are more men in science than women, overwhelmingly, and I thought I had three choices: 1.) make a list that truly represented science which would mean including one or two women on it; 2.) make a list of 50% men and 50% percent women to each gender a fair shake, although remember this would not be an accurate representation of science; or 3.) make a list that allows us to read about people who typically are not given a voice in science, for example, the women. How does that make you feel that I did that besides causing you to develop a cynicism towards feminism?

Ron: You could have been more realistic. It's not my fault there aren't that many women in science. I didn't stop them from going into science. You are being just as unfair to the men. I thought you wanted a "just" classroom.

DeShawn: Ron, I think you missed Angie's point: Science is more than learning about concepts and traditional scientists and that is why I think that witches and wizards ought to be included in science, although I don't agree with those terms you used. Personally, I have always thought of science as very abstract. It had little to nothing to do with what goes on in everyday life. I believe that has a lot to do with how it was taught to me. The oral report about mid-wives I found very interesting. I guess it changed my way of thinking as far as not see it as being absolute, but a political and economically controlled endeavor. I never read about midwives in school as far as science was concerned, or any women for that fact. It showed me history has to do with science and still does today. Whoever has the power gets the credit. Just like in every other field such as literature, mathematics or history.

Ron: Jesse, what's this world turning into. Science works. It's proven itself. I bet next time you are sick, you go to a doctor. And, I bet if it was life or death, you wouldn't care if he were a man or a woman.

DeShawn: All I am saying is that science is very political. Women had to learn by trial and error and weren't allowed in school. What we really know about

science is controlled, and we are given what status quo wants us to know. I guess I feel that science is like many other areas that need desperate growth before they can truly be effective.

- Angie: (Whispered to DeShawn, who is sitting to my left) Wow. Thank you.
- DeShawn: (Whispered back) You need to be more direct with Ron. Girl, don't let him jerk you around!
- Marie: I think what you are saying is important because different people have different ideas about chemistry. Chemistry is many different things to different people. You don't have to have a degree in chemistry to actually learn something. Some people learn by experiments on their own like with the plants, like Beatrice Potter. Science is more than just school or complicated experiments.
- Mark (mumbling to himself): Beatrice Potter. There have been, there still are, bigoted morons in the scientific community (oops). Only "big strong white men can do science." Oh please! I think the situation is hopeless.
- Becky: Yah, Marie, that stood out strong for me. Everybody has a different view and it helped me to listen and take into consideration other views and learn by their definitions of chemistry.
- Karen: And also, how ideas about chemistry change because of the time period. It showed me other outlooks on chemistry and different attitudes and practices of chemistry in different time periods. But also, one other thing I wanted to say was that the oral reports have made me realize chemistry isn't just solely working out problems, it has ethical and emotional sides as well.
- Kelly: Oh I know, like the fish, and the one about the eye surgeon. I have shaped my ideas about science in a more positive way knowing that we really do need science to survive, but at the same time we create our own disasters due to science which in turn need science to come up with ways to reverse what we have already done.
- Gene: Part of the reasons that science has emotional and ethical sides is that it is a human practice, it has a human side. For example, the oral report by the medical intern presented last week showed me how really important chemistry is in the medical profession. Somehow I didn't realize that everything you did in hospitals required chemistry of all sorts to function, serve and cure and heal humanity. People do science and people use science. It is human. I felt it was just books, methods in education and industry, but now I realized it can come alive and influence our survival as humans. Furthermore the injustice that women shared in the science and chemistry profession at all levels. That those men who share the elitist attitude are missing the point of science of the masses to appreciate. It is all our responsibility to change it.
- Julianna: Prejudice has also been present in the development of science, but not many people know about what minorities go through to have their theories accepted. I feel that science, like any other area of society, needs a lot of

revision. People, should not be ignored because of their culture. All people are capable of being an asset to the science community and should be allowed to do so.

- Gene: So, then we have to find the courage to go against tradition and break out new methods and ideas to make sciences more relative to all, not just the few to understand and appreciate to learn. It is our responsibility to change it.
- Tracy: How can we change science if it is full of people like the guy Laurie interviewed? This man's attitude seemed to be very self righteous, egotistical and extremely elitist. His image didn't ruin my impression of science as a whole, but epitomized the white, good old boys network that I find incredibly frustrating and sickening. What I think of science was shaped a little by this attitude because for some reason I hadn't thought of the extreme sexism involved in science and this report just brought it to my attention. Full force—in the face! I wish I could remember the details of Laurie's report, but I can only remember my general feeling about this man, his monetary motivation and condescending attitude towards Laurie's questions. It went along with much of what you have shared about your experiences in science and how your instructors or male counterparts have responded to you. These messages have only fueled more of the feminist activist in me. I can't stand the unfair treatment of people or the institutional discrimination! Maybe I should link about Labor and Industrial Relations, and law in addition to psychology!
- Gene: I don't know. The elitist attitude makes me feel angry at the injustice that attitude emulates to the every day spectator in regards to any type of knowledge, teaching, concept, philosophy and it holds, it bestows a false sense of superiority that the professor, elitist has and the anger I feel is that the student or the masses will have to feel insubordinate or can have an opportunity to attain the knowledge.
- Angie: I am really interested because you are both a teacher and a student of science simultaneously. Now these ideas that you talked about, how do they make you feel as you move back and forth between these two roles?
- Gene: Tired! I tell you, tired! At the end of the day I was tired. There is really a hunger there that I can feel. There is also a frustration. I am trying to find ways of trying to use the methods and all of the concepts that you are talking about in my class. I couldn't because, it was really frustrating. I couldn't because there were all these barriers. I think the majority of the children that I taught have some sort of attention disorder. The only way that I could get some of them to understand is if I grab them like this (he illustrates with his arms and hands him grabbing a student by the shoulders and shaking them) and it was so frustrating how many times I had to repeat my self.

As the conversation suggests, the oral histories helped us, in a small way to begin to envision a science better connected to our lives, because they brought into the conversation multiple and contradictory experiences and perspectives. The traditional content and practice of science as

masculine and politically and socially unbiased silenced our lives, as it has silenced the work of Harriet Brooks, Laura Bassi or the students in my class. For example, the students explored the idea of the political elite and used it to understand their own feelings in science. However, this also raised contradictions which may not leave us envisioning a better science, but only making us more uncomfortable.

I have learned through watching the students make connections between theoretical critiques of science and our own experiences with science that central to any revisioned science is providing students with opportunities to deconstruct the mythical images of science and scientists and revealing how our visions of science are produced within relations of power and social, cultural and historical practices. Creating contexts in which the science education regime of objectivity, homogeneity, and universal validity are interrogated contextually by students and teacher—interrogated through our cultural and gender specific experiences—make problematic pedagogical and scientific practices that inform and legitimate hegemonic visions of reality. A revisioned science also requires a space and a language in which to make public our nontraditional science ideas because this space and language enables us to begin to decenter the traditional power relationships in science and education.

The oral history conversations gave us a language and a space to resist and refuse alienating practices of science we have experienced through the promotion of science as ahuman—removed from personal, social, political and historical experiences in our lives or the lives of others. The oral histories helped us to think critically about our lives as science teachers and learners, men and women by insisting that we make "explicit our historical and social place as a concretely lived reality that touches us, like the wind, imperceptibly and yet unmistakably" (Lewis, 1993, p. 54) . I believe, in the words of bell hooks, they helped us to "decolonize" our science minds.

Yet, I can also see many places where we missed opportunities to decolonize our minds. We explored the gendered nature of science often. This was easy for me to recognize, especially through listening to the stories of the women scientists involved in the oral histories and the

connections that my students vocalized to the ideas raised by those women. We also began to explore the classed nature of science, although we did not get very far. This I think was the case when we talked about the elitist nature of science or the political nature of science, and how science requires a great deal of money, or how science is held up as an highly intellectual (read: you need a lot of education and not any one can do it). But, we rarely, if ever, talked about the raced nature of science. Perhaps this is because as a teacher and a researcher I relied on my white privilege to support my authority in the classroom or because of my complicity in interrogating my whiteness. I think maybe I need to try harder to bring a larger percentage of minorities into the oral histories. I know that on the list I created, I had a disproportionate number of women scientists. I think I need to do the same with race and ethnicity.

As I describe in the next chapter, a look into a series of summer conversations with former students, sustained reflection and conversation on our own multiple and sometimes contradictory identities and experiences in science through oral history conversations and summer conversations created contexts in which to reveal aspects of ourselves—who we are as learners of science, as gendered, raced, and classed people—that we might not have been able to do in the context of traditional science, even if that traditional science carried with it a radical critique. This is because no matter how hard we try, if we try to revision science through the language and image of science we are left to build any new science on the already established power, knowledge, and privilege of western science. But if we begin to rethink with personal reflections on our lives and how we are positioned into science, then we can create places of radical resistance. We can create a science imagined.

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CHAPTER 6

Summer conversations:

Building new ideas about science education through extending our spaces of radical resistance

What distinguishes feminism as a method and a practice is the way in which it insists on making explicit our historical and social place as a concretely lived reality that touches us, like the wind, imperceptibly and yet unmistakably" (Lewis, 1993, p. 54).

In this chapter I explore a series of summer conversations that I shared with a small group of students from the spring semester (evening section, Tracy, Laurie and Gene). I describe how the act of engaging in these conversations simultaneously pushed on the prescribed boundaries of science education and made these boundaries visible for the students and for me. I reflect on the role that these conversations (the "summer conversations") played in helping me to rethink classroom events and feminist liberatory education. I also reflect on how the summer conversations were a form of feminist liberatory science education and how they shaped the students and my own continued thinking about science education.

How the summer conversations started

In the middle of April Tracy missed one week of class so that she could attend a counselor training session for a domestic violence and sexual assault hotline. When she came back to class she wrote in her journal,

A break from Listening Ear Training! While this is a worthwhile experience and will come in handy often, I'm concerned about my chem and social work. It seems like its always one or the other. Only one more week!

In response, I wrote in Tracy's journal:

I think your presentation on Patti was exciting! It stimulated a great discussion! How did hearing Patti talk about her experiences in and beliefs about chemistry make you feel as a woman studying science? I am also curious, because of your last entry if you see any connection at all between what you want to do with counseling and chemistry.

To this Tracy replied in her journal a week later:

Angie, to answer your question, I am not sure how chemistry is going to relate to my desired profession. It may be useful in the sense if the neurosciences as Patti Ricker had mentioned or possibly in the use of different medications and their effect on the body or the psyche. I have not yet taken cognitive psyche, but I am sure that my chemistry will have some impact on my career to be. Thanks for your asking! Your question made me put into words my expectations of chemistry use.

Needless to say, I was quite disappointed in myself after the last test. While I missed the coverage of Chapter 14, I felt like I had an understanding of Chapter 12 - 13. The only explanation I can think of for my open book, open notes test would be just being completely emotionally and physically drained. Even though my classes and studies have suffered over the last two weeks, I must say that I have learned some very valuable skills and have personally grown through the listening and ear training. I don't think there ever would be a good time to do it. I highly recommend it if you are even the least bit interested.

Maybe we could do lunch sometime after the semester is over with? It would be interesting to hear more of your experiences with education and feminism. I guess this is enough writing for now. Thanks for your concern this evening! Time to study!

By now, it was the end of the semester and so as my last response to Tracy in her journal, I replied:

I enjoy having you as a student in this course. Good luck in psychology! Some of the things that I have tried to do in this course (although not always explicitly) was to bring a feminist perspective to teaching science by 1.) deconstructing with the class notions of elitism in science, 2.) not uncritically accepting the authority of GCC to tell us what to teach and learn 3.) making explicit the culture of power and relationships of power and privilege in science (i.e. domination by the good old boys network by controlling research money and the decision of what is acceptable scientific behavior and research subjects), 4.) heightening awareness, and 5.) by allowing the voices of women scientists to be heard—including the students in the class and the oral histories (if you notice my list for oral histories is 90% women. I wanted their voices to be heard, for they are rarely heard in the science community). I think with

some of these issues I was more successful than others. Mostly I think in meeting my feminist goals, I failed. I feel, as a feminist teacher of science I am silenced by the requirements of a department that does not understand the sexist domination in the sciences, and a general attitude about what science and science education in a society that does not value the experiences of women. Well, there is always next semester.

Since my dissertation is closely related to what I just wrote, I am curious to get feedback from students. Do you think that this course in any way (in any little way) contributed to breaking away from status quo and from maintaining oppressive relationships in the sciences?

I know that psychology is equally dominated by men and masculine world views. I hope that you can hang in there and begin to create change in the way that psychology is practiced. Following is a list of readings that you might find interesting. (You might have read some that are already on the list).

Let's have lunch!!

The conversations that Tracy and I shared throughout the semester in her journal served as a starting point for the various conversations that I shared with former students throughout the summer. Her initial invitation for me to join her at lunch provided my first realization of the value of conversation about chemistry and critiques of chemistry outside of the formal classroom structures. Throughout the entire semester I tried to engage students in conversation, believing that we could overlook the power imbalance inherent in our relationships as teacher-student, in order to engage in meaningful, sincere conversation about our feelings and experiences in science. Even though I think some of our in-class conversations were intense, no matter how much I hoped we could overcome the power relationship, our in-class relationships were nonetheless bounded and limited by our inscribed identities inside the classroom. How much could the students really risk sharing with me, the one who ultimately decides their academic fate in the class?

Tracy's invitation to lunch was also an invitation for me to question how my own embeddedness in the educational and science institutions and how my sometimes passive acceptance of these boundaries constrained my interpretations about what it means to teach and learn chemistry. Tracy's intervention enabled me to ask myself for the first time, why bound my teaching role to traditional structures? Aren't these the structures that I am seeking to

change? Why does all my "teaching" work have to be done in the classroom where my attempts to deconstruct the teacher-student relationship remains bound up in the hierarchical relationships of education and science? Why not take teaching and learning into new contexts where we can explore issues uninhibited by our institutions? I was not sure what to expect with the summer conversations, and I was a bit nervous having to construct a new kind of relationship with these students.

Themes

In this section, I share large pieces of transcript from the summer conversations. Because these conversations create different meanings for me than they do for the other conversation participants, and because they bring slightly different meaning to my teaching and research each time I reread them, I leave much of the conversations "unanalyzed" in a traditional sense. Instead, I break the pieces of conversation which I have chosen to share into three main themes: Critical awareness, awareness to praxis, and revisioning feminist liberatory education. I describe each theme, then follow the descriptions with different pieces of transcript which connect to the theme. Scattered throughout the transcripts are my reflections. My hope is that the reflections will provide insight for the reader about the ways that the conversations influenced my thinking about teaching a feminist liberatory science.

Critical Awareness

There are moments in my life where I feel as though a part of me is missing. There are days when I feel so invisible that I can't remember what day of the week it is, when I feel so manipulated that I can't remember my own name, when I feel so lost and angry that I can't speak a civil word to people who love me best. These are the times when I catch sight of my reflection in story windows and am surprised to see a whole person looking back...I have to close my eyes at such times and remember myself, draw an internal pattern that is smooth and whole. (Patricia Williams, *On Being the Object of Property*, cited in bell hooks, 1994, p. 74).

bell hooks (1994) writes of William's work that "it is not easy to name our pain, to theorize from that location" (p. 74). Developing a critical awareness in our lives of our lives is not an easy thing to do. It is also not without pain or struggle. But developing a critical awareness of ourselves and science in our lives which has, through, sexist, racist, and capitalistic intentions, dominated and dissected us, I believe we can begin to rename the power structures which define us in science.

When the spring semester came to an end, I tried to assess overall my progress towards my personal and pedagogical goals. As I described elsewhere, in the spring I designed my chemistry course with several pedagogical and personal goals in mind: I believed it was important for students to become fluent in traditional science so that they would simultaneously have access to the culture of power and develop a foundation on which to build a critique of science. I also believed that it was important for the students to understand how science played out in their lives in positive and negative ways. I also wanted the students to become familiar with feminist critiques of science so that they would have the theoretical tools by which to make sense of and organize their lived experiences (Middleton, 1993; Greene, 1988). Finally, I wanted to use my understanding of positionality to think about how my own actions helped or hindered our efforts in our science class to be critical of taken for granted beliefs and practices in science and education.

Did my students develop a critical awareness of science? Did they develop a conceptual understanding of the scientific principles which played out in their lives? Did they have the theoretical tools to make sense of their lived experiences in science as a way to work against their oppression, as a way to deconstruct their privilege? Were the students able to make connections between understanding and critiquing the science in their lives? Was this important to and for students? Did thinking about positionality help me to create new understandings, ideas, and interpretations that would help me to shape my teaching practice in ways which would help the students towards these goals?

I had mixed feelings about whether the students developed a critical awareness of how science played out in their lives. And, I wondered what good it did anyway. Maybe the students would be able to state a few chemistry theories and maybe they would be able to point out where the work of women or of minorities is missing from these theories, but did that mean anything in their lives? Was I kidding myself in thinking that these were worthwhile goals or that my teaching was a valuable use of the students' time? I wondered how the students interpreted my attempts to create and teach a liberatory chemistry, to help them become aware of the knowledge produced by science and that it is located within a particular social, economic, and political context.

My reflections on positionality during the spring as I described in Chapter 4 helped me to see that my actions, if anything, promoted a dichotomy between understanding the chemistry and critiquing the chemistry. In my own theorizing, and hence in my teaching, I had been unable to reconcile what I felt the students needed to know to continue in science successfully and what they needed to know to articulate their own oppression and privilege in science. In the summer conversations I learned how the students began to develop a critical awareness in science, when they believed it to be important or not important, and how our conversations were a place for us to continue developing a critical awareness.

I also learned that this either - or place I expected the students to be is not resolvable, but also not as dichotomous as I have just labeled it. My students in their own ways found ways to co-exist between the two worlds I had been trying to construct. And in my desire to resolve this uncomfortable tension, my students went on with their complex lives creating meaning from their own multiple and contradictory positionings. In the section which follows I hope that the reader sees how much I learned from the students about what it means to develop a critical consciousness and the tensions and contradictions inherent in that process.

June 15, 1994, Coffee shop

Tracy: I feel like, like I said, even little things, noticing that something is, or thinking about the background. I think about what does it mean to mix things and what do you have to know. What goes into a cappuccino or a

French soda? The gasoline. I think about it a lot more. I am more conscious of something being a part of science, going over the everyday types of substances—solids, gases and liquids, that sort of thing....If I were ever to teach a class, I would teach it similar to the way that you taught our class. With the journals, the open discussion and being flexible to let the students learn. Not just like cramming as much in as possible, and not really giving a rip if anybody understood everything. When you go to college it is nice to learn.

Angie: One thing I tried to do was make people aware of where they fit in science. How does science try to define us? Who does science say can do science? Who is good in science? Just how chemistry classes and labs try to perpetuate these ideas, perpetuate the elitism, and that we do not have to accept what they say. I don't think that transformation in science can occur without awareness.

Tracy: Right.

Angie: Do you think that anybody in the class became more aware?

Tracy: I do, I really do. Like I said, as far as science goes, I wasn't thinking in terms of science a whole lot prior to our class. After our class I began to think about science a little more. Shellie did too and it sounded like a couple other people in the class did. There were a few who didn't seem like they cared one way or the other. I think the people who were interested enough did learn something new whether it is about the department at GCC or science in general. Yah, I think it was evident and I like how you brought in women's issues a lot. I could tell that there were a few times that you held back though.

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Angie: What do you mean when you say science knowledge?

Tracy: I am not sure. The first thing that comes to mind is Algebra.

Angie: Why is that?

Tracy: Honestly, because we do so many calculations and there is the scientific notation sign on the little calculator. That was my gut response.

Angie: I like gut responses.

Tracy: I don't know, Angie. I guess scientific knowledge would just be the learning process, knowing the theories, the methodologies, the processes. I guess then you would have to be able to adapt to the new theories, the new everything as it comes in. Not just staying with the old traditional model, but being able to adapt to it....I would say that it is subjective because of what we discussed earlier. Everybody brings their own personal beliefs and value system into what they are working on. Somehow your personality seeps into what you are learning. At least your interpretation of it.

- Angie: So how does that make you feel, if you are sitting in a chemistry class and are expected to learn the knowledge as if it is some objective truth, without talking about its social, political and historical origins?
- Tracy: Well, it makes me feel like who ever created it is one person. It's one person's opinion, one person's subjectivity. It's one person's whatever it is that they study and it is not to be taken as fact. It is something to be considered. It is one possibility of thousands that need to be considered. Like the periodic table, there are tons of ways to do it... it makes me more mad that they don't give me more options. One thing is very evident at least in the book that we used, very rarely is a woman's name mentioned, and I think that I have become more aware of this. Women are practically nonexistent. You know that is not the way that happened unless they were jailed or burned at the stake. So I guess I would like to make it more broad. Give you more options as to what you want to believe and why. Encourage the student to make their own decisions...Doesn't that make you mad too?
- Angie: It makes me mad so much so that I feel like I need to spend a lot of time in the library finding out what really happened. But I wonder if what really happened is even in the library! I wonder if there were other views presented by women that weren't taken seriously and so they never made their way into the science conversation. What I found was in a dark dingy book in the corner of the library, and I just wonder how can I actually find that stuff?
- Tracy: Would it be recorded anywhere?
- Angie: I don't know. If it had been part of science all along what influence do you think it might have had on the periodic table or atomic theory or anything else?
- Tracy: It would look different.
- Angie: Why?
- Tracy: Because I think that it wouldn't be so, so rigid. I think that it would be more broad and encompassing of people's beliefs. And, it wouldn't be the white male status quo.
- Angie: Do you think that the theory of the atom, as we know it now, would exist?
- Tracy: I don't know. I know that it wouldn't if you wrote it, right?
- Angie: No, it probably wouldn't.
- Tracy: I don't think we would. No I don't. I don't know what theory we would have in its place. But it's interesting and it was very interesting to hear you say that you didn't believe in that particular theory.

Tracy is a woman returning to science after having been away from "formal science" for over a decade (last encounter: high school), and she was in this class to learn science (and

because it was a requirement in her program of study). To see her negotiate her way through the discourse of science—a discourse "not intended for her" (Lewis and Simon, 1986)—with the confidence and with the critical posture she demonstrated in this conversation illustrated to me that some students may have been making connections between critiques, subject matter knowledge, and personal experiences in ways that I had not considered, because I had not really invited (or listened to) the students' personal experiences into our exploration of chemistry (with the exception of our class conversation on the oral histories).

For example, Tracy talked about the periodic table and how she learned about atoms and their interactions from studying the periodic table (something I would hope any student would get from any chemistry class, feminist or nonfeminist). But she also said that it was helpful to know that it is not the only way to think about atoms, and had other people (in particular women) been engaged in chemistry at the time these theories were developed, we probably would not have the periodic table as it exists now, and that she is sure we would not have atomic theory as it is now. This helps me to see that some of the activities that we did in class (reconceptualizing the atom and the periodic table) helped students, or at least Tracy, to understand how social values influence knowledge construction in science. She did not accept the periodic table or atomic theory as fact, but as one way of interpreting the world. Most importantly, Tracy felt a certain freedom to critique that which did not fit her needs, despite her "outsider status" to science. Tracy began to make connections between her conceptual understandings and critiques of science. What helped her to do that?

June 29, 1994, coffee shop

Angie: Oh and then the other one [of the classes that I thought was important] that I had written down, and this is not just one class, but it is the oral histories. The one you did with Patti, the one Gene did with Karen, the one Shellie did with Lisa and the one that Laurie did with Dr. Phillips.

Tracy: (interrupting) He was the jerk.

Angie: Yah, he was, but it helped I think because of the discussion we had about the different messages. For me that was really important in helping me think about how I can get students to begin to talk about these issues. I was

wondering what classes you thought were particularly important to you and why.

Tracy: The ones that really stuck out in my mind? I think that the oral histories helped me a lot. A lot. Whether it was listening to Laurie's oral report with the Kurt Phillips guy, my own interview with Patti was good, and how she sees science and how women are treated at [the local state university]. The differences were telling, almost whenever someone brought in an oral history I really liked it. There were a couple of times that I was really bored.

Angie: Whose were you bored by?

Tracy: I had a hard time concentrating on Pete's.

Angie: Oh the jeweler.

Tracy: Yah, I was somewhat interested, but I just had a hard time concentrating. I should have moved from the spot that I was sitting in class, especially towards the last few weeks because it was really, Pete was sitting next to me and there was Mary and Kristen and they would talk and chit chat. I did move one day, but if I am trying to listen and understand something, I wish they would just shut up.

The other one that I really liked, I liked when we went over all of the theories, and talking about your perceptions of them, and then you gave us a list of the important details. I liked that class because I like structure, but I didn't like that book because there were no women mentioned. It was a very important [inaudible], here are all these men and here are all their theories.

Angie: Were you thinking about that at the time?

Tracy: Yah, the whole book was men, I didn't see any women in the entire book.

Angie: I know. There are no women in the book.

Tracy: It is a very, it is a large absence. That was a very influential class period. I really liked the class periods where we discussed. We discussed the difficulties that you were having with the chairperson because that helped you to see that yes, this is real and it is happening every day. It made you seem to be a great advocate for the students and I didn't see him as an advocate for the students. I saw him as person who is so caught up in his image and so caught up in being above everyone else. There were times in classes where you would walk through problems and examples. I found that very helpful.

Angie: You can criticize me.

Tracy: No, I found that helpful. The only thing that I can say is that you put yourself down. I thought you did a great job and other people thought so too. You have a lot of knowledge, and there is nothing wrong with saying yes I have a lot of knowledge and sharing that with us.

Angie: I am always self-conscious.

Tracy: Well even with what we were talking about I knew that sometimes you backed away from it, didn't tell us everything you knew. It seemed like you didn't want to blow us away....I thought that you did a wonderful job.

Angie: Quit saying that.

At the end of the semester, I felt like my classes did not look or act anything like the rather idealistic picture of feminist liberatory education I had in my mind. Talking with Tracy, Gene and Laurie this summer has helped me to see that what I did was not all that bad and they have helped me to see that if my class really went the way of the idealistic picture in my mind, then I was probably controlling the class too much; I was probably not being "an advocate for the students."

When I bring my feminist agenda to the classroom there are several immediate issues that I must deal with. First, my agenda is sometimes in conflict with the department's or the students' agendas. The students are not coming to class expecting or, in many cases, even wanting a feminist science class. They may come to class with the hopes of having an experience different than previous science experiences. They most likely come to class with the expectation that the course will be hard, abstract, and tedious²⁷. Second, the department (who pays my salary and observes my classes) has specific expectations that I agreed to when I accepted the teaching position. Their expectation was that I teach the subject matter of traditional chemistry; a tightly bound notion of the nature of chemistry. This means that there was a strong expectation that I teach, unproblematically, a traditional and narrowly defined chemistry (i.e. this is the knowledge that we had to learn and so we would learn it no matter who the students in the class were, what their intent with chemistry was, how we felt about it, or how it was represented in the text). I came to class with the expectation that I would try to

²⁷For example, at the end of the semester a few of the students, in their course evaluations wrote that the oral histories were fun or interesting, but that they took up too much time, or took time away from learning chemistry.

challenge the traditional structures in science education through my practice. I also came with the belief that this would be good for students.

Part of my feminist agenda then was to help the students be critical of the knowledge generated in the course (critical of it existing as Truth or Fact, critical of its social, historical, and political origins, and critical of what is chosen for us to learn and not to learn). I also wanted to help the students connect chemistry to their personal lives (not as a set of decontextualized ideas). Furthermore I wanted to help the students become critical of the power structures in science and school; to become critical of my decisions as a teacher. I make many decisions about what (and who) is important in our class, and although I try to take the students' ideas into account, some decisions are still made without their perspectives, without their knowledge, without their consent. I believe it is important for the students to question decisions, to be critical of decisions of the department, the textbook and author, the authority of science, and me if they are to begin to build a science consistent with, yet critical of, their own lived experiences. The last piece of my agenda was to work with the students to envision a science of the future where we are all included.

I felt torn between these agendas all semester. Initially, I saw this as a failed attempt on my part to meet either agenda or even to find any satisfactory common ground. (What I really mean here, as painful as it is to admit was that I thought if I were truly successful, then I would have won all of the students over to my agenda.) But as Tracy pointed out in our conversation about the oral histories, the tension between these competing agendas is useful—if not necessary—in our class. This is because it is our articulation of differences which allow us to remain critical in science. For example, my original list of oral history subjects was rigged to contain a disproportionate number of feminist and other nontraditional scientists (90%). Yet, because I allowed the students to choose an oral history person on their own, and not necessarily from the list, some students chose people who were very traditional in their scientific ideology (Laurie's oral history of Dr. Phillips for example). The ideological and epistemological differences we confronted with each new oral history did not serve to alienate radical

scientists, as I feared. Instead, as I pointed out, the differences created spaces where we could locate our critiques and our lives. These conversations have helped me to see that my vision of a science of the future is my vision. If I impose it on others, I will be as imperialistic as positivistic science. I need to keep my mind and my agenda open to the needs and experiences of the students. Together we can create a critical awareness of our beliefs in science. Together we can be critical to build a science of the future.

June 15, 1994, over lunch at a local restaurant

Angie: How does the elitism in science feel [to you] as a person in society?

Gene: I think the elitist attitude makes me feel angry at the injustice that attitude emulates to the every day spectator in regards to any type of knowledge, teaching, concept, philosophy and it holds, it bestows a false sense of superiority that the professor, elitist has. The anger I feel is that the student or the masses will have to feel insubordinate or they can't have an opportunity to attain the knowledge. It made me feel good to know some real interesting things about science.

[D]uring our class, I also learned much about the field of science as a whole. One observation about the science department at GCC was the department chairperson was overly concerned that if students actually did well on a test (or god/goddess forbid—the class), it would make the chemistry curriculum appear open to everyone. Worse yet, it may even appear easy/understandable to outsiders. Through the realization of this attitude, with the oral reports given in class lending more evidence of the same, I began to understand that many chemists/scientists have elitist attitudes. Many of the oral reports revealed the discrimination that women face both when entering the study of science, and once they are actually in the field of science. Throughout history, women have been unequally compensated even when the work they do parallels or surpasses that of male counterparts, and once again this pattern is perpetuated. I'm sure that there were quite a few women who have contributed to the study of science, however we don't see their names, photographs, and contributions listed in our college textbooks. It was frustrating and discouraging to see that in science, as well as the rest of society, the white, Protestant, male dominates and controls the accepted standards.

If there were more women in the field of science and science education, I'm certain that the learning process, teaching manner of an overall scientific concepts would be much different than what is currently the norm" (Tracy's response to Gene's comments, July 29, 1994).

June 15, 1994, over lunch at a local restaurant,

Angie: This is very interesting. Do you think before the chemistry class last semester you would have said the same thing?

- Gene: I do not think that I would have said the elitism. Well no, not all of them either.
- Angie: What do you mean by that? Or let me say that in the best and worst worlds what do you mean?
- Gene: Let me give an example. The worst situation is where the scientist sits back in the ivory tower and works on solving problems in the physical world.
- Angie: Why is this a worst case?
- Gene: Because they are sitting back up in their ivory towers and this is elitist because they just sitting up there, with no care or connection to the masses. Who cares about the masses? But the best situation is where the scientist goes out actively and joins the masses and is able to relate to the everyday person who is trying to find answers. They need to be more human. They need to be out and about and stimulate educational growth. Contact with the common man, the common person is important. Like in manufacturing they get into the nitty gritty, they have to make it work. They are playing the science game, and making things useful for the future. At the college level, it can be just like teaching. In the science methods course, they never covered the stuff that I need on the front line. Anybody can talk about subject matter knowledge. But I learned more about science in my first year of teaching than I did in four years of college.
- Angie: What is this thing scientific knowledge that you are talking about?
- Gene: It is information that is obtained through experimentation. Stuff that is learned in chemistry is scientific knowledge. The periodic table, atomic theory, stoichiometry, gases, liquids. Like the periodic table. It is because, it is related to some different things and way it related to the rest of the elements. We were experimenting and trying to deviate from the norm. We learned that there is more than one way, it is not that clear cut.
- Angie: Like how we rethought the periodic table and there were other ways to conceptualize it. Do you think our way of putting the periodic table together was scientific knowledge?
- Gene: I think it was because we related some of the different things in a specific category. We put them in different groupings and with the experimentation we gained some knowledge.
- Angie: What is the experimentation?
- Gene: We did some basic things. We put, I can't remember, we were experimenting with different ways to think about it, we were deviating from the periodic table and in our experimentation we came up with a different plan. It's like there is more than one way to skin a cat kind of thing... I think it is, I have used a lot of things from our class in my class.
- Angie: Like what?

- Gene: The periodic table, the thought process, testing liquids, the experiment I came up with to test saturation points.
- Angie: So, you used the experiment you made up in class with your students?
- Gene: Yes, I worked the sugar and salt and the potassium nitrate, and then I did a comparison. I took the sugar and the salt and the potassium nitrate and added all three and supersaturated it and we figured the concentrations at each level and heated them up. And the nitrate was eventually gone and the students were like, "whoa where did it go?" The other ones were having a tough time dissolving. Then we took them all out and put it on cold water, and then the students were like, "oh look at that one, it looks like it's freezing!" And then they said, "it can't be freezing, it's not 32F, it's only cold water. It can't be freezing!!" As the crystals came back it was kind of neat. (pause) It's tragic. I've got thirty something kids in my class. It's really hard. It's tragic, but that's what I deal with. I should be thankful that there were some students who got excited, because at least I have reached somebody.

June 15, 1994, coffee shop

- Tracy: Well, this class certainly made me aware [of the elitism]. Like I said, I never really thought about science having an elitist attitude about it. I never really thought much about science. I knew that it made my life more easy, convenient, and that was a good thing, but I never really thought about some of these issues that were raised in the oral histories or in class. You know, it's ridiculous to cram eighteen chapters in one semester. It makes it impossible to learn, and that is their way of weeding students out. It's discrimination.
- Angie: How does this make you feel about whether you like chemistry?
- Tracy: I liked our class, but I am sure that I would not like all chemistry classes. You showed a real commitment to the students, you cared about whether we learned the material. You didn't just stand in front of the room for two hours and lecture. I could tell that many times it was hard for you as you struggled with the department's requirements, but I know that I am grateful for the way that you treated the class. I felt like I had more of a chance to learn the concepts, even though we did not get through all of the material that we were supposed to.

June 14, 1994, over cookies in my office

- Laurie: I think that taking chemistry helped me to understand the psychology of why some people go into science. It made me think about scientists and where they come from. Most interestingly on TV recently there was an interview with some doctors in Russia. Did you see that one, it was on 60 Minutes? [Angie: No] Doctors in Russia don't get paid as much as the bus drivers! It was just, a lot of it, the scientists, the values that they place in society on their field. The value system of Russia versus the US. It made me wonder what caused that the value system difference. It makes me wonder about the value system and the difference.

- Angie: What do you think caused that difference? Well, first what do you think that the value system of science in the US is based on?
- Laurie: Values of science in the United States are economics. Economics are the value system. Oh, and science hold the answers, especially in the medical field. Medicine in the field, you know dominance in your life. Some, I guess that some, I think part of it is that accessibility to medical treatment is much more dominant in the US versus Russia. What's present in everyday life—what you get used to having as your standard of living. So, I think maybe it boils down to your standard of living you are having.

Wow! These students really did begin to challenge the scientific knowledge, the scientific community and the science department. Three of the biggest themes for Tracy, Laurie, and Gene seemed to be the "elitist" attitude in science, the control of science and in particular medicine by economics, and the role of science (not) in their lives. I can see that these developing critiques for the students grew out of their personal experiences and the oral histories more than the more formal critiques of science I introduced. They have made specific connections between the critiques of science developed through the oral histories, the practices of the chemistry department at GCC, and their personal experiences. What was interesting about this group of evening students was how we were able to make meaning despite our (my) ambivalence in terms of the competing needs to conform and to challenge. There were varying degrees to which the students had feelings about this situation. There were varying degrees to which the students were able to live between both worlds. It is interesting to take a moment back in order to look at how the students contextualized these ideas and what that might mean for their own need to resolve this tension (or not to resolve this tension). For example, I think Tracy talked about the weeding out process and who defines valuable knowledge and access to valuable knowledge. I believe that Tracy would challenge the institution of science in order to redefine what is valuable knowledge and in order to make any knowledge more accessible to all people. I believe that this is more important to here than learning the acceptable knowledge of chemistry. Gene, an urban high school teacher, talked about how "science does not care about the masses," and that we need to find ways to engage the masses in science so that they will be enlightened. I think Gene would like challenge the authority of science but his reasons for

doing so, I believe come from a resistance fueled by his life as high school physical science teacher, and not from a feeling that he has been alienated from science. On several occasions, Gene has expressed how much he likes science "at its core." But, at the high school he has a boss who tells him how and what to teach despite the fact that his boss has no formal training in the sciences. Laurie talked about the psychology of why people go into science and the values which science espouses. I think that Laurie was comforted with our discussions and our class decisions because it seemed that the elitist aspect of science was what alienated her from science over ten years ago.

June 22, 1994, coffee shop,

Gene: I think that, I learned a lot from talking and from talking about my and your frustrations about how important it is for science to be more human. I saw you struggle with that, about you trying to make it that way. That is very admirable. That's a sign of things to come. You have touched on something that has got to happen. We have got to be a more enlightened society. It's got to happen. It's gotta be more human. We have to strive to make a connection with the masses. We need to start at school, at home, with parents. It's got to happen.

Angie: When did you start to think about this stuff? Did you think about it before our chemistry class?

Gene: Oh no. No! Thanks! It's helped me. I think about it a lot now, trying to get kids involved. Science is not always fun. School does not have to be fun, but it can be exciting. I think enjoyment is the sense of accomplishment, that you have learned something. School is not just a place to play. School's not always entertainment. It's not TV. It is work and takes discipline.

Angie: Did you learn anything else?

Gene: I learned a lot about all the different opinions and concepts of the people interviewed and how each person had a beef or statement they wanted to make public about how things are now and what they would do to change it. They are trying to strive, and really is the first step in gaining knowledge, trying to strive to make it better...The injustices performed to females in science would in past and present but not the future. And that it doesn't have to be that way. There is ignorance and intelligence. No matter how smart, there is ignorance.

I think that Gene is trying to tell me something very important and very interesting.

He struggles with the elitism theme in ways which are very telling. He wants science to be more human so that we can make a connection to the "masses." He also talks about the injustices

done to women in the past but not in the future. He also talks about the co-existence of intelligence and ignorance. I have to admit that whenever Gene talked about the masses, all I could picture in my mind was a herd of cattle being herded down the street from one pasture to another so that they would have fresh food to munch on. I picture the men on horseback circulating among the cows to make sure that none of them go astray, using their whips if they have to, sometimes coaxing them with their voices. The cows have to conform. They have to do as they are told or they are whipped. Although the cows have a choice about what they want to eat, where they want to eat, and when they want to eat, and which cows they want to hang out with, once they get to the appropriate pasture, but this choice of pastures was ultimately controlled by those in charge. I never told Gene about this image, but was prompted to write about it when Wanda May said that she was intrigued by Gene's choice of words. I wonder why Gene chose this word. Did he see large groups of us—like his students—not having access to science and being herded around by the scientists because we were ignorant to the ways in which the scientific community controls us? Does his own need to make science more human a way to get science into the masses so that they cannot be herded? Does he think that this humanness in science will stop the discrimination against females, or does he think that finding ways to bring the masses in will actually change science so that it is more friendly to females?

As I publicly struggled with the aims and goals for the course, in order to get the students' input, together we began to deconstruct how the GCC chemistry department perpetuates the elitist attitude of science and together we began to revision what it might mean to challenge that elitist attitude. This influenced our class conversations, attitudes and actions. We began to deviate from the official requirements of the course through acts of political resistance.

July 13, 1994, over lunch at a local restaurant,

Angie: Do you think I am a chemist?

Tracy: Yes, you are, but I think that you are student to, only because you are learning. Even if you weren't an official student, people are still learning. I think that there are so many people who get to a place in their life and they are stagnant. I can't remember the names of the people who were interviewed, but some of those chemists who have the elitist attitude, who think they know everything, they are not really learning. They are not students anymore. They think they are gods. I like the attitude of wanting to grow, wanting to learn more. That is something that I value. So yes, I would say that you are a chemist. It is something with which you work daily. It is something with which you have training. It is part of who you are.

Angie: Do you think chemistry is a part of who you are?

Tracy: No (very firm and definite).

Angie: Is it something that you ever want to be part of who you are?

Tracy: Not really. I want to always be aware of it but I don't want it to be something that is so prevalent in my life or in my mind that it is everything. The part that I want to take over me is the social work, the psychology, so that when I look at someone I can hear their feelings or I can try to empathize with them. That's who I want to be. Do you think that sounds corny?... I don't think of [psychology] as science, I think of it as psycho social sort of stuff. I don't think of, depending on if I go into the neurosciences, I just always thought for such a long time that what people do with their lives and how they deal with their emotions is up to them. To a degree there is going to be an influence from the environment that you are in and the parents you are raised by, or the culture that you are in, but for the most part, if someone in our culture makes up their mind that they want something they can go after it, and if they keep their goal in mind and their sights where they want them to be, they can make it. And, I never thought of myself going into science. Listening in counseling to people, it's more about understanding the thought processes and I haven't thought of that as a science either. I guess that I see science as more predictable even though, or more exact almost... Sometimes what we did in class was not science either because we did not always have to be that way.

Angie: Do you think that you intentionally dissociate these in your mind because you don't want to be a part of science?

Tracy: I think so. I have never thought of it that way. I have never named it more or less. So I don't think that I ever considered the sciences for me.

While Tracy may experienced academic success in my chemistry class (despite a ten year boycott of formal science), she emphasized that the process was difficult and sometimes disempowering. Tracy came to believe that I meant well when I tried to talk about women scientists, and when I tried to put the departmental requirements to the side in order to meet the needs of the students, but she could not help feeling that no matter what I did, as the teacher, there was no room in science for her views of the world. I think that Tracy is trying to tell me that no matter how much we critiqued science, what is out there is still science—a science which does not value her experiences. However, this idea that Tracy expressed raises a contradiction. Tracy suggests that our culture allows anyone to be able to do anything if they put their mind to it. Yet, she also says that she does not want to do science because she does not want it to be a part of who she is. I wonder how Tracy would respond to the cow metaphor for the masses. Does she see the choice to do science as giving up her agency to pick her own pasture? How can we begin to tie in critical awareness with revisioning science so that students do not leave my class with a critique of science, yet feel paralyzed to use that critique?

I learned through conversation with my students over the summer that some of the students, despite my ambivalence, developed a critical awareness of the science in their lives. I also learned through these conversations about the ways students made connections so that I could help my summer semester students do the same. The connections the students made between concepts in science, critiques of science, and their lived experiences were connections that I did not expect; connections that I did not even think to consider. For example, I knew that Gene was a high school science teacher, but I had not considered that sharing with the students my struggles to teach science through a liberatory agenda and meeting the requirements and responsibilities of the community college would parallel (in some ways) Gene's own struggles at the high school level. I also knew that Tracy wanted to study social work, but had not thought about why she actively resisted psychology as a science. Listening and learning from my students, as they developed a critical awareness of the science in their lives and of the theoretical tools needed to make sense of the science in their lives, I recognized my own need to

foster that kind of conversation as part of my pedagogical practice in science class. I can see that I had been so caught up in trying to understand how our positionalities shaped what we did, that I had ignored thinking about the ways that a critical awareness of our own positionality in our chemistry class could help us to value our lived experiences and to rethink the kinds of relationships we believed we could construct in science. If I wanted to help students make connections between their lived experiences, science, critiques of science, and oppression and privilege, I needed to create opportunities for a class conversation that allowed the students to talk about their struggles. I needed to value the kinds of conversations which allowed our full range of lived experiences in our class, and I had to do so in ways which did not set up a fixed oppositional discourse: Science or nonscience voices, masculine or feminine voices. The oral histories, because they were about people and lived experiences helped the students to become critically aware of their own experiences in science and relationships with science. Teaching science—even with the critiques of science—did not foster this kind of thinking.

Awareness to Feminist Praxis

In the examples and reflections which follow, I hope that it is obvious how the students showed me that praxis cannot be imposed. Rather, it grows out of our efforts to bring in our own lived theories into action. This action shapes our relationships with science which then shape our future actions. I hope to share with the reader how the students taught me to think more about the relationships we have with each other and that revisioning science can grow out of these relationships.

June 29, 1994, coffee shop,

Tracy: Have you always been a feminist or did it happen in college when you started studying?

Angie: No. It didn't even happen in college, it happened after college, when I was working in industry. The college that I went to was politically conservative, well the school was progressive in its thought, but the student body was rather, uh, republican. There were a lot of things that we did not talk about in chemistry and sexual discrimination wasn't one of them. I was discriminated against, but I don't really know how I viewed it

then. I was angry but think I mostly blamed myself. It was actually when I was working in industry, I was frustrated with a lot of things and I became interested in women's issues. Reading about the things that the women wrote about in some of the literature provided a way for me to make sense of my experiences in ways I hadn't been able to before. I began to see how the institution of science defines science, the practice of science and women. Since then, my life has changed drastically.

Tracy: The activist in you has come out?

Angie: Well...

Tracy: You said earlier that scared you—thinking about the activist part.

Angie: It doesn't scare me, well it scares me only in that I am afraid that it will, uhm, hum, maybe I am afraid of being marginalized. It's like you know I am trying to play the game of science and higher education, but you can't do that very well and stay true to your position... There are a lot of hoops that you have to jump through and you have to make sure that you do not hurt those who have control over decisions which decide your fate.

Tracy: It is very political.

Angie: Yes, and I don't know how to be political. I have gotten myself into trouble with the department. Now I am worried about what to do with my chemistry classes... Last semester when we decided near the end of the semester to learn what we felt was important in our own way, not what the department felt was important in their own way, well I kind of got in trouble. The department chair kind of found out that I did not require the students to memorize the seven page list of ion nomenclature. I do not want to use a single exam from the department, like I used the first exam last semester because I think that the exams do not test conceptual understanding and I think they deny the social nature of science. But I am afraid. And, now I am worried about what to do with my chemistry classes. Tracy, why should I be so afraid? I know and you know that these exams are not helping you in chemistry!

July 2, 1994,

In a conversation with Gene that I did not record he shared with me that he was leaving his current job at the local high school to take on a new science teaching and football coaching job in a town nearly one hundred miles away. He referred to all the talk in our class about elitism and said he experiences a similar sort of thing at his high school. He said he was sick of being on the bottom of those sorts of relationships. He was sick of not being listened to by his local and district administrators. He was sick of not having his teaching ideas valued. He felt like he was not growing and neither were his students because of the circumstances. Most of all, he was sick of the political nature of school and of science and how everyone seemed to deny the politics. He seemed really excited about moving.

Tracy and Gene talked a great deal about the political nature of science education and how we are all a part of "power relationships" (my phrase). They also talked about how these

circumstances have an enormous impact on what we (can) do in our science classes. Being able to articulate how we are all so caught up in such power relationships is a big reminder for me of how we are all defined in terms of these power relationships—as teacher and student, scientist and nonscientist, men and women. It also reminds me of how these definitions impact our expectations of ourselves, both inside and outside of chemistry class. It is obvious to Tracy that I struggle with these partially inscribed identities. Is there a way to break down these walls, to deconstruct the meanings which have been given to our roles in science class? Is there a way to create our own ideas in science class without worrying all the time about trying to fit into these power structures, or without having to use all our energy resisting the same structures?

"Institutionalized discourses define the classroom, the teacher and the student. For instance, we are inscribed as either student or professor: Students take exams, teachers do not; students are graded, teachers grade. Such inscriptions are key in the production of subjectivity, identity and knowledge" (Luke and Gore, 1992, p. intro.). The degree to which my knowledge about teaching, learning and researching is shaped around these inscriptions, is the result of my lifelong socialization in schools and society. My work as teacher-researcher is partially defined by various authority figures in my life: My parents, the teachers in the schools I attended, the scientists in the labs where I learned to conduct scientific research. I have learned through these inscriptions what it means to "know something" or to "learn something," what it means to be a student, teacher, researcher or researched. I have also learned that I could only be at one end of the relationship at any given time; never both at once. I have always been either teacher or student, teacher or researcher, researcher or researched. I have constructed these roles and these identities the way that the dominant discourses would have me. Reflecting on the power-knowledge relationships in our class (Gore, 1993), I question if, as a group of teachers and learners, we can ever move away from our roles inscribed by power relations active in our classroom. "My students" are taking "my class" to learn the knowledge that "I have." I am in the position of teacher because I "have the valued knowledge" and the supporting credentials. Although I struggled publicly in the classroom with my attempts to

learn to teach a feminist science and to uncover the meaning inscribed by the power relationships, I also continued to claim power and authority publicly as I assigned projects, exams and grades. Tracy is right, the process is very political. Gene's insight into our actions during the spring semester and the connections he drew to his personal life as well as his subsequent actions, helped me to see how what we did in class during the spring semester pushed on these power-relationships. It also helped me to see that if I wanted to try to do feminist praxis again, I need to start with the lives of the students. I had to find more ways to allow the students to shape our class and the science in our class through their wants, needs, and beliefs.

June 29, 1994, coffee shop,

Gene: ... I would say that at least sixty percent of the kids in [my] school, do not get the right nutrition. We got so many processed foods. There are so many things in science related to improving the quality of life. Putting processed foods has pickled the American people.

Angie: That kind of grosses me out.

Gene: Well, they did studies over in Vietnam. If an American got shot, if a Vietnamese got killed on the battle field, it took them twelve hours before the body started to decompose. If an American got killed on the battle field, it took forty six hours to start to decompose. They were actually pickled with something like monosodium glutamate. They were pickled, and that is because of all of the processed foods that we eat.

Angie: We should have talked about that in our chemistry class. It really relates to chemistry.

Gene: That is big time stuff!

Angie: Where did you read that stuff? I want to go look it up and read it and share that with my class.

Gene: (laughing) Okay, well actually, I am seeing a nutritionist at the center and that is where I got the literature.

Angie: Do you think that if I just went over there that they would let me have some of those articles?

Gene: Yah, the guy was talking about it and did a lecture on it. I have a meeting over there at my place today that is why I am cleaning my house. It's made me feel real good. When I went off the diet a few days ago, I didn't feel so good. But I went back on it, and I felt so much better, I don't need as much sleep.

Angie: Hmm, I know that we try to eat a lot of fresh fruits and vegetables.

Gene: That's good, you need at least thirty grams of fiber a day.

Angie: That's what my father tells me.

Gene: You need big time fiber. It helps to cut cholesterol.

Angie: Do you know why I am interested in sharing an article like that with my chemistry class? Well, there are two reasons. You can talk about the chemistry of the compounds placed in foods, the reactions that occur. But you can also talk about the issue of science—how science controls our lives in ways which we don't even understand.

Gene: There is so much power there! There is a lot of ignorance, that science lives on. (pause) We drink chlorinated water, right. Part of the ignorance is that we just accept the fact that we drink chlorinated water. What do we even know, as every day people, what that does? What if chlorinated water is not even good for you? All these toxins can be captured by your body. We are taught to accept that it is okay because it does something good. But, what else does it do?

Angie: I want some of my chemistry students to read these articles. It could provoke an interesting discussion about what knowledge we really have privy to.

I wonder if what Gene is saying here connected to his ideas about the masses, ignorance and intelligence, and the connection to what happens in science class. The "American people are being pickled," and despite how much traditional science they are learning in science class, we will probably continue to be pickled!

Gene's ideas about who gets to know what in science and society point out to me that part of a feminist agenda in addition to pushing on the boundaries of power relationships through my actions in science class is helping students to become aware of the power relationships in science as well. Not only is it important to deconstruct with students the teacher-student dichotomy, but it is also important to look at the scientist-nonscientist dichotomy. As Gene asks, how much of our lives do we not even question just because we do not even know enough to realize that there is a question to be asked! I wonder how much of our lives in and out of chemistry class we have accepted or silenced passively because our roles have unknowingly been defined for us. For example, in chemistry class, as teachers and students, we define ourselves in relationship with each other, the educational process and

science (and in turn are also being defined by these structures). We learn to construct meanings about and within these relationships through engaging in them. But because of the ideological underpinnings in science education, in teaching, as in science, we learn to work within prescribed relationships, we learn to think about science and ourselves through the boundaries of inscribed dichotomies, even when these do not speak to our experiences or understandings of the world. As Davies (1989) writes, engaging in socially defined dualisms means "being socially competent" or means "not being deviant." Thus, teaching is inherently political in facilitating—and often times validating—particular power arrangements and the associated knowledges. I know that presenting students with a critique of science is not enough to challenge these relationships. As Gene did by examining his personal situation at his high school and by learning more about his diet, we need to find aspects of our lives where these critiques play out, or are noticeably absent in order to begin to re-write our lives and our relationships with science.

June 29, 1994, coffee shop,

Gene: We have to change science. Only at that level, at the teaching level, not only as a member of society...The injustices performed to females to science would in past and present but not the future. And that it doesn't have to be that way. There is ignorance and intelligence. No matter how smart, there is ignorance. It comes from the church: "Woman is submissive and man is dominant." This is based on the ignorant male in society. It makes me feel like I can be different and don't have to be a part of that message. We have choices. For me to feel good, I don't need to make someone else feel bad.

Gene again reminds me of the agency we all have. Part of doing feminist praxis as a science teacher is finding ways to help all of us use our agentic positions to challenge ideas, beliefs, relations in science that silence or oppress our lived experiences. Gene and Tracy are also teaching me that feminist praxis is, by its nature, evolving. I did not need to know a revisioned science to teach to the students, in order for us to do feminist praxis. Deconstructing my teaching practice in private did not wholly constitute feminist praxis either. Rather, by creating opportunities in science class to understand how knowledge is constructed through experiences, how such knowledge reflects subjectivities, and how it relates to power, privilege

and oppression, we would be able to interrogate the assumptions of scientists and society and be less likely to be taken advantage by knowledge that promotes inequality. By creating opportunities in science class for critical exploration of lived experiences—as we began to do with the oral histories, and most certainly did through our summer conversations—we were able to reconstruct scientific knowledge that did not deny or oppress our gendered, raced, and classed experiences, and that required us to rethink agency in the sciences.

I understood that to juxtapose a feminist critique of the sciences with traditional science educational practices (content and process) did not adequately challenge the power structure in science education and hence the kinds of relationships we engaged in and the knowledge we constructed in those relationships. Liberatory education hinged on our ability not only to locate scientific knowledge and our practices within particular social and cultural conditions, but also to rewrite our relationships in science through deconstructing the theoretical foundations which silently bound our actions.

July 13, 1994, over lunch at a local restaurant,

Angie: It is really hard in chemistry because there are not many things that you can get the students to do to make changes in science. I think part of my agenda is to get people to think seriously or critically about an issue and then sort of act on it. You can sit in a classroom and theorize all you want,

Tracy: (interrupting) But it doesn't make a bit of difference in the real world.

Angie: It doesn't unless you act on it. So one reason that I am actually teaching chemistry right now is because if you think about women's issues in science, you can theorize all you want, but unless you try to do some of these things you are thinking about with people, what difference does it make? One of my biggest goals and I hope it was obvious—I don't think that I did that good of a job—was to try to get students to question science and not to accept it passively and not to accept everything everyone says because it is not Truth with a capital T and not to accept the power structures of science or within the institutions that teach science.

Tracy: I think you did a good job. Angie, you are so hard on yourself. I think that you got a lot of people to think in there who would not have thought twice about chemistry or science or anything about the power structures had we not had our class. I know that Shellie and Gene asked some really interesting questions.

Angie: But, it is frustrating. It is frustrating to see people passively accept things when you see those very things hurting people. And I know that there are

probably a lot of things that I don't realize that I passively accept. In science I probably only understand a tenth of all the oppression which goes on in science in relationship to everybody else and try to act on what I recognize. For me, thinking about some of this stuff has really helped me to name my experiences in ways which connect with me more. I know that I am a smart person and to have science tell me that I am not capable of doing it, there are also other things involved there. One thing I thought was really neat was my summer class when on a field trip to the cyclotron and in one sense I thought it was really good because, well, what do you think when you think of a cyclotron?

Tracy: I don't even know what one is.

Angie: Oh, okay, uh,

Tracy: Well, you wanted the truth.

Angie: Okay, uh what do you think of when you hear the words particle physics or quantum mechanics. Yah, what do you think of when you hear the word quantum mechanics?

Tracy: Steven Hawking [laughs]. I do not think about it, honestly. There are a lot of things that I still don't think a lot about. It's because, I don't want to deal with it. It's too complicated and in other ways it's not complicated, but that's what's been shoved into my face. I think I did all right in your class, though, considering that was my first science classes since high school. Well, anyway, what is a cyclotron?

Angie: It's a place where they take atoms, or supposedly take atoms...

Tracy: (interrupting) They take energy!

Angie: ...then they accelerate these atoms. They get them going really fast; they accelerate them by having them move in circles by being pulled by magnets. Then you take some more atoms and shoot them into the accelerating one so that they bombard, and the nuclei collide and a new atom is created. That's what they say happens.

Tracy: And, how did your class respond?

Angie: Well, I did it for a few reasons. We just studied the atom, and so with this trip, it might have helped them take the atom from the abstract level and see it in a more practical level—if they were actually there, seen the equipment, talked with people who used it. In that sense I think it was good. And also, you see real people working on the cyclotron, everyday people. Well not really, mostly men, but half the real people. And so just seeing everyday people doing this brings it down another level, so that was good. What I thought was bad about it was, they just, they make it sound so complicated. The equipment just looks so, so fancy.

Tracy: Overwhelming?

Angie: Yes, I mean when I looked at it, the 4-pi detector with all these little gadgets coming off it. I mean I know what the thing does, it just looks so complicated and so sophisticated, that I wonder if that aspect intimidated people. I am sure it intimidated people. It intimidated me and I know, understand, and feel comfortable with the theoretical understandings behind it. And, now I am debating if overall, it was a good experience or not given these two different ideas.

Tracy: Did you have a chance to talk about it as a class?

Angie: Yes, and we actually had a very good conversation. One person asked the question, does anything good come out of that research? Does anything good come out of cyclotrons? Because billions and trillions of dollars are spent yearly on that research at the various cyclotrons in the US. For example, the electric bill of MSU cyclotron is about \$4000 dollars a month. The electric bill of the Fermilab cyclotron, just outside of Chicago, is about a million dollars a month. Their cyclotron has a circumference of ten kilometers, so you can picture how big it is. These electric bills just give you a little idea of the expenses and they are just a small portion of their expenses.

Tracy: How many people can be fed by that do you think?

Angie: Yah.

Tracy: I'm sorry, but does it serve a purpose?

Angie: The one thing, as far as I know, there is only one direct application. They have this thing called a medical cyclotron, and they have three in the US. One is in Detroit because MSU developed it, one is in Seattle and one is in Houston. They use it treat soft tissue cancers, and they are using them solely to treat prostate cancer. I wonder why they chose prostate cancer. Of course because it a soft tissue cancer, but there are other soft tissue cancers, such as breast cancer. So, I wonder about that.

Tracy: Exactly.

Angie: Well, that's my personal opinion. Anyway, they use this thing that sends a beam of neutrons into the cancer infected area and it is suppose to kill all the cells. Traditional radiation treatment takes 6-8 treatments, this is suppose to take only two. Right now they don't really know how well it works and what the long term affects are. But that is the only application they told us about.

Tracy: The medical cyclotron that's not a normal cyclotron is it?

Angie: No, they have a normal one at MSU. The medical cyclotron is a spin off from the normal cyclotron; it developed out of their research. But, they told us of no other application, which leads me to believe that there are no other applications.

Tracy: I like for things to have purposes and goals. It sounds like if you guys did have a good discussion than your trip did have a purpose. You opened up,

there were some discussions that we had in our class that, that I don't think we would have had in any other class. I am serious, whether we were discussing money or the elitist attitude in science or GCC. I mean are you talking about all that kind of stuff in your class right now?

Angie: Yes, it is just part of me. There is this one guy who comes to class everyday and he is constantly laughing. I can't even look at him, he always laughs when I raise these issues. Well anyway, we had a good discussion about that because they were really frustrated knowing how much money went into the cyclotron, and of course I bring my skepticism towards a great deal of the current scientific research and my feminist attitude to class with me and they see those sides of the picture from me. I am sure that there are a lot of people out there who support a great deal of the current science agenda who may get really frustrated with my own views. What I really hope happens is that my perspective allows them to begin to question me and my views, the establishment of science and its views, and their own personal views. I think by sharing this rather nontraditional framework with them publicly, it creates a dissonance in what we are suppose to believe and talk about in science class and our mini reality at the moment, that it begs we explore and question. But I wonder how much the students think they have to listen to me as authority, something I am trying hard to get them precisely not to do.

Tracy: You were not saying this is my view and you have to believe it. To me it seems that you were saying this is my view. And, like you said, you hope people will talk about it and question it. It is hard for me to understand people who don't question things at all, or actually people who are bored in life. There is so much to do, so much to learn, so many places to see, how can you be bored? You know? I would take another chemistry class from you in a minute. I would. And maybe if I have to take another science class, I will do it before you leave.

Angie: I am only teaching CHEM 125.

Tracy: Really, oh dang.

Our most transformative moments in class occurred when our engagement with science pushed traditional relationships and caused them to be reformulated in content and position. When this happened as a class we couldn't go back to accepting our original practices and discourses. Even though Tracy may not want to go into science because science is the white male dominated enterprise which does not adequately connect with her lived experiences, her positive evaluation of the cyclotron trip indicated that Tracy has, in the course of our summer conversations, shifted to become critical of science. She feels the authority to talk back to science, and the confidence to reread her experiences in science. Tracy is still the same person, yet she related to science very differently than before.

Tracy, Gene, Laurie and I, by talking about ourselves and about science, have formulated new ideas about who we are in science, what we know and what we want to know. By having the chance to rearticulate and give new meaning to our experiences, our positionalities have become re-situated in science. Furthermore by having an awareness of the positionality that we bring to relationships we also have a better understanding of how the power arrangements influence such relationships in science. Tracy's understanding of what it means to be a female nonscientist gave her a chance to work through and change definitions of herself imposed on her in science education. At the beginning of the semester she believed she was not smart enough—did not have the aptitude—to do chemistry. She began to critique that belief and the power structure which imposed that definition on her with the support of some of the students through our oral histories. Gene and Laurie seemed to have similar experiences as they rethought their own science experiences (Gene's experiences, of course, being rather different from Laurie or Tracy because he started our class liking science "at its core"). Through critiquing science from the standpoint of their own lived experiences these students point out to me that positionality is more than being white, being female, being a teacher, being a student, being a scientist. Although these identities play central roles in the ways I choose to make sense of events, they do not change as a result of relationships. (I am still white, female, a teacher, a student, a scientist. Tracy is still white, female, student, lesbian.) The ways in which we understand how our identities are defined (and bounded) by particular power arrangements in science and education do change. It is through rereading our lives (and our lived experiences) with knowledge of power arrangements that such changes can occur and allow us to begin to reposition ourselves in science and education. This is the notion of positionality and feminist education that I brought to my future teaching.

Rethinking feminist liberatory science education

Talking with students about their experiences, as well as my own experiences, in our class helped me to construct more informed meanings of events which occurred in our chemistry

class. By pushing me to consider their interpretations of our class, these students emphasized the situational nature of knowledge, the situational nature of relationships. Our places in class as students, teacher, male, female, minority, working class, and the ways in which these places are embedded into the power structures active in our class, created different contexts from which to make meaning in class. Tracy, at the end of the semester believed firmly that much of what we did in our class was “not science” and that her intended major psychology (in the context of social work) was “not science.” These things were fun, and valued her ideas and experiences, and therefore were not science. It became obvious to me that Tracy learned to critique the institution of science and how it defined her, but possessed no overt desire or energy to try to revision it. This left me wondering if her relationships with science marked by her continued oppression within that power arrangement as female, working class, lesbian, told her that revisioning science was not a worthwhile or even possible course of action despite the fact that she learned to critique and rebuild new relationships in science.

Feminist praxis as a basis for science education is dependent in our ability to construct new kinds of relationships which allow for critique as well as the expression of our full range of lived experiences. To me this means a rethinking of positionality in terms of continuously developing relationships in science class. Through the recognition that these relationships we construct in class mirror the power structures promoted by racist, sexist and capitalistic society and the connection that our own positionality has in shaping those relationships, we could begin to critique and change those relationships. We could begin to understand science as a political act (Foucault, 1980); to examine and name our own scientific knowledge and questions and to become critical consumers of the other-formulated knowledge taught us in traditional science classes (Hollingsworth, 1994b).

June, 15 1994, coffee shop,

Angie: What did you learn in class last semester?

Tracy: [laughs]. I learned that it wasn't as bad as I thought it was going to be. I learned about the periodic table and I can actually remember some of the little symbols. I learned about the atoms, and about some of the theories. I

couldn't quote them back word for word, but I could give you a basic idea of them. You know if I am talking to someone at least I am not totally ignorant. Basic chemistry stuff. The part that I hated was the stoichiometry. Surprise, surprise.

Angie: Why did you hate stoichiometry?

Tracy: I am not sure exactly why. I think that I had a hard time concentrating at certain times in the semester and I think that might not have anything to do with your teaching. Whether it was the people around me or something that was going on personally. I just didn't keep my focus on stoichiometry very well.

Angie: But what made it boring? To tell you the truth I hated that section too. I did not want to teach it that way but I felt like I was stuck because the department chair wrote the test for the unit. You know, I hated the text book that was selected for the course. I did not like the way it was organized, the way it presented the material. It had a lot of historical mistakes. It presented ideas as if they were fact; it gave us no chance to search for alternatives. But in the summer, I am not going to let the exams he writes strap me into a way of thinking about chemistry. I am not even going to use them.

Tracy: Oh really, does he know this yet?

Angie: No. I am not going to tell him. The last time I tried to discuss a similar issue, he did not respond very well.

Tracy: [laughing] Anyway, do you feel like you have an idea of what I learned in chemistry class? I know I didn't repeat a lot of it, but I feel like I understand it. I feel like I learned a lot. And, if nothing else, just the awareness in science has helped me, you know.

Angie: When I asked you what you learned, you listed a bunch of facts and theories, did you learn anything else? Did you learn anything from the oral histories?

Tracy: Oh yah.

Angie: Do you consider that stuff that you learned to be an important part of chemistry?

Tracy: Oh yah, definitely. I think that the biggest thing I came away with from the oral reports would have been the elitism, the sexism and the broadness of what chemistry involves. You know, gosh what was it. Who was it that Pete interviewed?

Angie: A goldsmith

Tracy: A goldsmith. You know I wouldn't have, that wouldn't have been my first thought for chemistry. So from a gold smith to a pharmacist to a you know a chemical engineer. The range was much broader than I expected it to be.

It was kind of cool. Lets see who did I talk to? I talked to Patti and that was a good experience for me.

Angie: Why was that a good experience for you?

Tracy: Because she was interesting to talk with, and she felt much the same way as you or I do about women in the field of science, just the feminist theory. She had a background in the neurosciences and that was really interesting to me.

Angie: Wow, she was a good person for you to interview!

Tracy: Yes, she was. She was very good and I was very pleased and I think that I still have her tape at home. I feel like she is someone who I could call up and talk to again if I had questions about the neurosciences or education in the neurosciences.

Angie: I think that she would.

Tracy: She seems really nice. I guess I really did enjoy the oral histories. Normally I don't like the oral kind of things, but it didn't, I didn't feel, it helped that we did not have to go to the front of the room and talk, people felt more open to discuss. It was easier to do the oral history from your seat because that's where you are comfortable, that is where you are secure, that kind of thing. Rather than having to get up and stand in front of everyone. That kind of thing. With me, I don't like being up in front of the class a lot.

Angie: Me either.

Tracy: Oh really?

Angie: My favorite way to teach is when we all sit down together in a circle.

Tracy: Like a little support group.

Angie: Yah, that is nice.

Tracy seems to have created for herself a critique of science that is firmly grounded in her lived experiences. This is important: "We, as students and teachers, come to know and understand through the filters of our experiences, our social positions in life and work and our senses of personal (and political) agency" (Hollingsworth, 1994b, p. 1). Tracy's ideas led me to think more about how our chances to construct a re-visioned science are dependent on our relationships with and in science. I knew that it was possible for us to reread our experiences with and in science in ways which did not silence, oppress or diminish them—we began to do that through our oral histories conversations and through our critique of the department. I

know that these rereadings and rearticulations of our lives in and out of sciences were the source of our ability to construct new relationships with science. I can see that a revisioned science can not be developed by me (or any one else) before I come to class based on some essentialized notion of what it means to be a woman or minority. It is dependent on our ability to reread the nature of science from our multiple standpoints. I do not want to dissect and label us as science has done, yet I do not know how to speak about our lives and our experiences without somehow creating a space for changes, without defining at least a temporary place for responsibility.

June 29, 1994, coffee shop

Angie: I know that a lot of the issues that I want to raise can be so personal, really connect with you at a personal level and to ask people to do that in a public setting with people who they are not friends with is difficult. I think it gets easier as the semester continues because you build some sort of community at least I hope and think we have built some sort of community,

Tracy: Right.

Angie: But still, we are very much strangers. I know that sometimes I said a lot about myself and then afterwards I wondered why I said so much.

Tracy: Sometimes when you revealed more of yourself, it helped me to think about and say some things about myself. It's that trust thing: If you open up, then maybe everyone else will open up.

June 14, 1994, over cookies in my office

Angie: What about some themes besides the theories ideas?

Laurie: Definitely the psychology of scientists and why people go into science.

Angie: Why was that such a strong message?

Laurie: Because with all the oral histories, the role of the elements in daily living, how powerful the field of science is and how controlling. How it has a strong dominance in the economy in a lot of ways. I mean, how our government has safeguards to make sure that we are protected against like chemicals, and the new discoveries and how long it takes a drug to be approved. I don't think that there are enough checks and balances. It's a positive for the economy, it's positive for the sciences if stuff goes out on the economy and not if it is held back.

Angie: Tell me more about the government thing. How does this last thing make you feel as a person, as a woman in our society?

- Laurie: This makes me crazy because there are so many things, there are so many chemicals, and there are probably drugs out there that might benefit people but there are so many you know political or even values that prevent them from not being passed. You know they would help certain people, so that I am sure that there are many chemicals out there that are causing cancer. Cancer is just too prevalent. There is not enough emphasis on studying. One of my friends is going into medical geography and that is fascinating.
- Angie: Oh neat, what is that?
- Laurie: They study trends of different diseases and things like that that are occurring high cancer rates in this region or high this type of disease, like medical disease types of trends.
- Angie: Wow, I just learned in the midwest there are a large number of people, of babies being born with holes in their hearts. Much more than the national average. I only learned about this last summer, because my sister who lives in Cincinnati, her daughter was born with a hole in her heart.
- Laurie: I have heard of that. But I mean I think that the scientists hold back so much information from the public. Then the media chips away, and then you never really find out the truth because of governmental controls. It is such a controlling factor in your life and you don't have access to it. I think you have a right to that. That is what bothers me the most when it comes to those chemicals that are killing you. You never know until it is too late or so many people have died. It's just, science controls every aspect of our lives. You don't have, you are not given the rights you should have. Science controls all that information so does the government.
- Angie: Did you think about this much before our class? Do you feel like you know more or could do more now?
- Laurie: I think about it much more though and I have thought about it before because I am from a small town and there are so many people who are dying of cancer and you know it's got to be from the fertilizer.
- Angie: In your town?
- Laurie: Oh I am from Ashford. My mother had a really good friend that died of cancer just in the village and almost every one had died of cancer. There are just too many. There are a lot of people out there with cancer. Just a small farming community. To see all the people with cancer in such a small geographic area. I mean there is just so much cancer around, in the small towns, that just bothers me. I can't believe that they haven't figured out that there is a problem or what it causing it. It is so obvious that all these people are getting cancer. Why can't they figure it out? I think they know some of the things and they just don't want to let it out because it is going to have a drastic effect on the economy. Why don't they really know? They know so many other things, like with what NASA can do and I mean I think that the technology is there. Maybe it's not, you just don't know. I guess that is why, well I can understand too it's a complicated area. They are coming out more and more with genetic

findings and they have to be really close, and they might know it already and not want to say or help. Just like with the [inaudible] and all that, I can't believe that it's happening, there is living proof that it causes problems, but they are really not doing much. They haven't taken it off the market, but they haven't done anything about it.

Laurie began the semester with a "negative attitude" about science. Learning more about her family history, the rate of cancer in her village, the lack of knowledge dissemination in her community about the cancer rates and their causes, and the detached apolitical stance of the government and the science community towards the cancer epidemic in her community speaks so clearly to me that no amount of "fun, hands-on activities," cooperative groups, or positive role models in science will make science a positive experience for Laurie. Her community is disproportionately dying from cancer and no one (as far as she can tell—her reality is a valid one) is intervening through education or regulations to improve the situation. This suggests to me that a feminist science is much more than "female-friendly" classroom practices. It is highly and intensely political and requires an interrogation of science from our marginalized lived experiences.

These conversations have raised a series of lingering questions on what to teach in chemistry class, how to teach it, and what it was I hoped my students would gain: If the institution of science conforms to a positivistic world view which names a white middle class masculine perspective as the normative perspective, what are the implications for theorizing about positionality in science class? What did the answer to the previous question suggest for the possibilities of a feminist liberatory science class, or did it suggest that a feminist science class was not possible? Were there ways in which we, as members of our science class, could reposition our relationships within science, without leaving ourselves too open and too vulnerable to the seemingly ubiquitous power and authority of science? What does it mean to understand privilege and oppression in the context of learning science?

Reflections

Rethinking a feminist science education

Summer conversations with former students helped me to see how I was using the agenda of western science to undergird my feminist liberatory agenda, and that I was using positionality in a limiting way. I was using it as a static filter to define why we did what we did in science class. I was not exploring how our positionalities shaped our relationships with each other and with science and the influence this had on what we did in science class. Because of my narrow vision of positionality in the spring semester, my teaching intentions were to make our positionalities an issue in science class without considering the positionality of science and the kinds of relationships that science helped shape for us. Although I tried to problematize the discourse and practice of science through the introduction of feminist critiques of science in our class, I had not considered our relationships with science a part of the process beyond a practice of science as socially constructed. When my students helped me to see how I had not challenged the nature of my own relationships with science by subtly pointing out that I was defining my liberatory agenda through the eyes of western science, it was a call to me to redefine the role of positionality in feminist liberatory education as well as the nature of feminist liberatory education. I needed to examine our moving relationships in the classroom, as they are informed by the positionalities we bring and the positionalities we encounter. Therefore, by engaging in a series of summer conversations with former students, I went from thinking that it was enough to think about how my positionality influenced my teaching actions and decisions, to how the positionalities of my students and me shape the kinds of relationships we have with each other and with science. And, in turn how the kinds of relationships we have influences the kinds of knowledge we construct about science and ourselves in science. I found that creating places to challenge our relationships with each other and science by exploring our positionalities in science class is where the possibilities for

feminist liberatory education lie. Because we act and think through these moving relationships in science class, then part of creating a feminist liberatory teaching and learning setting is learning how to challenge traditional relationships.

These summer conversational meetings were important in helping me to deconstruct my engagement in the spring and to revision a more interactive pedagogy for the future. Central to this was the shift in my role from teacher to co-learner (Hollingsworth, 1994a). During the summer, the power relation changed, as I no longer held the students' "chemistry fate" in my hands. Furthermore my stance as learner and as one who needed the conversation of others to learn reaffirmed our equal footing (although this was slippery at the beginning).

The opportunity to talk with students allowed me to rethink my teaching and reflections from their perspectives. I believe that our conversations provided a place for us to continue the conversations we began in class about science, education, society, ideology and our lives, as a way for all of us to continue to learn how we shape science, how science shapes us, and how can begin to shape science. Through these conversations, we all learned more about ourselves and science education.

I admit that the focus of these summer conversation has not always been so multilayered. Originally, I intended to interview students as a way to understand how they thought about what went on in chemistry class. I expected to learn something from what they had to say, but what I did not expect was that a sustained conversation would influence my own thinking about science and education as radically as it had. My former students—my friends—were teaching me about feminist science teaching and feminist research. I was learning to look at science through their multiple lenses to learn more about their wants, needs and beliefs for a liberatory science education. I was also learning that to be a teacher-researcher intent on creating a "liberatory" science classroom, I needed to continually re-articulate my political and epistemological agenda to meet the shifting needs of each person in our class.

Rethinking positionality: Moving relationships

The summer conversation helped me to rethink positionality and the role it plays in creating a feminist liberatory teaching and learning setting, changed. I began to see that because each student comes to class with her (his) own positionality and I come to class with my own positionality, then what becomes important, is not the decontextualized positionality we each bring to class or even how these separate decontextualized positionalities shape how we interpret knowledge or events in the classroom. Rather, what I began to see as important were the ways the students' and my own positionality came together to shape how we interacted with each other and with science and how these interactions shaped how we interpreted knowledge and events. The emphasis here is not on our own individualized positionalities (as it was earlier), but rather on the moving relationships we are able to construct because of our positionalities interacting in the context of learning science.

I use the phrase "moving relationships"²⁸ because I want to imply several ideas. First, I use the term to describe that relationships are contextually dependent. The relationships we have in class with each other and with science are in constant change because how we view knowledge and how we view ourselves is contextually dependent (i.e. Haraway's (1988) notion of "situated knowledge"). Relationships are negotiated intersubjectively through power arrangements, and are dependent upon the backgrounds with which the participants bring to such interactions (Rommetveit, 1980). For example, in our urban chemistry class there are a diversity²⁹ of relationships between us, and these diverse relationships require us to respond in different ways. Therefore, our relationships in science class are determined publicly and socially through our collective set of lived experiences rather than by the private intention of either the students or the teacher. Therefore, our relationships with each other and with

²⁸This phrase was suggested by my dissertation writing group (Kathy Roth, Elaine Howes, Kathy Peasley, Constanza Hazelwood).

²⁹Diverse across race, ethnicity, class, gender, age, and sexual orientation.

science shift as we encounter new situations, new ideas, and new people. As Gergen (1990) writes, "the trajectory of coordinated efforts of any two persons will thus be vitally influenced by these multiple enmeshments. As any two of us develop as a relational unit, we are the common interstice or point of confrontation for a multiple of relationships" (p. 586). Here, Gergen is advocating that we are defined by our relationships, that we are involved in a "multiplicity of relational processes" (p. 585), and these relationships move as we engage in new experiences and encounter new people.

Second, the relationships are also moving because, as we reread our lived experiences, and bring this knowledge to understanding, critiquing and revisioning science, our relationships with science are fundamentally altered. Traditional relationships between students and science are hierarchical, such that science holds most of the authority and prestige. Students' ideas, values, experiences, and feelings typically are not valued in science class. By creating spaces for these kinds of ideas to be valued, then the dynamics of the relationships that students have with science change because they are able to interrogate what they know in science through new lenses. This connects to the first description of moving relationships because in both instances, relationships in science class can be recognized as "moving" once it is also recognized that our relationships in science class cut across power hierarchies (due to the racist, classist and sexist intentions of the dominant groups in American society).

The relationships are moving in that they are also affective; they reflect and embody our passion. This notion to highlights my belief that the relationships we have in science class incorporate much more than just subject matter knowledge. Learning a feminist science implies creating a science education that brings in the whole being, not just the intellect (as posited through the positivist notion of the mind/body split), and not just the subject matter knowledge in both content and process (as suggested through many state and national reform initiatives). Bringing in the whole being means exploring ourselves in science (not just our knowledge).

Looking ahead: Moving relationships and feminist liberatory education

The summer conversations helped me to see the agency in positionality. In the spring, positionality helped me to understand how our lived experiences shaped our understanding of science and our attitudes about science. But because my teacher-research is firmly grounded in my political commitment to push for social justice in science and education, my understanding of positionality and how it influences my teaching and my students learning in science is important but not enough. This understanding needs to be put into action to revision a living science education.

Therefore, I see these summer conversations as a transition period in my own orientation towards a feminist liberatory education in science. Through my students interventions, I learned that their ability to deconstruct the hierarchical relationship between science and nonscience or insider and outsider and to struggle against the boundaries imposed by the pervasive political agenda of science and education were grounded in our commitment to give voice to their marginalized and silenced experiences in science.

When I was teaching in the spring I did not understand the importance of allowing the students to share stories of their lives as they connected with the oral histories or the subject matter knowledge conversations. I realized that their stories were a powerful witness to the political and ideological dimensions of science and how science shapes our lives in positive and negative ways. Yet, I constantly wrestled with the fact that some of their stories seemed so distant from the critiques that I wanted to share and even more distant from the subject matter knowledge we were required to learn in the course. What I recognize now is that by creating spaces in our chemistry class for students to share their lived experiences in multiple contexts (Lisa Karms, Dr. Phillips), we were also learning together how our multiple positionings in the world shaped our experiences in science and hence our ideas about and relationships in science. We were learning to rearticulate the meanings imposed on our experiences. Therefore, as a feminist science educator I recognized how the interventions by my students widened my

narrow vision of positionality. It is not just a theoretical construct I can use to understand what we do, but it is a dynamic set of relationships we can explore to interrogate our understandings in science.

In the next set of chapters (Chapters 7, 8 and 9), I explore how these new ideas about positionality and feminist liberatory education influence my teaching of the gas laws in the summer semester. I illustrate through my summer teaching that valuing the experiences of all students in the classroom (not just those students who know how to engage in white middle class masculine world view) also creates possibilities for new and moving relationships in science class. I argue that a recognition of the ways which positionality shapes relationships in science class is important because it denies the implicit expectation that everyone will engage science in traditional terms. It reduces the influence of western science on the relationships that students have with each other, with science, and with the teacher in science class. Because we bring complex positionalities to teaching and learning science, we need to move beyond the limiting power structure of western science.

PART III. CONTINUING TO TEACH A FEMINIST SCIENCE

The following three chapters tell the story of my attempts to teach about the gas laws to my summer semester students. In these chapters, I reflect on classroom events and other conversations with students and describe how they have influenced my thoughts on positionality and feminist liberatory education. I show how feminist liberatory education is muddled up with positionality. The feminist liberatory education I tried to construct with the students was partially dependent on our abilities to make our positionalities as teachers, students, gendered, ethnic and classed people in science class a central part of our moving relationships in science class; unmasking positionalities in science class served as a basis for challenging and revisualizing the content knowledge of and identity formation in science.

The first of these three chapters explores reflections on past events which helped inform my teaching actions, reflections and decisions in the gases unit during the summer. In this chapter I explore personal attempts to learn the gas laws in order to highlight my own standpoint towards the meaning and purpose of the gas relationships. I also revisit and reflect on an oral history from the spring semester in order to highlight the standpoint that many of my students bring to learning the gas laws. Also, by revisiting the oral history in the context of teaching the gas laws, I share with the reader how the oral history projects helped to change my thinking about the role of positionality in defining a feminist science education. I also revisit and critique my attempts to teach the gas laws in the spring semester as I look forward to teaching them in the summer.

In the second of these three chapters, I share with the reader large pieces of the two class periods³⁰ in which the gas relationships were explored. Although included in this chapters are personal reflections, the purpose of those reflections is not "to analyze what did and did not happen" (that is the next chapter), but to serve as a window into my thinking.

In the third of the three chapters I analyze what happened during these two class periods along three threads. First, I will point out how the notion of moving relationships guided my teaching and thoughts and actions in my effort to construct a feminist liberatory education. Second, I will step away from my teaching role to examine what made these lessons examples of feminist liberatory education (as well as what did not). Third, I will join the previous two strands of thinking together by sharing what have I learned about teaching-researching, students, and science as well as positionality and feminist liberatory education as a result of teaching the gas laws in the summer.

³⁰Each class periods is two hours, forty-five minutes.

CHAPTER 7

Preparing to teach the gas laws: Critically rereading personal experience

In this chapter I explore pieces of my efforts to plan to teach the gas laws in the summer semester. Integral to my thinking in this chapter are the new ideas I have constructed about the connections between feminist theory, positionality, moving relationships and liberatory education which my reflections on the oral histories as well as my summer conversations with students helped me to construct. As I prepared to teach the gas laws for the summer semester students, my planning and reflections brought me back to three moments in time: A particular oral history of Martha Ballard from the spring semester, my attempts to teach the gas laws from a feminist perspective during the spring semester, and visions of learning the gas laws as a students. These events, both in their passing and as sources of reflections have guided my actions and decisions in planning and teaching the gas laws in the summer. Having the luxury of time and intellectual support to reread these events with new ideas about positionality and feminist liberatory education, I would like to walk through pieces of each event to share their significance in my efforts to plan to teach the gas laws in the summer.

Rereading the Oral Histories: Midwives, science, and intuitive scientific knowledge

Late in the spring semester, as a part of the Oral Histories projects component of our chemistry class [refer to Chapter 5, Oral Histories], Ann³¹, a young, quiet, white, working-class

³¹This oral history comes from the afternoon section in the spring semester. The oral histories in chapter 5 are from the evening section in the spring semester. In this afternoon section, I have

woman and an Occupational Therapy major, shared her oral history report on the life of Martha Ballard³², a midwife who lived and worked during the late 1700's to the early 1800's. Ann shared with the class ideas about the content and process of science she has learned by reading excerpts from Martha Ballard's diary. Ann's main points were that Martha developed her understanding of science and her midwife practice through personal experience and observation, and that midwifery was political in nature during the late 1700's and early 1800's because of the prevailing social norms. This second theme came out strongly when she explained to the class,

Men monopolize business, medical doctors, and other stuff. Women are treated as property and as baby makers. She [Martha] would receive letters from women who were pregnant, then she would go help them through labor and spend all her time there till the baby was born. Women were noticed as nobodies, even as a midwife. In my opinion, women would know more about giving birth even by experience and not by schooling.

After Ann nervously shared her ideas with the class, the students engaged in a lively (and almost combative) conversation. Students debated questions about the nature of science: How could the work of Martha Ballard be characterized? What does it mean to know and do science? Did Martha do science? Or, as John asked, "What does [Martha Ballard's] occupation have to do with science?" Martha Ballard's life provided us with a context from which to talk about the nature of science as we entertained these questions. Martha had no formal training in the sciences, but learned a great deal of science through observation and personal, although informal, research with the medicinal herbs she cultivated at home. When challenged with the authenticity of Martha's scientific practice, Ann defensively informed the class, "[Martha] didn't have any formal training; she never went to school. What she knew about science or about medicine, she learned by herself. She learned a lot just by being one of the only midwives

20 students, all of whom are white except for DeShawn, who is African American and Val and Reana who are Latina.

³²Ann based her oral history on an excerpt from the book, Ulrich, Laurel Thatcher. (1990). *A Midwife's Tale: The Life of Martha Ballard, Based on her Diary 1785-1812*. New York: Vintage Books.

in the area. I think the book said that she took care of hundreds of people. She also learned a lot just by observation and doing."

As we searched for answers about what it meant to know and do science through Martha Ballard's lived experiences, our discussion shifted from Martha's lifework as science to ways in which we knew science:

- Ann³³: Men were the main people in science and women were not sought to be scientists and doctors. Midwives were the highest women could be. Martha did not agree with that, and I do not agree with that either.
- John: What does her occupation have to do with science?
- Ann: She delivered babies. She saw herself as a scientist because she brought the babies into the world.
- Andrea: Did she have any training?
- Ann: (defensively) She didn't have any formal training; she never went to school. What she knew about science or about medicine, she learned by herself. She learned a lot just by being one of the only midwives in the area. I think the book said that she took care of hundreds of people. She also learned a lot just by observation and doing.
- Andrea: (sincerely and with concern) But what happens if something went wrong. Would she have to call a doctor? It seems to me that without school she couldn't handle an emergency.
- DeShawn: (with frustration) I think they have learned a lot through experience. Experience was their education. Just because she didn't go to school just like the men could go to school, doesn't mean that she didn't understand what she was doing.
- Val: (nodding in agreement) Men don't know the experience of having a baby.
- DeShawn: (continuing where she left off) We've poopooed a lot of old wives tales. Going through experiences and making our own assumptions and observations is important. It sounds like Martha learned a lot about medicine that way. She grew her herbs and made up her own medicine. There are probably a lot of old wives tales that really work, but people just don't listen because they are not doctors.
- Val: (with passion) I have four children and every time I have gone to the hospital to give birth, the doctors have always treated me as if I were an object. They seemed to care more about their doctoring and their fancy

³³In this conversation I call on people to talk periodically if the students are raising their hands waiting to talk. Therefore to bring some continuity to the transcript conversation, I took my brief comments such as "okay, Val" or "DeShawn" in between student comments.

equipment and with the fact that they have to deliver a baby, than the idea that I am there struggling to give birth. I probably know more than they do about some of the things related to having a baby, just because I have experienced it four times.

- Alleria: (to me) Yah, but is it better to be treated as an object and to not have problems or to be treated like a human and have something go wrong?
- Andrea: (with excitement) I'd rather go to a hospital! I wouldn't want anything to go wrong if I were going to have a baby!
- Lynn: (appearing annoyed) You are assuming that by having a baby with a midwife, something will go wrong. Most births, either inside or outside the hospital happen without any of the major problems. Besides a midwife probably is capable of handling a lot of problems. Like Martha Ballard, is that her name? (Ann: yes), she was able to deal with a lot, because she spent time doing that kind of thing.
- Alleria: Yah, that's true, I am just saying . . .
- Ron: (interrupting) Would you be more apt to sue a male doctor or a midwife?
- DeShawn: (to Ron, with anger) Not all doctors are male.
- Ron: (to DeShawn, with some anger) You are making this into a man - woman thing.
- DeShawn: (to Ron, defensively) I am not, I just want to point out that you were assuming that the midwife was a woman and the doctor a man. [transcript April 18, 1994].

As the transcript indicates, our talk about the nature of science developed into a discussion on how we already intuitively knew a great deal of chemistry because of everyday activities some of us needed or were required to perform—childbirth and health. Through personal experiences, a few of the women began to challenge each other's vision of acceptable science, including those visions which represented most fully the institution of science. These women began to challenge the accepted canon of scientific knowledge with their own personal knowledge. I think it was important to note that Val and Ann really pushed their peers to reconsider childbirth, personal knowledge and science. Val is an Hispanic mother of four, full time care giver in her family, part time worker and part time student. Val cherishes her duties as a mother and caregiver. She feels it is her duty as a woman and mother to take responsibility for the care of her children. As she write in her journal towards the beginning of

the semester, "I do not really like science, and I have never had the chance to study it. I need to take care of my children. That gets in the way of school, but they are worth it and that is what I like to do." These multiple and contradictory roles have given Val a unique position to explore what she knows about herself and about her world and that knowledge is valued in particular situations.

Ann also brings an interesting set of lived experiences to the conversation which help her shape our talk in interesting ways. Ann has spent several years working as a receptionists aid in a doctor's office. She has also been suffering from chronic asthma, and as a result spends a great deal of time in the hospital in out patient treatment for her breathing. These experiences certainly give her a great deal of contact with the medical community and some insight into what it means to work with that community as a semi-insider (receptionist) and outsider (patient and receptionist).

Although John attempted to defend traditional science, the women's conversation pushed on the limitations of the abstract nature of chemical concepts and its relationship to the practices of those "scientists" who have chosen to "name the world" in ways discontinuous with their own lived experiences. As the excerpt from our class conversation highlights, initial attempts on the part of some students to challenge the nature of science as well as relationships with chemistry—relationships which in part define a vision of chemistry, in both content and participation rules.

In addition to focusing on the nature of science, several students, both male and female, developed ideas originally presented by Ann, which alluded to the political nature of medicine: Martha was not valued by the medical doctors in her community because she was a midwife and a woman, even though her practice was as extensive as theirs, and perhaps more physically and emotionally demanding. These challenges to the traditional practice of science were continued to be refuted by Ron. The class explored this theme by discussing it in relationship to current issues in health care.

- Mark J: I think part of the way that doctors treat you is related to hospitals being businesses. They are out there just like everyone else trying to make money.
- Mark L: (nodding in agreement) It's hard to tell with a hospital because who are hospital for now anyway? They are just businesses now. Nobody really cares about the patients, they just have to get the money and make a profit.
- Rick: (sounding frustrated) But some of those doctors have been to school for at least 11 years. That's got to mean something.
- Lynn: Have you ever noticed that women doctors pay more attention to you?
- Mark : (ignoring Lynn's comment to respond to Rick) Well, I, medical science is too commercialized to be objective.
- Lynn: Oh I know, how they treat you is all based on insurance.
- Ann: That's true because I have asthma, and sometimes I need to go to the hospital for treatment and I spend more time doing stuff for insurance before they even will see me, than I do with the doctor.
- Lynn: Medicine is all about money. That's kind of depressing because I want to go into medical research, and I just wonder what it will be like.

In the second half of the oral history conversation the students began to articulate the notion that doctoring has become an economically and politically motivated profession. For example, "medicine is all about money;" that it is just a "business" with an emphasis on "making money" rather than treating people. In so doing, the students seemed to have expressed standpoints critical of science. They began to critique the socially acceptable belief that midwifery is only a "nonscience science" while doctoring is a "science science." What I found particularly interesting here is what experiences and ideas pushed particular students to take a critical stand. Several of the women (Lynn, Val, and Ann) were immediately critical when the class discussed how people are treated in doctor's offices. Some of the men (Mark L. and Mark J.) began to articulate a critical standpoint when business issues were raised.

The conversation about Martha Ballard, science, politics, and personal experience left a vivid imprint on my mind. After hearing Ann's presentation, I expected the students' discussion to focus on the question, "Who was considered a scientist and who was not?" I was curious to learn more about how the students would grapple with this question, especially after

having been presented with pieces of the dynamic life of Martha Ballard. But hearing the students struggle with knowing science in ways which were at once similar to, and yet different from, traditional ways of knowing science as a result of lived experiences pointed towards new connections between the experiences of my students and science. Indeed, I was surprised by the intensity with which the students wanted to define their own knowledge, or with how problematic that process was for them. In our conversation, Val struggled with finding a place to define her own science when she passionately stated,

I have four children and every time I have gone to the hospital to give birth, the doctors have always treated me as if I were an object. They seemed to care more about their doctoring and their fancy equipment and with the fact that they have to deliver a baby, than the idea that I am there struggling to give birth. I probably know more than they do about some of the things related to having a baby, just because I have experienced it four times.

This struggle with defining knowledge was also evident in DeShawn's ideas about how midwives learn science,

I think [midwives] have learned a lot through experience. Experience was their education. Just because she didn't go to school just like the men could go to school, doesn't mean that she didn't understand what she was doing.

I felt the opposing tension—a fear or unwillingness to define their own knowledge—which was articulated by Andrea when she stated sincerely and with concern, "But what happens if something went wrong. Would she have to call a doctor? It seems to me that without school she couldn't handle an emergency," and also when she declared that if faced with childbirth, "I'd rather go to the hospital! I wouldn't want anything to go wrong if I were going to have a baby!" This tension was also evident in Alleria's comment, "Yah, but is it better to be treated as an object and to not have problems or to be treated like a human and have something go wrong?"

These issues raised by the students in the Martha Ballard conversation occupied a visible place in my thoughts throughout the rest of the semester, in part because it appeared as if they had a lasting impact on the definition of science made public by the students. Up until this conversation, the students never so explicitly nor so passionately defined for me their

(dis)connections with science. This conversation created an uncomfortable tension between our experiences in science and the science of the educational institution. It was not until the summer months when I began to draw connections between the dynamics of the Martha Ballard conversation (and other oral history conversations) and the role of positionality in teaching a feminist liberatory science.

When the conversation about Martha Ballard occurred during the spring semester, I was defining positionality as the standpoint I brought to interpret events, a standpoint defined by the interaction of my experiences as a white woman, scientist, teacher, student, researcher. Consequently, the original meaning of the Martha Ballard conversation held for me was that we were able to create spaces for our female, nonscientists, working class, and government-big business controlled voices, thereby providing us with new and different opportunities of making sense of the nature of science.

Rethinking this conversation and some of the students' struggle to define their own knowledge in the following months meant asking myself: What did it mean to understand the gas laws, (the acceptable canon of science), challenge or to create the gas laws when who we were as students of science, as (non) participants in science, did not connect with or perhaps even interact with the controlling world view of science? What was the nature of the relationship which existed between the students, the gas laws, and myself and how did this bound (if at all) our vision of the gas laws, of science, and our relationships with and in science? How could thinking about positionality help us to make sense of science, and our relationships in class with each other and with science and the knowledge we were able to construct within the relationship?

This new reading of the Martha Ballard conversation suggests that the students and I shared ideas and experiences which explained and confronted how societal, economic, and political agendas influence science and our relationships with science and with each other in science. Many of us explored how we could learn science through experience and observation, rather than as traditional abstracted school knowledge. Despite Ron's very strong vocal

support for traditional science, many of us expressed how we felt controlled by science because of our material circumstances as female and nonscientists, even when we felt our experiences warranted our participation in science. This idea was clearly evident in Val's comment about the birthing process and modern medicine.

The Martha Ballard conversation helped me to see how the possibilities for feminist liberatory education are connected to positionality, and gave me new ideas for teaching the gas laws in the future. By thinking about how positionality (re)constitutes our moving relationships in science class, I found new possibilities for revisioning science education from a feminist perspective. I began to think that if we are able to revision science we must begin by challenging and changing our relationships in our class because such relationships ultimately determine what knowledge is important. It is in this changing of our relationships that thinking about positionality becomes important. This was the case with the Martha Ballard conversation: By valuing our feminine³⁴ experiences and bringing it into our class conversation, the authority of western science was demystified. Western science was not so central to our relationships at that moment. In this very short instant, it seemed like the class, through recognition of their lived theories, began to redefine science in their lives. I began to see that, we, in a very small way, were able to challenge a relationship marked by power hierarchies (non scientist-scientist), by publicly examining our own positions in science class (when Val suggested that her knowledge of the childbirthing process was just as important as the doctors). This conversation gave me hope that we could interrogate the master narratives in science which legitimate the white middle class masculine standard which simultaneously delegitimizes any other perspective as "nonstandard" and "nonwhole", then we need to find ways which valued our full and shifting identities. We needed to live our knowledge, as did Martha Ballard and Val, rather than appropriate it abstractly.

³⁴feminine NOT female

For example, in the Martha Ballard conversation I have reread the students' and my own actions as contributing to a process of making our relationships with the institutions of science and education problematic because we redefined them through our experiences in science and education not representative of white middle-class masculine culture. I believe that attempting to articulate and highlight the complexity of our lives which has traditionally been silenced by science and science education, and then publicly reconstructing a relationships with science and each other in science class which embodies and reflects such complexity, constitutes an effort to reinvent our relationships with science. It constitutes an effort to reshape the power arrangements in our science class by decentering the omnipotence of traditional western science. By rereading the Martha Ballard oral history conversation with this new perspective, I can now see how Ann created possibilities for our class community to explore the relationships we have with and in science when she defensively articulated her views about the life of Martha Ballard:

She didn't have any formal training; she never went to school. What she knew about science or about medicine, she learned by herself. She learned a lot just by being one of the only midwives in the area. I think the book said that she took care of hundreds of people. She also learned a lot just by observation and doing.

Possibilities for defining our relationships in science were illuminated by Val with her passionate response to the relationship between child birth and modern medicine, and by DeShawn, in her expression of the diminished value of old wives tales,

We've poopooed a lot of old wives tales. Going through experiences and making our own assumptions and observations is important. It sounds like Martha learned a lot about medicine that way. She grew her herbs and made up her own medicine. There are probably a lot of old wives tales that really work, but people just don't listen because they are not doctors.

What did new ideas about positionality and moving relationships as portrayed in the Martha Ballard conversation have to say about teaching the gas laws? Would my change in thinking help me to construct with students more authentic attempts at feminist liberatory education? Could my new understanding help me to reinterpret my previous attempts to teach the gas laws in constructive ways as I looked forward to teaching the gas laws again?

Rereading past attempts to teach the gas laws: Learning to build a feminist science through relationships

After teaching the gas laws in the spring [refer to Chapter 4], I struggled with my own ambivalence. In a journal entry several months later, I articulated how I felt about my inadequate attempts to engage students in understanding and critiquing science:

Teaching Journal entry, June 30, 1994

. . . Even though at the end of the unit the students were able to mathematically manipulate the gas laws with increasing success, I felt like, as a class, we had been artificially separated from our socially constructed scientific knowledge. It was not so much that the relationships between pressure, volume, amount and temperature remained abstract, untouchable, but that their place in our lives were uncertain, or perhaps simply unwanted. I was puzzled by this feeling because I thought I had brought a more "connected teaching" approach to the unit (Belenky et al 1986). I presented [the students] with a problematic historical development of the gas laws (i.e. why does the book only mention four male chemists: Boyle, Charles, Guy Lussac and Avagadro, and out of what research and political circumstances did this work develop?), chances to explore the gas law relationships, lab equipment in class (hands on, personal exploration and theory building through small group interaction), and with practical examples from everyday life. Yet, I am left wondering if my attempts to "liberate students" from the strictly and traditionally defined canon of western science only served to oppress students more: Many students still [appeared to feel] disconnected from the gas laws, even though they exhibited . . . a resistance to confront the social and historical situatedness of science and school and the taken for granted nature of the authority and power of the institution of science.

Juxtaposing these teaching reflections with the memory of the Martha Ballard conversation, I began to understand that my vision of feminist teaching was inconsistent, at best. It was not woven into the larger picture of who we were at that moment, and how we wanted to be (in science). And, my feminist approach was still defined largely by the agenda of western science. In our study of the gas laws during the spring western science held the center position in all of the relationships we engaged in class. Our lives were secondary.

Rethinking my teaching with the framework that possibilities for liberatory education were intimately connected to moving relationships, uncovered assumptions which uncritically guided my teaching thoughts and actions. "Liberating" students from the canon of

science could not occur solely by critiquing western science from a feminist perspective because it still required that students master the gas laws on the terms of western science. My teaching plans for the summer would be different. Paramount to teaching the gas laws would be an effort to decenter the standpoint of western science in our classroom relationships by making central and problematic in our efforts to construct ideas about the gas laws, our relationships with each other and with science. We would be more explicit about the ways we have chosen to name our "informal" and "personal" experiences with the gas laws. This process would help us to integrate our voices into our relationships with science in order to decenter the claims of western science in its own formulation of the gas laws (including its claims to objectivity and authority to name experience). In other words, explicitly talking about our personal experiences with the relationships between pressure, volume, temperature and amount, we would create opportunities to build our own theoretical bases from which to think about the gas relationships and from which to critique the ways of knowing and doing western science. For my teaching practice, this meant I could not hold the expectation that we needed to appropriate western science or even the formal feminist critiques, in order to critique it.

As I wrote in Chapter 4, I still uncritically allowed the standpoint of science to define the relationships within which I acted in science class. Throughout the gas laws unit in the spring, I wanted the students to be able to work within the canon of western science so they would develop a foundation from which to become immersed in a critique of science. Now, I can see how I was trying to make the students fit into the traditional insider/outsider relationship set up and perpetuated by the institutions of science and education: The students and I needed to be fluent in this abstract language of chemistry and in particular of the gas laws and the associated (tedious) calculations to be insiders to chemistry. And, we needed to be insiders if we were to have the "intellectual capacity" to offer a critique. Therefore, if either the students or I did not possess the "technical jargon" of chemistry, we would be outsiders to chemistry, no matter how intuitively we understood gas laws! This was not the vision of science I wanted to create with my students.

Rereading personal experiences of learning the gas laws: Renaming my own relationship with science.

Exploring the gas laws draws me back to an earlier struggle I had with the gas laws:

Journal entry, May 20, 1994

I remember the ways in which I was taught the gas laws when I was an undergraduate chemistry student and I remember how much I HATED it!! Especially in "P-Chem" —thermodynamics class. Of course remembering events and ideas is a tricky thing:

When talking about their lives, people lie sometimes, forget a lot, exaggerate, become confused, and get things wrong. Yet they are actually revealing truths . . . the truths of [their] experiences (Personal Narratives Group, 1989, p. 261).

The mothball-banana scent of room 352 Nieuwland Science Hall—an immediate and intense reminder of the student labs down the hall—and the glaring sun reflecting off the right side of the chalkboard are some of the images conjured up when thinking about learning the various derivations and applications of the gas laws as a junior in thermodynamics. I intentionally sat toward the front of the room on the left side so I would not be bothered by either the glare on the board or the smell from the labs. Considering the clandestine sunshine and the lingering sticky-sweet odor belched from the ethanol plant in next door South Bend, it probably didn't matter where I sat. I knew deep inside I needed a sense of identity, a place I could call my own in a room filled with men and with mental compressible gas cylinders, pistons, tanks.

The professor, a nice enough middle aged white man, spent hours gabbing on and on about the seemingly important act of compressing gases in long, cool, metal cylinders, and the influence this had on the boiling point and pressure. Although the logic behind the relationships made sense and the math required to muddle my way, alone, through problem sets and exams was relatively easy (compared to quantum mechanics), the ideas had no meaning, no beauty. I could not find ways to relate to them. Even though I aced the course work, I felt like an outsider to this material for a long time. I felt controlled by this knowledge that I could not find meaning in for a long time. And, if I could not grasp, embrace, embody that knowledge in the most technical, abstract, meaning-filled, and masculine senses, then I obviously had no place in the field, and no claim to a reputation of "rigorous intellectual capacity" (whatever that is—I just remember hearing that phrase used a few times in that setting). Of course, I could not tell anybody about these feelings because they would really think that I did not have the intellectual capacity to be an adept chemist.

My learning of the thermodynamics of gases had been an alienating effort. To succeed in this arena, I needed to redefine my knowledge of thermodynamics and my place in science

through "a more truthful, more rigorously intellectual" lens. I needed to place to the side my "naive understandings" of the world in order to more fully understand the abstract nature of our world. I needed to acknowledge that the theoretical, mathematically derived formulations of the gas laws which predicted empirical findings were superior to the actual empirical findings and to my own practical understandings.

As I struggled to find meaningful and unoppressive ways to explore the gas laws with my students, I reread my own learning of the gas laws. This was my own enculturation into the discourse community of science, a result of uncritically assumed power arrangements between the institution of science and its related discourses and practices, my teacher, my fellow students, and me. One manifestation of these power arrangements was the prevalent belief that "positionality"³⁵ was assumed either nonexistent or unproblematic even when it did not feel that way to me. This rereading of my experiences learning the gas laws, in my own mind, begs the question: How could I expect my students to build a foundation from this knowledge when such a foundation may be one of mystification, fear or abstract nonsense?

The gas laws unit this summer would take a different form than it had in the spring. First, as my students helped me see through the conversation about Martha Ballard, the other oral histories conversations, and our summer conversations, we would explore the gas law relationships as we have understood them in the contexts of our own lived experiences. Working in groups, students would be asked to theorize about how they have used their knowledge or understanding of the relationships between pressure, volume, temperature, and amount in an intuitive sense at home or work. They would publicly share with each other the

³⁵I use this word in quotes because I do not think that anyone in that setting, including myself would have used the word positionality. Most recently I have studied statistical thermodynamics at the graduate level (a quantum mechanical treatment of classical thermodynamics) where we theoretically derived many of the thermodynamic relationships of ideal gases. I can say from the perspective of one who has been thinking a great deal about positionality, that the assumption made by the professor teaching the course, the authors of texts which we read, and many (but not all) of the classmates with whom I interacted in the course, that positionalities were again assumed either nonexistent or unproblematic even when it did not feel that way to me.

ways in which their own set of lived experiences have provided them a context in which to name the gas laws, in ways different than (or, in some cases similar to) chemistry. Each group of students would then be asked to find a way to share their personal knowledge of the relationships between pressure, volume, temperature, and amount with the class. Central to constructing new knowledge in class about the gas law relationships would be the opportunity for students to articulate their own naming of the gas law relationships (with or without the technical jargon). The "chemistry formulation" of these ideas would be situated as secondary. We would use these personal explorations to develop theories. The insider/outsider dichotomy would not be so neat and tidy: We would be both insiders and outsiders to chemistry and we would be neither insiders nor outsiders to chemistry. The students' personal experiences, encounters, explorations, and theory building would be the primary body of knowledge for our unit on gas laws³⁶.

A second, and critical piece to my feminist teaching agenda is that we would use our personal theorizing of the gas laws³⁷ as a theoretical base from which to understand and then critique the knowledge of western science. This process would allow us to deconstruct our relationships with science in ways which would make problematic traditional assumptions about self and science undergirding those relationships. This is the piece of this lesson which I believed to be critical to my feminist liberatory agenda. It is one thing to help students

³⁶I find this planning sort of problematic for the kinds of expectations set up by educational institutions in general and the science department of which I am a faculty member, in particular, because of its inherent uncertainty. I cannot predict the kinds of theorizing in which the students will engage if I open it up to being founded on personal experiences, beliefs and values. My students are primarily female and working class, ethnically diverse, all of which represent voices historically silenced by western science. Yet I worry that we may not even reach the uncertainty because of overriding efforts by my students and even myself to keep the canon of Western science in control.

³⁷I felt this plan was risky because I could not predict what would happen, and that made me very nervous. How should I deal with potential inconsistencies the students understandings may have with Western science? Could students experiences be "wrong"? What is implied in labeling a students experience as "wrong"? How would I even choose to characterize inconsistencies? Would I define inconsistencies from the standpoint of Western science and if I did what did that mean for making my students experiences the foundation for our knowledge of the gas laws?

conceptually understand science from the standpoints of their own lives, but it is quite another to help them use that understanding to critique a powerfully long-standing and commanding knowledge base.

I planned to follow this work with an exploration of the historical development of the gas laws. This would be similar to last semester—we would discuss the people (men) who created the laws, the people who were left out explicitly (women) and implicitly (minorities, women, and working class)³⁸, and would explore the social circumstances surrounding their development. Yet, this historical exploration would also be different from last semester, because this time, we would use our lived experiences, our lived theories, as the basis for our critique of western science.

As I thought about the lesson, I was reminded of bell hooks' (1990) description of the political and chosen nature of positionality, which is critical to the nature of liberatory education. hooks provides a provocative understanding of the relationships between politics, oppression, liberation, and positionality when she writes that positionality, is crucial, for it is the "standpoint, perspective, position, the 'politics of location' which necessarily calls those of us who would participate in the formation of counter hegemonic cultural practice to identify the spaces where we begin the process of revision" (p. 145). With my teaching plans for this next time through the gas laws I hoped that we could take a political stand with our own ideas. I wanted explicitly to make our own science from the standpoint of our lived experiences, and to disrupt the traditional kind of relationship with which we engaged science; to promote moving relationships. I did not want to have our lives or our understandings defined by science

³⁸I suggest that women were explicitly silenced because even though they engaged in a great deal of scientific work (in most cases, in collaboration with their husbands), they were intentionally not given credit for their work. I suggest that minorities (non Europeans) were implicitly silenced, because they, unlike many of the women, were not even given a chance to engage in scientific enterprises. This gets really messy because few women were allowed to do any work at all in science because they were expected to tend to other domestic duties, and so they too were implicitly silenced. The same is also true of most of the working class people.

because science did not take into account much of the nature of our lives. Therefore, I want to turn our relationships with science on their sides through the politics of location.

CHAPTER 8

Teaching the gas laws:

Our lives are our theories are our lives

In this chapter, I share with the reader my attempts to teach the gas laws to the summer semester evening students. In my telling of the story, I try to give the reader a sense of what happened in the lesson through my retelling of the events which took place. I also include my reflections as a feminist teacher researcher to illustrate to the reader my thinking about the lesson. I hope that my choice as the author to move back and forth between the telling of classroom events and my thinking is not too distracting. It is my intention to bring the complexity of the situation alive in this text. As a teacher trying to use the students' lived experiences as locations for revisioning science, I find myself constantly having to rearticulate my own ideas about beliefs about the gas laws. I also find myself rethinking my ideas about and understandings of the students and our relationships with each other as they reveal themselves to each other and to me. Therefore, although the purpose of this chapter is to share with the reader how my thinking about positionality and feminist theory shape how I think about liberatory education in the classroom, telling the story through a retelling of class events from my perspective allows me to share in a contextualized way my teaching beliefs and actions.

Tuesday night:

I was tired when I walked into class the night we were to start the gas laws. Most classes I am tired, but not as tired as some of my students. The summer semester class is an

evening class—we are meeting from 6 - 8:45 PM on Mondays, Tuesdays, and Thursdays (and it was only Tuesday!). Like myself, most of my students work all day long before coming to class. I admit I am lucky though: My work sometimes consists of sitting in front of my computer, thinking and writing for hours. Today, though, it meant testing water all morning long with third and fourth graders in a summer science program. I know that Juan, a Latino, mixes asphalt everyday. Gloria, Latina, digs gas mains and puts up with all the "shit" that the men in her company give her for it. Rita, a white woman is a secretary for a small town pharmacy. And Becky, also white, tries to split her time between her children, working full time as a cashier at a local discount super store, and school. Tired, I think, is an understatement.

As usual, Holia, Sol, Gloria, Tammy, and Rita have arrived before me. Most students arrive at our fourth floor classroom in a building sandwiched between the state capital district and low income housing, only a few minutes before the class officially starts. Most students sit in their seats talking with the people near them about the days events, although a few students have their notebooks or textbooks out reviewing for class.

Tonight's class started with Lisa's oral history project. Lisa, a part-time nursing student, interviewed her mother who is a chemotherapy nurse. She shared with us the responsibilities her mother has, the different kinds of treatments she administers, and the most common side effects of such treatments. Lisa then shared with us information about the kinds of patients her mother treats. She told us that a large portion of her patients were "AIDS victims," in part because her mother worked in the city hospital where the majority of the AIDS victims are treated, but also because many of the AIDS victims develop various cancers due to their weakened immune systems. The students, including myself, seemed to find the project quite interesting, and asked many questions about the nature of chemotherapy as well as the economic, social, and physical implications of such work.

I usually plan ten minutes for our daily oral history conversations. Sometimes they take a lot less than ten minutes (like the time Pete talked about the goldsmith). Sometimes, like today they take a lot more than ten minutes. Between Lisa's discussion about various

items used to combat the side effects of chemotherapy (for instance, a special kind of toothpaste that she passed around), there were several questions many of the students had about chemotherapy, AIDS victims, and even Lisa's mother's health safety (because she works with intravenous drug treatment and AIDS victims). I felt uncomfortable when I ended our discussion after thirty minutes because of a need to "get on with the subject matter knowledge".

It seems like whenever we have an interesting discussion as a result of the oral histories, I always close the discussion before it would have naturally ended in order to get on with the subject matter knowledge. I suppose this means something. Perhaps it tells the students that the chemistry we are there to learn is more important. When I asked Tracy (student from the spring semester) what she thought, she said, she wished she had more time to talk about some of the issues that come up in the oral histories, but understands that we are in class to learn chemistry, and it is probably "best that I move on. Besides, there are some people who probably prefer that you move on anyway." This is frustrating to me because it shows my inability to integrate these oral histories into the study of chemistry. I felt I probably should have let the conversation continue.

Gas laws Phase I - Developing a common language to talk about gases

To shift our thinking from Lisa's mom to gas thermodynamics and to get the class ready to think about the gas laws, I initiated a conversation which helped us to revisit our previous work on the properties of gases. At the beginning of the semester when we talked about the language that chemists used to describe the world (to describe matter), we spent some class time exploring what it meant to talk about the states of matter—solids, liquids, and gases. At that time, we talked about the differences that the students observed between solids, liquids, and gases, and based on what they knew about how to get matter to change states (we talked about heat and pressure changes), we hypothesized what might be happening at the molecular level.

I feel I must back up for a minute to problematize my thinking about this conversation. In order to develop a conceptual understanding of chemistry, there are certain assumptions which must be made. It is assumed that atoms exist, and that they can combine with each other to make molecules, even though they cannot be seen, except when they are lumped together in huge bunches (about 10^{23} atoms bunched together, at least, for some of the smaller elements). Earlier in the semester, I tried to create learning situations where the students learned to be critical of this theory. I wanted the students to realize that the way in which atoms have been conceptualized is a *human construct*, and that there are other ways to think about matter at the microscopic level. We spent time at the beginning of the semester reconceptualizing atomic theory (usually pretty unsuccessfully as far as building a new theory goes, but pretty successfully as far as getting the students to be critical of such theories). Anyway, the point I am trying to make is that to understand the acceptable scientific ideas, we have to revert back to specific assumptions about atoms and molecules which leaves me feeling uncomfortable, I can only hope that my students are being critical of these assumptions in the back of their mind. I felt that I somehow needed to let you know that even though it may seem by reading this story by itself, that our class has not been critical of these ideas, they are really taken very seriously at different points in this class. Although it may seem like the ideas of molecules is assumed uncritically to be true at this juncture, that is not the case (at least I have tried to make that not the case, but of course in reality, this is probably on partially the case).

At the end of the previous class meeting, we went back to that early semester conversation to begin to think about gases more thoroughly. So, tonight we started thinking about gases by returning to the previous day's conversation. To begin our investigation into

gases, I wanted the students to have an historical understanding of where and how the term came into existence^{39,40}.

I shared with the students some of the work of Johan Baptista van Helmont (1579-1644), a Flemish nobleman, who only practiced medicine (chemistry) as charity. Until van Helmont's work with the gaseous state, most chemists (and alchemists) witnessed "gases" when bubbles came out of their reaction solutions. But, up until van Helmont's work, these bubbles were believed to be excess air—at that time, the Greek theory that all things were composed of air, fire, earth, and water was widely accepted. Van Helmont did not accept this theory constructed by the Greeks, and even more he wanted to prove the Greek's wrong! But, in order to prove that the Greeks were wrong, he needed to study the bubbles that came out of solution. He tasted them, touched them, smelled them, observed their color, and he tried to dissolve them back into solution and also into water. What he concluded was that because the bubbles did not taste or smell like air, they were not air. He also concluded that because the

³⁹This information was not available to the students through their text book. Instead I shared with the students information that I have learned through my own library research, and referred them to books such as:

Salzberg, H. (1991). *From Caveman to Chemist*. Washington, D.C.: American Chemical Society. (got to love that title!)

Holmyard, E.J. (1931/1962). *Makers of Chemistry*. Oxford: Clarendon Press.

Author. date. *Women of Science*

Jaffe, B. (1930/1976). *Crucibles: The story of chemistry from ancient alchemy to nuclear fission*. New York: Dover Publications.

Liechester, H. (1951). *The Historical background of chemistry*. London: John Wiley & Sons. (I wonder if John Wiley had any daughters).

I need to find a better way of sharing this historical stuff with my students. Also, as is evident by the books I recommend my students read, I have found a dearth of literature which searches deeply into the history of chemistry to learn about the work of women and minorities (work that might not be considered "mainstream science", or work that was simply appropriated. We have come to some of this information through learning about Martha Ballard, but I am at a loss for what other sources to use.)

⁴⁰ I am including a brief discussion of the first half of class to contextualize the gas law story. I also include this because one dilemma I face as I attempt to construct a liberatory setting is how inconsistent my practice is. The semester was spent weaving in and out of authentic and liberatory feminist praxis. I believe in the portion of class about the gas laws, we were able to construct new and liberatory relationships with science. This was not all that common an event in our class. As the first half of the class illustrates, even though I incorporate elements of feminist pedagogy (historical analysis, critical of passive acceptance of scientific ideas, etc), I was unable to find ways to help students create new relationships with science.

bubbles dissolved back into liquid when using a very cold liquid medium, heat must play a role in the formation of gases. After sharing with the students this historical story, I also shared with them that Robert Boyle, a British chemist who worked during the same time frame, produced similar data in his own lab. But, Boyle used his data to very clearly support the Greek's hypothesis, and not van Helmont's.

As a class, we examined the story I told them and together extracted useful and interesting pieces of information to begin to put together a theory for gases. I asked the class what they thought was important for building a theory of gases from the story I told them. I mostly received a set of ideas I mentioned in the story repeated back to me. For example, Bill suggested that "gases turn to liquids at colder temperatures." Linda suggested that heat can cause liquids to turn into gases...[that] the heat is transferred to the atoms and so they have more energy." Rico suggested that because "the gas tasted different than air...[then] It could not be air."

When I asked the students to draw connections between the ideas raised by the members of the class and the possible ideas about what is happening at the molecular level, Gloria suggested that if the gas was a different color, you could tell how fast it was moving by watching how fast the colored gas spread. When I pushed her more about what she meant, she suggested that one way to determine if gases moved faster than liquids would be to see "which spread out faster, the colored gas or the colored liquid⁴¹." I asked the class what they thought about Gloria's proposed experiment, and whether they could think of events in their life where they witnessed this phenomenon occurring or events which proved the opposite. Sol then reminded the class of the experiment we did earlier in the semester where we dropped food coloring in cold and hot water, and how the food coloring spread out much faster in the hot water. He seemed to feel this was good evidence for Gloria's claim. Although this was not the kind of example I was hoping for (I was hoping for something more connected to their everyday

⁴¹Gloria's proposed experiment is very similar to an experiment we had done earlier in the semester. I think that is where her idea came from.

activities), it gave me the chance to remind them what they hypothesized earlier in the semester, when they did that particular experiment.

I then pushed the class to think about how these same results could be used to disprove van Helmont's theory (or to prove Boyle's belief in the Greek's theory). This part of our conversation was awkward and uncomfortable. I think this was due to the fact that my students are not familiar with the Greek theory in which all things consist of a combination of air, earth, fire, and water. I was therefore difficult to show them how van Helmont's result's could also be used to prove that theory. I was also very critical of the objective nature of science at that point, and the students may not have had the language, the experiences, the beliefs, or the confidence to take up the conversation.

Angie: Now, that we have some idea about what van Helmont's result's means to us, how do you, or I mean, maybe why do you think that you could get different results? Take a few minutes and think about it. You can talk with the people around you if you want, or, its up to you.

[students are talking quietly with one another or writing or just sitting in their seat (either thinking or pretending to think).]

Angie: Okay, what did some people say? Sol?

Sol: Maybe his results were not exactly the same. They might have done some different experiments that we didn't know about.

Angie: Would anyone like to respond?

[silence]

Angie: Rita, what were you thinking?

Rita: That's probably true, we don't really know what they both did?

Angie: Yah, that's true. All I know is what I read, and that probably, well not probably, it does, have its own slant on the story. But think about it. That's a really good point. The stories that I have read have their own slant on the issue, so couldn't the scientists have their own slant. Who wants to respond to that idea?

Bill: Its what we have been saying all along in this class, that there are political reasons that control science.

Angie: Are you saying that there are political reasons controlling van Helmont's and Boyle's science?

[some students laugh at my question.]

Bill: I don't know, I wasn't there and I have not read anything about it, but it could be the case. You don't know who they were working for. Didn't a lot of scientists work for the nobility?

Angie: Well I think a lot were the nobility, but I bet that some worked for kings and queens, just like scientists today work for our government. Who would like to respond to that idea? [pause, then with growing frustration] No one? Come on, I know some one has to have an idea, or at least a question.

[silence]

Angie: Doesn't that idea seem sort of heretical? What do people think? [pause] Linda, what do you think?

Linda: I work for the government, so I know what kind of pressure that can be. I never thought about it that way. I don't know.

I then shared with them that there were other hypotheses about gases by other chemists about gases since then from experiments like these and that when put together made up the Kinetic Theory of Gases⁴² and suggested to the students that we would come back to these ideas next week to find adequate evidence for these ideas. I felt very uncomfortable doing this without spending anytime on it... Its one of those dumb teaching decisions I made because of the intense pressure to cover all the material required by the department.

We then spent some time writing in our journals about what it meant to talk about pressure, volume, temperature and amount in gases. I wanted the students to begin to think about these concepts in the context of gases, but I also wanted to make sure we shared a common understanding when we used those words. We went back and forth on the meanings of these words, until I felt comfortable that the students had a common understanding of pressure, temperature, volume and amount. All I was hoping for in this part of the conversation was that we shared some meaning. This notion of shared meaning is messy because we never developed a common definition which was written on the board, spoken by me, or commonly written in their

⁴²Gases consist of molecular particles moving at any given instant in straight lines; molecules collide with each other and with the container walls without loss of energy; gas molecules behave as independent particles; attractive forces between them are negligible; gas molecules are very widely spaced; the actual volume of molecules is negligible compared to the space they occupy

journals. I intentionally tried not to approach definitions in that way because I wanted the students' experiences to help them define these words. I know this shared meaning for which I strove had been defined by science, but I rationalized this in two ways: I wanted the students' definitions to be personal. If personal meant, as it did with Bill, the official scientific, textbook definition, that was acceptable, for now, as long as it was meaningful to the student. But, non textbook definitions were also acceptable to me, if the "scientifically accurate" meaning of the word was there in a meaningful way, as was the case, I think with Lisa. As I write about this I feel, again, really uncomfortable, because I seem to be shifting back and forth between valuing the students experiences and valuing the power of science.

However, this is more problematic than my teaching actions may make it seem. If I did allow Bill to keep his scientific definition and Lisa to keep her nonscience definition, would I not be promoting access to the culture of science by a man and denying that access to a woman? I worried that my decision to value these definitions equally potentially devalued Lisa's experiences because her definition was clearly "not as scientific as Bill's" in a very traditional and narrowly defined sense. And, even though I never said that, I just wondered if the students' experiences of years of schooling led them to implicitly believe that.

Gas laws Phase II - Exploring personal experiences: Making our lives our theories

After working through the meaning of the words, I had the students work in groups in order to think about how they understood the relationships between pressure, volume, temperature, and amount in their lives, and to construct relationships between the variables based on their lived experiences. I encouraged the students to search for ways in which they used an understanding of gas relationships in everyday life. Were there any particularly routine or commonplace activities that required some knowledge of gas thermodynamics? Were there any everyday sorts of activities which caused them to think about how gases behave?

I also told the students that each small group was responsible for sharing with the rest of the class their theories about the gas behaviors and how they have used them in their own lives, and for engaging the class in a discussion about their own understandings. At the end of the hour I wanted the students to have thought through the relationships between the four variables, and I expected that they would have a manageable plan for sharing their ideas with the class which included:

- What story or event did the group want to share with the class?
- What did the group believe were the physical relationships of gases being expressed in their story or event?
- What questions did they want the other members of the class to think about as they listened to or watched their story or event?
- What sort of mathematical equation could they write to represent those relationships? (optional, although I did not require or emphasize this question at this point.)

Having students work in groups is not a new activity for our class. Given the length and intensity of the course and my own pedagogical beliefs, my students have grown to expect a myriad of activities other than the formal lecture. I think, at first, students did not think they were "getting their money's worth" because I was not spewing forth every known fact engraved in their texts, but that response seemed to diminish as they found themselves thinking hard and for themselves, in a field implicitly and explicitly believed by many students to be far removed from the course of daily events. I remember laughing delightfully when Kim asked me to lecture because she did not want to "theorize"! It is funny, as I read what I just wrote, it seems like our class was one big happy family who enjoyed co-constructing our story of chemistry. In many ways I would like this to be true, and in many ways I do believe this to be true, but I do not believe that it is as simplified as I portrayed, because it does not capture our hidden ideas, values and feelings about each other and science. It does not highlight the contradictions and tensions inherent in making meaning across race, class, and gender, especially when that meaning is made within the physical and intellectual barriers of the institutions of science and education.

The students' conversations started off rather quietly. I knew this would be a difficult assignment, in part because of the open-ended nature of the questions they were expected to explore. I also worried that the silence in the room was a result of the students feeling unable to become immersed in the group work because "they had not learned about the gas laws in class yet" and as a result felt they had nothing to contribute, no knowledge to share. If this was the case, then this activity would serve only to perpetuate what I hoped to challenge—the authority of science over our experiences. Then, finally, after a very long five minutes, the students began to talk and laugh together as they shared with each other their own various experiences with gases.

Because I encouraged the students to think about the more routine experiences in their lives to explain pressure, volume, temperature and amount, their ideas and conversation seemed to hover around a set of experiences to which most students in the groups could relate. For example, as I walked around the classroom and took part in the different conversations, I wrote in my notes some of the stories and ideas raised by the students. One group of students was laughing about Linda's, an older white woman's "first attempt" to cook spaghetti. Linda described to the group, that in one of her first attempts to cook spaghetti, she filled a pot with water, let the water boil, placed the spaghetti in the water, put the top on the pan and walked away with the intent of coming back to the stove in ten minutes to drain her cooked spaghetti. But, she said, her cooking plans did not go as smoothly as she thought or hoped they would. She said, as she sat at her table reading a magazine, she heard a crash from the stove. The top to the spaghetti pan was pushed off the pot with boiling spaghetti! She noticed that there were "tons of bubbles overflowing the pan" (which she interpreted for the group as bubbles of gas created by the water boiling). She said that she then realized that boiling water required more room, it "sort of needed a way to let some of the gas to escape." She understood the boiling water as having pushed the top off the pan because the top was limiting the room that the boiling water needed. She said now, she cooks spaghetti with the top "half-on and half-off" so that the boiled water has a place to go. She then made a connection between heating the

water (temperature) and the amount of space needed (volume). Bill responded to Linda's story with a similar story about his own attempt to cook rice. Kim, another member of the group then began to talk about making tea and coffee.

I have to admit that I did much more listening than talking in Linda's group. What did Linda mean when she said, the "gas needed to escape from the pan?" Did she mean something different when she said "it needs more room"? Was she really making a connection between temperature and volume or was she thinking that the gas just needed to fly away or to disappear? I chose not to interject at this point because I wanted her experiences, not my store of scientific knowledge (as I think they often view the origin of many of my comments) to serve as a basis for her understanding of the physical relationships in the world. I also wanted to leave this for the class to discuss when the groups shared their ideas.

In the course of the conversation, Linda shared with her group her surprise with her own understanding of gases. She knew from her experience that heat, size, and pressure are related. She learned that she could make informed and intellectual decisions based on her own theories. Later, when I read her journal, she shared that she developed these ideas "long ago" and used this knowledge several times since, but never thought of her ideas as "science" and, in particular, never thought of her ideas as "abstract." She just thought of them as "common sense about cooking." This is important because abstract was something which Linda said was clearly the message she received from the author of the textbook when reading his presentation of gas laws.

The conversation in this group is significant for several reasons. Bill typically asserts his authority to shape the class conversations. Although Bill has had many wonderful insights in the course and has helped push the discussion forward regarding the economic control and destiny of science, I often think of him as "Science Big Brother" watching us. First I feel bad saying this, but I do feel this way for several reasons: First, he is a neatly composed and well articulated (and well dressed I might add) white male, who is very vocal with his opinion. His ideas are always presented clearly and concisely. Even as the teacher I find him

intimidating. I often think that if I were the student I would think that he was "totally smart and always right." I am lucky in this case to hold the position of teacher because I "know" that his answers are not always correct in a Western science canonical sense, and so I am not persuaded by the coolness of his argument. I am however, often tripped up, and forced to rethink my ideas when he does represent an idea different from my own. Second, he is well read in "popular" science and very obviously has had some experience with formal chemistry before taking this class (this class is for students who have not had chemistry or have had it a long time ago). He, more than anyone else will bring the conversation back to the canon of science through the types of questions he asks and the language he uses. Linda and Kim rarely are as assertive as Bill. Rarely do these women as aggressively as Bill work to shape the tone and intent of a conversation around their own perspectives. Even though it was my agenda as the teacher to help to create settings where students could explore their own lived experiences as theories in science, I could not dictate the dynamics of the small group conversations. I most certainly was afraid about how all the students experiences would be received by the groups—especially any experiences which seem on a cursory level to have little to do with science. I was also afraid that the students may use their experience to try to validate an already prescribed science. I think my presence in this group during their initial discussion allowed the two women's experiences to be central to the group's theorizing about gases. I explicitly asked the class to talk about the everyday activities. I think my presence as a woman in the group made cooking an acceptable option to explore.

Other conversations in the room focused on similar themes. Maggie, Lisa, and Holia first talked about the process of making bread. Although I missed the earlier part of their conversation, they said that they knew if they wanted their dough to rise faster, then they could put it in an oven at a low temperature. Holia, a young, Middle Eastern, single mother, commented that bread probably rose twice as fast if she placed it in a warm oven than if she left it at room temperature. When I pushed her to explain what she meant, she suggested that the heat caused the bread to rise faster because the yeast, when activated, produced "gas

bubbles" which then expanded in the bread and made it rise. The students abandoned this idea when Maggie, a young white college student home for the summer asked a series of questions about whether the heat was used to activate the yeast in order to produce the bubbles or if the heat made the gas expand, or if it was both and what this meant for what they knew. The group decided there were too many unknown variables for them to consider and collectively decided to abandon this conversation. Although I was curious to see how they might make sense of the added variables and how they would create a shared understanding I decided earlier to let the experiences of the students, and not my own desires, shape their conversations. That was particularly difficult for me in this instance where I thought Maggie's authority persuaded Holia and Lisa not pursue their own ideas.

Maggie seemed to hold a great deal of authority with the students in the class. I think in part because her experiences were very different from the typical GCC student. She was taking this course over the summer while she was home from a prestigious four year college. Although I believe her gendered experiences as a woman diminish her authority in the class, particularly when she and Bill engage in debate, I also see Maggie as bringing a degree of cultural capital that most of my students do not have. She is very articulate in her explanations and often asks very complex questions beyond the scope of the course.

Maggie then raised the idea that hot air popcorn might be a good way for them to express what they knew about pressure, volume, and temperature of gases. I felt here that Maggie was looking for a way to impose her understanding of the gas laws on the things she did at home (she had taken high school chemistry only a few years back and based on her the science language she brought to the course, I think she remembered a lot of it). Even though this was not what I hoped the students would do with this assignment, it still seemed to help students draw connections between the characteristics of gases and ideas they had before taking chemistry.

As a group, Lisa, Holia, and Maggie talked about how they knew that the corn kernel would pop if it was placed in the proper heated conditions. Although Holia said she knew the

heat would cause the kernel to pop, she said she never knew why. Lisa then suggested that she knew the heat made the water in the corn hot and that was why it popped. This group of students then began to talk about this reflected the relationship between pressure and heat and space.

Holia appeared to be fascinated by Lisa's explanation. She told Lisa that she had never really thought of water existing in the kernel, after all corn kernels were dried out corn! But after learning that corn kernels were a special kind of corn which appeared dry, but had water in them, she wondered out loud if heating the popcorn was like boiling water, and so the "steam" that comes up out of a pan of boiling water pushed at the sides of the kernel. When she learned that water existed in the kernel, she also made the connection to heat boiling the water which would push the kernel open. I viewed the dynamics in this group as very different from the first group. In Linda's group, gender seemed to be a particularly salient issue in a positive way. The group explored the complexity of the relationships between temperature, volume, pressure and amount through traditionally female activities. In the group with Holia, Maggie and Lisa, even though the group was all women, I think that the dynamics were shaped by a conflict between gender roles and class. Because Maggie asserted her authority as an education person who knows science (which was often respected by the rest of the class), I do not think that these students explored their own theories from their lived experiences as much as they did from the theories of science.

I then left Holia, Maggie and Lisa to figure out, on their own, how they wanted to share their ideas with the class. I moved to Gloria and Rita. As usually they were working as a team. These two women are always in class and always on time. Rita is about ten years older than Gloria, married with one son, and works during the day as a secretary. Gloria is a young Hispanic woman who digs gas mains for the local gas company. Gloria and Rita are related by law—their husbands are brothers.

I did not have much time left to talk with Gloria and Rita. At the time I joined them, they were already discussing how they were going to share their story about Rita's seven year

old son's birthday party and a whoopee cushion. When I asked to be filled in on this story, which had been making them laugh for the last half an hour, Rita said that she bought her son a whoopee cushion for his seventh birthday party last year, and that ever since, the whoopee cushion was a source of family jokes. When I asked Rita and Gloria how they thought about pressure, volume, temperature, and amount in relationship to the whoopee cushion, Rita gave "two possible theories depending upon how you look at it," she would share with the class for discussion: First, by sitting on the cushion, the pressure would increase. She then suggested that if you "kept the hole to the cushion shut," the volume would decrease, although not as much if "the hole were open." In other words, an increase in pressure relates to a decrease in the amount of space taken up by the whoopee cushion. Rita's and Gloria's second theory was that if the hole to the cushion remained open while some one sat on it, then the increase in pressure would cause the amount of gas to decrease (because it passed through the hole⁴³). I left Rita and Gloria with this question: "Is the volume or the amount of air really decreasing?", and moved over to a large group in the back corner of the room.

In the back corner of the room was a large group which included Sol, Juan, Tim, Maria, Sarah, Mark, Tammy, and Becky. I did not get much of a chance to talk with this group before class officially ended, but I did ask them what they planned to share with the class during our next class period. There were two main ideas that they talked about during group work: Squirt guns and warm car tires. How was knowledge of squirt guns and car tires also knowledge of gases? As I listened to the group share their plans with me for bringing in a squirt gun, I wondered to myself about car tires. Car tires have air in them. Air is a combination of gases. What is the connection they are making to possible relationships between pressure, amount, temperature, and volume?

⁴³This second theory developed by Rita and Gloria is sort of misleading. The amount of air in fact decreases, but the pressure does not increase because as the system is shrinking air is leaving. Pressure in this system is constant.

When I asked the group to explain the connections they were making between gases and car tires, most of the students in the group looked around at each other as if they did not want to answer my question. Finally Sol suggested that at work he learned that cold tires are not to be filled up with air. When I pushed him for why this was important (I never really thought about this before) he insisted that it was because once the car starts to ride along the road, the tires become warmer and the pressure in the tires increases and causes the tire to blow out. When I began to think through their idea in my mind out loud, Juan assured me that indeed it is better to fill car tires when the tires are not cold.

Personally, I have never been excited by cars beyond learning to drive one so I can get where I want to go independently. That is not totally true: I also know how to change a flat tire, change the oil (sort of), put gas in the gas tank and water in the place where you are suppose to put water—my car knowledge really shines here—but I have never really thought it fun to sit in a classroom and theorize about cars for an hour, or squirt guns for that matter. I just wanted to stress at this point that I intentionally chose the word "theorize" to use with my students because, despite the informality of the process in the course of everyday events, that is in fact what they are doing: They are creating valid scientific theories which they drawn upon later in the day or perhaps later in life to work through particular situations. I have to admit that theorizing about cooking is not my favorite activity either, but to me its actually fun, and it is a ton more fun than thinking about cars. Theorizing about cooking is something to which I can relate, something in which I have invested some time. I neither build, nor fix cars.

I wondered to myself how Becky, Tammy, Maria, and Sarah felt about cars. I knew that I was stereotyping gender roles by this thought, but I was concerned that Sol and Juan were controlling the conversation, especially since Sol and Juan were the only students in the group to explain to me the group's thinking behind the squirt gun and the car tires. Also, it was only Sol and Juan who assured me that what they said about cars was, in fact, "correct." So, I asked the group if everyone really thought about cars in the ways that Sol and Juan presented to me. As it turns out, the car tire was Becky's idea; she spent many hours working on her own cars during

the past "30-something" years. I find this interesting because the car tire was Becky's idea but Sol presented it with Juan's support. Becky said nothing. Maria, Sarah, and Tammy said that it was okay that their group talked about cars because even though these were not their own ideas, it was interesting, and besides, they both drove cars everyday to work. I guess I am still bothered by this comment. How can I help the groups discuss ideas that are meaningful to everyone. I think car tires are interesting to the extent that I drive a car too and I fill up the tires with air too, but I do not think that it would make my theorizing about gas relationships any more personal or intuitive. In retrospect, I wonder if this happened to people in the other groups too in ways which weren't as obvious as the car example was to me (For instance, with cooking). I think this raises several important issues in using lived experiences for revisioning science. First, it stresses the importance of paying close attention to group dynamics. Why was it that Becky's group did not talk about the rice, or why was it that Becky did not present the car tire idea? Second, what if the students or the teacher cannot connect to the lived experiences of other members of the class? I do not think that these issues place this kind of thinking at an impasse. Thinking harder about the importance of lived experiences in science class does not mean that we accept all lived experience unproblematically. We can value all lived experience as a way to rethink science and our relationship with science. Just like Dr. Phillips—we valued his lived experiences in our class and in so doing we were able to articulate why we felt certain ways in science. Of course this becomes a much more delicate project when it is our lives we are talking about in class. Then Becky informed me that they also thought about cooking rice, but heard that another group was going to make spaghetti, and that they wanted to do something different.

It seemed that the students in their small groups were able to relate to each others experiences with the gas laws, to some degree, and in many of the instances were able to construct new knowledge together about the ways in which personal understanding of the gas behaviors have become an integral part of everyday life. However, in some instances, I think that the opposite was the case. I know I have to think harder about how to value lived

experiences critically. Since we ran out of time this class period, I wanted to start the next class with a large group discussion for three reasons. First, I wanted the students to think more about their own understandings and the understandings of their fellow students. I wanted the class to create a set of shared understandings about the gas relationships so that as individuals in the class we could begin to reformulate and rethink our own understandings from the standpoints of the individuals who made up our class. For me, I wanted to learn from my students more about how they were naming these relationships in their own lives: I learned the gas laws through the language and imagery of western science, and I needed help rethinking these laws from experiences a part from, yet apart of, my own experiences.

Second, I also wanted to make public students personal experiences with gases. I believed that this would create room in our classroom discourse for the political standpoints that science is not monolithic, unchanging or static—that there is a need for a counternarrative in science with new visions and desires for science and which is contextually dependent on cultural differences and gender issues. Politicizing the master narrative of science, I felt would be important when we looked at the western science formulation from an historical perspective. It would allow us to build not only an understanding of their knowledge, but also a critique of their knowledge. For example, a traditional look at the gas laws involves studying the relationships between temperature, pressure, volume, and amount through abstract pieces of lab equipment such as Boyle's J-tube. What would our understandings of the same events have to say to western science? Our events and stories are neither as neatly nor as rigorously designed. We cannot, for instance, vary only two parameters (i.e. temperature and volume) when we cook or when we drive. Our ideas and explorations in science were messier, just like Laura Bassi's work in the eighteenth century was messier. Third, I also wanted to create a shared foundation from which to think about the gas laws: I wanted to help facilitate a common understanding of the gas laws based on our experiences as people with multiple and complex identities (not just the white male middle class person in us). Later on in the semester we were going to think about how knowledge of the gas laws can be used to calculate reactant or product amounts in various

common reaction and we needed a common base on which to begin to do such work. We could use the understanding presented in the book—it was certainly the acceptable approach and a common formulation from which to engage in such work, but I was weary about renaming our experiences with the experiences of the dead wealthy male chemists who only did chemistry as charity. I was weary about placing our experiences as secondary to science. These activities would allow us to emphasize how knowing and doing science is wrapped up in our relationship with science. By using our relationships as raced, classed and gendered people, we could begin to reinvent our relationships with science—new relationships which did not centralize western science.

Thursday night

Gas laws Phase III - Sharing our personal experiences

Rita and Gloria started the discussion Thursday night with their ideas about how a whoopee cushion works. Before they shared their theories, I suggested that each group present their demonstration or story to the class, so that the rest of us could write our own ideas about temperature, pressure, volume, and amount in our journals. Rita then told us that they had been thinking about her son's whoopee cushion. At that point, I asked Rita and Gloria to wait for a few minutes while the class took some time to reflect on their own ideas about the whoopee cushion in their journals. After a few minutes the following conversation ensued.

Rita: This is my son's whoopee cushion. Gloria and I thought that we kind of understood the relationship between pressure, amount, and volume of a gas by this toy. I think even my son knows. Well anybody whose seen one of these before knows that when you sit on it, the pressure forces the air out of the hole.

Kim: (laughing) Are you going to demonstrate?

Gloria, who looked a bit embarrassed, put the whoopee cushion on the table in the front of the room and pressed down with her hands and it produced a "fart" sound. Most of the students and I laughed.

Kim: Aren't you suppose to sit on it?

Rita: (appearing uncomfortable) Yah, but I don't want to.

Gloria: (quickly volunteers) I don't either.

Angie: (in an attempt to displace Rita's and Gloria's visible discomfort) Does anybody want to demonstrate for us?

No one volunteered to sit on the whoopee cushion. Because I did not want to force the issue, I told Rita and Gloria that I would sit on it. As most of the class sat giggling, and apparently happy that they were "off the hook," I put the whoopee cushion on a chair in the front of the room and sat down. "Thbbbbbbbbbbbbbbbt." After I sat on the cushion (which I have to admit was slightly embarrassing), Gloria explained to the class that when I sat on the cushion, the pressure forced the air to leave the cushion, and so they knew that when the pressure increased, the volume of the cushion decreased. Although the idea that an increase in pressure results in a decrease in volume in a closed system (Boyle's Law) is "scientifically accurate", their system was not closed: The amount of their gas was changing (leaving the cushion) and so it appeared that their volume was decreasing, when it was only being displaced. At this point I felt a certain dilemma because I did not want to tell them that their experience was wrong, because in fact, it was not. It was just different, and more complex, than the system that Boyle used to develop his law.

Before their story was opened to class discussion, Rita wanted to share with the class another theory related to the whoopee cushion that they developed because they were not really sure which way to explain the cushion. She then told the class that they also noticed that when someone sat on the cushion, the air—which was the gas—was forced out of the cushion. That is why there was an obnoxious sound associated with cushion. This fact they found confusing because it worked against their pressure-volume theory they just shared with

the class. Then after apologizing to the class for not really knowing what they were talking about, they opened the floor for discussion.

Rita and Gloria were typical "good" students; they both read the text book and solve the problems in the chapter even though this was not a required activity in the course. I wondered if sometime between Tuesday and Thursday they looked at the book to make sure that the explanation they developed about gas behavior was "correct". In their small group discussion on Tuesday they decided that they could explain a relationship between pressure and amount: As pressure increases, amount decreases. In the book, the scientific explanation in the form of Avagadro's law states just the opposite: When amount increases, pressure also increases. I wondered if they read this idea, and decided that they could not present their original theory to the class because it suggested something altogether different than the book. I also wondered if they worked through the various gas laws in an attempt to find a place where their ideas fit, found Boyle's law and noticed that he suggested pressure and volume are inversely proportional and connected that to their system, brushing over the fact that the parameters of their system were different. I wondered if this is why they presented the ideas that they did. Although these thoughts were distressing it was comforting to see that they did not totally accept Boyle's ideas for their system. They seemed to see that there were problems inherent to their pressure - volume relationship they were trying to share with the class (and I think it was their original theorizing about amount and pressure which lead them to think about particular problems with associating the events of the whoopee cushion with Boyle's Law).

Bill immediately picked up their discrepancies, and suggested to Gloria and Rita, that their questions about their theories were indeed warranted because when "Boyle talked about pressure and volume he was talking about the times when only those two variables were changing, and in the whoopee cushion, you had been allowing the amount to change too and so you really could not say that pressure and volume varied in relationship to each other in the whoopee cushion." I was afraid here that Gloria and Rita and their ideas might have been

silenced, shut down, and placed as secondary to the canon and laws of Bill and of western science. Furthermore, the canon of western science had been explicitly invoked for the first time since we began the "gas laws" assignment. Bill mentioned Boyle's law, something I hoped to put off until we had a theoretical basis for critiquing it—a theoretical basis built with our lived experiences.

Maggie then raised her hand, and disagreed with Bill by saying that it was true that the amount was changing, but you could not say that there was "no relationship between pressure and volume" because there was a relationship, just "different than what Boyle was probably getting at in his law." For me, Maggie's comment, although bothersome because she too invokes the authority of western science, was important because what I had not seen was that Bill, although correct, was not correct. The volume and pressure varied with one another but in ways different from the canonical understanding and it took the perseverance of at least one student to help me see that. For the class, Maggie's statement was helpful in highlighting that the complexity of an experiment might change how a relationship gets interpreted. Although I do not think that the whoopee cushion experiment helped us to come up with any gas law relationship resembling the formal canon of science⁴⁴, we were able to begin to make some sense about how pressure, volume, and amount can influence each other in a more complex environment. Furthermore we were making sense of gas behavior, without relying on the canonically accepted gas laws, although, as I found out, it is nearly impossible to keep the canonically accepted gas laws, out of the discussion⁴⁵.

Maggie, Lisa, and Holia volunteered to go next: Maggie talked, Lisa wrote on the board, and Holia put the popcorn popper together and began to make popcorn. Maggie shared with the class that "there is water in the corn kernel, and when the kernel heats, the water

⁴⁴Its was an startling insight for me when I realized that was what I was expecting them to do! I was expecting them to derive the western science gas laws. In retrospect, this seems sort of contradictory.

⁴⁵I had been using all my attention to make sense of what the students were saying, I forgot to share with them the story of Laura Bassi. That would have to wait.

heats causing it to put pressure on the inside walls of the kernel." Lisa wrote on the board, "increase in temperature causes an increase in pressure." She then drew a kernel of popcorn with water pushing at the inside walls [refer to Figure 9.1].

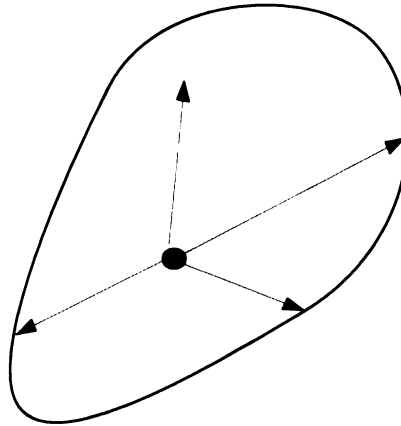


Figure 9.1 Pressure Inside a Popcorn Kernel

Mark P., who had not been in class the day before, and so was not part of any of the groups, suggested that he thought that something different was happening: "When you heat popcorn kernels, their size increases because they pop!" Mark P. was arguing that increasing the temperature meant increasing the size (volume), not only increasing the pressure⁴⁶:

Mark P.: I have a question.

Angie: Okay.

Mark P.: When you heat popcorn kernels, their size increases because they pop. So how can you say that only pressure increases?

Angie: So, Mark, you are saying that the heat causes the popcorn to pop, thereby increasing the volume of the popcorn, and Maggie you and your groups is saying the pressure increases.

Can we figure out what is happening?

⁴⁶The problem of gases versus nongasses (that is, solids or liquids) is a recurring one in this class on the *gas* laws, most likely because it is not often in our lived experiences where we deal with isolated gases.

- Maggie:** Well size does increase, but later. I am only saying that the pressure increases first. Anyway, popcorn is not a gas, but the water is.
- Mark:** Oh. (He pauses as if he is thinking about how to respond) But the water does not start off as a gas either!
- Linda:** Well even though they might not be gases, I can see a connection: The heat causes the water to boil and so it pushes on the kernel. That's the increase in pressure. The pressure builds up and causes the popcorn to pop and so the size increases too. So, they both happen (Her statement seemed to be made to find some scientific common ground, but also to soothe the conflict brewing).
- Angie:** Who wants to respond to Linda's theory?
- Becky:** I just have a question. So the heat causes the pressure and the volume to increase?
- Angie:** Who can answer Becky's question?
- Lisa:** Yah, I guess it does. We didn't think of it that way before but it makes sense.
- Bill:** But not at the same time.
- Angie:** What do you mean, not at the same time?
- Bill:** Well once the popcorn pops, the pressure is released and the popcorn increases in size.
- Angie:** Who can respond to Bill's idea?
- Maggie:** (with frustration) Well that kind of what I was saying before: first the pressure increases, then it causes it to pop.
- Angie:** What happens when it pops? The popcorn increases in size, but what about the water vapor? Keep in mind we are thinking about gases. [pause] Maria, do you have any ideas?
- Maria:** No.
- Angie:** Well, where do you think the water vapor goes?
- Maria:** Into the air. I don't know.

I was happy with the way our discussion around this group's ideas was developing. Even though the popcorn was not a gas as Maggie pointed out, it provided a context for a very interesting discussion about temperature, pressure, and volume and the complex relationships between the three characteristics. I felt that the students were learning how these concepts

worked together and how they caused other related concepts to enter the picture, through talking about their own experiences rather than thinking about the formal gas laws. I also thought that their experiences provided for a more complex understanding than the formal gas laws would have allowed: We did not have controllable closed systems: We could not vary only pressure and temperature without considering changes in volume. Had we studied only the gas laws as they are formally presented by western science, had we studied the gas laws in the ways in which I had been taught, we might not have thought about how a complete system shapes what actually happens and the causes and effects of such happenings.

As Linda, Bill, Tim, Kim, and Rico moved up to the front table to make tea for the class, Holia passed around the popcorn that she made during the previous discussion. Because they had set a tea kettle on the hot plate earlier in class, when it was their turn to share their ideas with the class the water was nearly boiling. Linda started off the conversation by directing the students attention to the boiling water in the tea kettle and asking them to write down what they expected to hear once the water actually boiled. Kim stood ready at the board to write down the ideas shared by the class. Bill then jumped into the conversation and suggested that the whistle we would hear from the tea kettle was caused by the gas of the boiling water escaping from the pan. He then suggested that the heating of the water caused the water to boil and to increase in volume. Therefore it needed more room than what was in the kettle. Rico added that you heard the whistle because all of the gas was trying to escape through the tiny hole, and that there was also probably an increase in pressure because all of the gas wanted to get out through the little opening.

I then jumped into their conversation by asking the rest of the students in the class about the ideas that they wrote in their journals. Both Becky and Mark P. volunteered that the tea kettle, because it was the whistling kind, would whistle. When asked why, Mark P. volunteered that the whistling would be the result of the boiled water escaping through the kettle spout, just as Linda explained. Becky concurred. When I asked her to expand on her reasoning based on the four concepts of temperature, pressure, volume, and amount, she suggested

that when the water was heated, it boiled, and changed to gas. This gas took up more room than the water and needed more room than what was inside the kettle, and so left through the kettle spout. Sol then volunteered that this was obviously what was happening because you "could see the steam coming out of the [kettle] arm."

Kim, another group member, then joined in the conversation for the first time by explaining to the class that group had one more point to make. She said that they considered cooking spaghetti, but it was too much work, so they were going to do something else. She then moved back to her desk, pulled out a mug and a tea bag, walked back up to the tea kettle and proceeded to make tea. As she dipped the tea bag into the water, she shared with the class, that if you observe the tea bag in the water you would be able to see that the color from the tea spread rapidly in the water. She told us it was because the water was hot. She then asked the class to raise their hands once they began to smell the tea.

I have to admit I was a bit confused by what she was trying to share with the class. I guessed that Kim was attempting to demonstrate empirically the theory that Gloria shared the day earlier about colored gases and solutions—she was trying to demonstrate how quickly a hot solution moves, then how quickly a gas moves. I was unsure of the connection that she was trying to draw between her experiment and the gas laws, so I let her continue with her demonstration.

A few students near the tea kettle raised their hands and said that they could smell the tea (it was raspberry tea). None of the people who were farthest away could ever really smell the tea, including me. Kim then suggested to the group that the reason the people in the front of the room could smell the tea so fast was because "tea gases" require more room and "so they begin to fill up our room, not just the tea cup." As I thought about Kim's insight, Maria raised her hand to ask a question. She wanted to know, why, "if the tea gases fill up the room, can only the people near the tea kettle smell the tea and not the rest of the class." Kim, nervously turned to me, and suggested that she did not know.

I opened this question up to the rest of the class, to learn more about what they thought. Linda, who had been standing by the tea kettle, volunteered that it "had to do with diffusion." When I asked her what she meant by diffusion, she suggested that as the gas particles moved about, they spread out, and so there wasn't enough tea particles near each other to make a smell. Bill quickly added that this was the reason why people near the kettle could smell the tea—"the particles had not spread out enough yet to fill up the room."

At this point, I decided to bring the conversation about diffusion back to the gas laws. I was not really concerned with constructing a definition of diffusion as much so I wanted to help the students to construct ideas about the gas laws. So, I asked the class to take a few moments to write their ideas of how the spreading of the tea odor related to the relationships between temperature, pressure, amount, and volume.

After a few moments of silent writing, I asked if anyone wanted to share their ideas. Rita suggested that the increase in temperature caused the volume of the tea gas to increase, and that is why people in the classroom could smell the tea. I then asked if there was anybody who either had evidence for Rita's idea or who had a different idea. Juan then suggested that maybe we could not talk about increasing temperature because the "tea was not increasing in temperature, if anything because it was no longer sitting on the hot plate, it was starting to cool down." He then added he "had no idea how this related to the ideas we were supposed to think about." Maggie responded to this comment by suggesting that maybe the relationship we were thinking about here was related to something other than the four variables I restricted to the students to theorize about. She then argued that "because the tea is hot, some of it is boiling off, changing into a gas. Gases have more energy than liquids, so they can move farther and faster and take up more volume, and that is why we smelled the tea. "

I admit that at this point I was stumped. I did not know how to use the students experiences to think about the gas laws in this situation⁴⁷. Furthermore, Maggie was using some of the ideas from the Kinetic Theory of Gases which I introduced the previous class meeting, but they were ideas we had not yet taken the time to explore and find evidence or justification for, ideas I had no intention of using in this discussion. I decided that I would put this conversation on hold for now, that we would return to it later after we examined the gases more thoroughly and produced more information. We then moved onto the next group.

The last group to share their ideas was that of Sol, Juan, Tim, Maria, Sarah, Mark F., and Becky. When I called on their group to share their ideas, all seven of them got out of their chairs and walked to the front of the room, except Sol who walked out into the hall way with a bag. While Sol was out in the hallway, Sarah took a worn brown stuffed animal dog and set it on the table sitting at the front of the room.

Sol then entered the room with a high powered water gun. He told the class that while he was out in the hallway, he went to the water fountain and filled his gun with one cup of water. He then "pumped up" the gun for the rest of the class by successively pulling in and out at a rapid pace a piece of his gun which looked like a syringe handle. After about a minute he was ready. He then aimed his water gun at the stuffed dog and shot it and knocked it over with the stream of water.

Most of the students laughed hysterically, some rolled their eyes, and some said and did nothing. I suggested to the group that I thought their demonstration was violent even though they only aimed the gun at a stuffed dog. I said that I did not want to play a role in advocating violence to animals. Sol, quite defensively answered me by arguing that he was not promoting violence. He said that he squirts his own dog at home and his dog likes it. "It's a game." The Becky shared with us that they thought about cooking rice, but did not want to

⁴⁷This is complicated by the fact that at the time I was teaching the class, I still expected the students to start with their own ideas and end up with something which resembled Western science.

copy the other group that was going to make spaghetti. Not really knowing how to deal with this unexpected conflict (although I did know they were bringing in a squirt gun so I probably should have been more prepared), I pushed the conflict back under the surface by ignoring it and asking the class to write in their journals what they thought Sol needed to know about the relationships between pressure, volume, temperature, and amount in order to work his squirt gun.

When I asked for responses, Lisa volunteered and suggested that if you decrease the pressure, the volume increases. Technically, Lisa was correct, but I did not think she was thinking about that relationship the way it was intended by western science. When I asked her to explain what she meant, my suspicions were confirmed: "The amount of water leaving the gun increased as the pressure in the gun went down." I then opened her comment up to class discussion:

Angie: Who would like to respond to Lisa comment? Gloria?

Gloria: I don't know. I am not sure how that squirt gun works.

Angie: Did Lisa's idea make sense to you?

Gloria: I don't know.

Angie: Just think about her idea for a second.

Gloria: No, well, uhm, yes. The pressure made the water squirt out. I don't think the gun would have worked unless [he put] pressure in there to begin with.

Angie: So the pressure made the water squirt out? Then, when the pressure decreased, what happens? Rico?

Rico: Eh, yes, the pressure had to decrease when the water, eh, the water, the pressure forces the water out of the gun.

Angie: Bill?

Bill: It seems to me it's just the opposite. Sol initially increased the pressure in the gun. We are talking about gases. When Sol pressurized the gun, he was increasing the pressure on the water, but pushing more air into the water compartment. So actually what is happening is the amount of air is increasing and that is causing the pressure to increase.

Angie: Oh wow, I can see the confusion now. Lisa, you were thinking about the amount of water leaving the gun as increasing. You were talking about the liquid weren't you?

Lisa: Yes.

Angie: Oh wow. Okay. Lets think about gases. Go back to what Sol was doing to put pressure in his gun. What are the gases involved? Anyone?

Bill: Its air.

Angie: Okay, lets think about the air. This is confusing isn't it?

At this point I asked Sol to repressurize his squirt gun to show us more carefully what he was doing. Sol then refilled his gun with water, pressurized the gun, all the while explaining to the class the manual steps involved. I was not really understanding this example myself until now because I too was confused as to how that squirt gun worked. I then asked the class to spend more time writing in their journals about what they thought Sol needed to know to use his squirt gun. When I asked for responses, Bill suggested that Sol needed to know that adding more air into his gun would increase the pressure in the gun, and that it was the increase in pressure which allowed the water to shoot faster and farther. I asked Sol if this was true, and Sol agreed. I asked if anyone had questions for Sol. Mark P. responded by saying that he did not have a question, but that almost the same principle was the reason why if you shake a pop or beer can, they explode upon opening—pressure forces the liquid out. I then asked if there were any other questions or comments and suggested to the students that they think about this comment in their journal over the weekend. People seemed to be tired, and it was time for a break, so I suggested one.

Gas laws Phase IV -Attempting to make connections between our ideas and western Science

After our discussion of the groups' ideas of their experiences with pressure, volume, temperature, and amount of substance, I made available to the students some of the more traditional laboratory equipment used to illustrate the relationships in various gas laws in

class (in lab). This was demonstration equipment purchased by the department within the last few years for the sole purpose of helping students to visualize the gas law relationships, a topic which has traditionally been known in this department as being abstract and difficult for students to comprehend⁴⁸.

My reasons for bringing this lab equipment to the class discussion were two-fold. First, I wanted to help students draw connections between our ideas and ideas presented by western science and I wanted to validate students experiences in the context of western science. I believed we created some well formed, well grounded, and detailed ideas about the relationships between temperature, pressure, volume, and amount by exploring how we have encountered these relationships in our past experiences (and having to talk and write about and compare these experiences). As the teacher and a chemist, I was in a position to publicly accept or reject these experiences as part of or apart from science. I was aware that the decision to involve students in rethinking the gas laws with the aid of the "formal" lab equipment might serve to devalue their own experiences. The very act of following up our ideas with verification measures—although an act synonymous with "good" scientific practice—implies that original ideas required validation and context. I believed I might be facilitating ideas, beliefs, and actions in students which promoted the suppression of personal ideas, experiences, and voices in the name of official, non everyday laboratory equipment and language.

Secondly, I was also curious to learn if our own personal explorations would make our visit to "traditional science" and our participation in science less authoritarian. Would these experiences reaffirm the belief that personal experiences and understandings of the gas laws were not real science? Even if the students continued to perceive their experiences as science, would messing around with gadgets define their science for them? Would they define their own homebound work in terms of the gadgets and fancy jargon instead of re-defining the gadgets and the jargon in terms of their experiences? Would those of us who have learned to be alienated

⁴⁸This was stressed at a chemistry department meeting, 4/94

from mechanical gadgets (as many women have, including myself) handle and explain these gadgets with confidence? These questions made me nervous, but I went ahead with the activity anyway, rationalizing my actions by telling myself over and over that I just wanted the students to draw connections between their experiences and the formal practices and discourses of science.

Angie: Here is some equipment that we usually use in this class to present Boyle's Law, Charles' Law and Guy Lussac's Law⁴⁹. I have to admit that I think these pieces of lab equipment do not do as nice a job at explaining these gas relationships as your experiences have...

We will use these pieces of equipment to think about the gas laws as they are presented in our book, and make connections between our ideas and those ideas. Do people have questions?

The first piece of equipment [refer to Figures 9.2-9.4] was cold, intellectually and physically; the big shiny round metal ball which seemed to be the focal point (visually, anyway) and clearly screamed for attention had done its metallic, thermal conducting duties well as it sat in the cool air-conditioned science building. It had been neatly packed away in the CHEM 125 demonstration cabinet in a tight fitting white cardboard box. As I took the equipment out of the box, Lisa asked out loud, "What is it?" Not really knowing the best way to describe it myself, I suggested that she and any other students who wished could come up to the front table and look for themselves. Lisa, Linda, Sol, Bill, Becky, Rita, Gloria and Holia all walked toward the front of the room while the rest of the students stayed in their seats.

The metal ball was connected to a piece of thick plastic tubing. The tubing extended into a metal handle where there was a notch needed to let air in and out of the system. From the side of the plastic tubing extended a small thin rubber balloon. The accompanying directions to the demonstration read that first, air must be pumped into the system with a

⁴⁹As a class we had not formally talked about these formal laws before. I used the names of the laws because, at that point, I intended to use the demonstration equipment to draw connections between the students understandings of thermodynamics and western science. I also knew that many of the students were familiar with these names because I noticed that some students were looking through the gas laws chapter while they were working in groups during the previous class meeting.

bicycle pump until the thin rubber balloon inflated slightly. After removing the pump and ensuring the system is closed, the metal ball is to be dunked into a dry ice - acetone bath (-20°C). When the metal ball is submerged, the thin rubber balloon is to deflate (because the decrease in temperature, decreases the volume in a closed system). Then the metal ball is to be removed from the dry ice - acetone bath warmed to room temperature, then placed in a beaker of boiling water (100°C). The thin rubber balloon then inflates. This demonstrates Charles's Law: When temperature increases, volume increases as well or $T_1V_1 = k_b$ [refer to Figures 9.3 and 9.4].

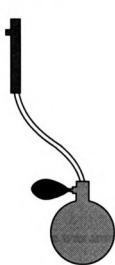


Figure 9.2
Apparatus Used to
Demonstrate Charles' Law

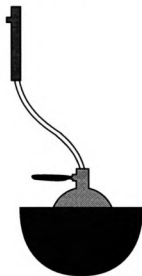


Figure 9.3
Apparatus Submerged
in Dry Ice Bath

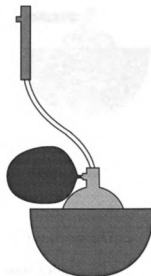


Figure 9.4
Apparatus Submerged
in Boiling Water Bath

The same equipment can also be used to demonstrate Gay-Lussac's Law, which relates pressure to temperature in an otherwise constant closed system ($P_1T_1 = k_b$). To do this, the opening to the thin rubber balloon is replaced with a pressure gauge, so that the volume of the system remains constant while the pressure varies. The same procedure is followed as with the previous demonstration except this time observations focus on the temperature of the metal ball and the pressure gauge, rather than the temperature of the metal ball and the size of the balloon. By immersing the metal ball in the dry ice - acetone bath, then in the boiling water

bath, it can be shown that the pressure decreases as temperature decreases, and the pressure increases as the temperature increases or $P_1 T_1 = k_b$ [refer to Figures 9.5–9.7].

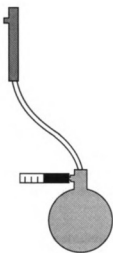


Figure 9.5
Apparatus used to
Demonstrate Gay Lussac's
Law

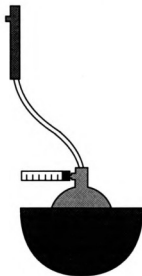


Figure 9.6
Apparatus Submerged
in Dry Ice Bath

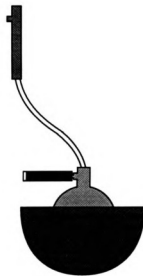


Figure 9.7
Apparatus Submerged
in Boiling Water Bath

There was another piece of equipment [refer to Figures 9.8–9.9], that consisted of a square piece of transparent plastic. Embedded in this plastic is a pressure gauge with a mechanical dial. Connected to this pressure gauge is a thick piece of plastic tubing which is connected to a syringe, also embedded in the square piece of plastic. The purpose of this piece of equipment is to illustrate that when the volume of a system increases, the pressure decreases and when the volume of a system decreases, the pressure increases or $\frac{P_1}{V_1} = k_b$ (Boyle's Law). Therefore by changing the volume of the system by either pushing the syringe handle in or pulling the syringe handle out, the pressure gauge would indicate the change in pressure within the closed system [refer to Figures 9.8–9.9].

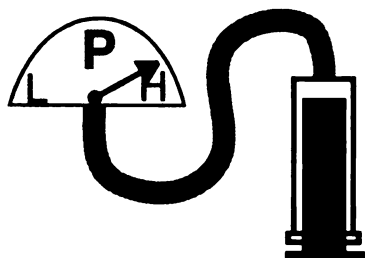


Figure 9.8
Syringe at High Pressure

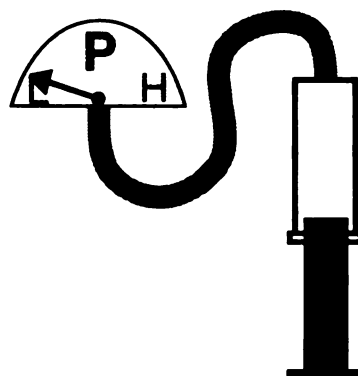


Figure 9.9
Syringe at Low Pressure

As the students began to pick up and muddle around with the equipment, I stood there for what seemed like an eternal moment, silenced by my own actions. Perhaps I was right when I thought previously that my choice to use this equipment was based on my own rationalization that it was important to draw connections between "personal" and "formal" scientific discourse and practices. Perhaps I was right when I thought previously that the only impact this activity would have would be to redefine students' understandings of science and the self in science. In the instant of this moment, I was reliving all of my interactions with a science I learned to imitate yet be otherized from. It wasn't that we could not handle or interpret these demonstrations, but merely what they represented: In all their exactness, of perfectly fitted, marked and measured intricate little pieces, lay the foundation of a science education I hoped to challenge in my teaching practice. In a culture where we have learned to define and diminish our personal lives in the shadow of the towering institution of science, how could our personal explorations of pressure, temperature, volume, and amount in the context of everyday activities stand up against the authority of a deeply embedded institution? Despite the thousands of images and voices screaming and moving through my whole being at that moment, I could not force myself to stop the classroom activity. I could not get myself to pick up all that equipment and throw it back in the cabinet, even though that is what I really wanted to do. It

was like I was strapped into a roller coaster cart already set in motion; I could not get off until the ride was over.

The students were talking among themselves about the equipment (primarily what the equipment was, not what it did or how it could be used to illustrate some of the relationships we explored earlier in the context of our lives). At the moment, I was finding the equipment rather confusing and abstract myself, even though I used it in the past (and admittedly not feeling comfortable then either). For me, the demonstrations did not help me to connect with the ideas represented in the gas relationships, except in the most formal and abstract ways: I understand that the demonstrations are highly visible representations of how changes in one variable can influence the dynamics of the system, but the demonstration itself did not "speak" to any of my own personal experiences. It is rare that I even come in contact with a metal ball which must be submerged into either boiling or freezing water!

Angie: Does anyone want to help me work these demonstrations?

[Holia and Linda, who are already standing around the equipment, volunteer]

We began with the Charles' Law demonstration required equipment [Figures 2, 3, and 4]. Holia, Linda and I worked together to set up the equipment. We borrowed Mark's bicycle pump and the college supplied everything else. After successfully setting up the needed equipment, I engaged the class in a discussion about our expectations once we immersed the metal ball in the dry ice - acetone bath:

Angie: This dry ice bath is very cold, about -20 or -30°C. If we submerge the metal ball in the bath, what do you think will happen to this little balloon?

Bill: The ball will decrease in temperature because the bath is cold, so the balloon will have to decrease in size.

Angie: Who would like to respond to Bill's idea?

[no one volunteers a response]

Angie: Does anybody agree or disagree with Bill?

Linda: I think Bill's right.

Angie: Why?

Linda: Well because, like he says, Charles's law says that when the temperature decreases, the volume decreases.

Angie: Do you want to dunk the ball in?

Holia: Okay

[the balloon in fact decreases]

Angie: Does this remind you of any of the earlier group projects?

[the student silence here feels like an eternity!!]

Angie: Go back and look in your journal. What are some of the ideas we talked about earlier?

Sol: Well, nobody did this experiment, but my group talked about how you are not supposed to fill car tires with air after you have been riding on the road for a while, that's the same thing.

Angie: What do you mean?

Sol: Well, I guess the air is a gas and it gets warmer when the tires has been rolling against the road for a while. It makes the air expand.

Angie: I see your connection. Do people see Sol's connection?

[a general yes nodding of heads from the class]

Angie: Who else remembers some of the ideas we talked about earlier?

Tammy: That one group made tea.

Angie: Okay, tell me more.

Tammy: (starting to sound nervous) Like what Sol said.

Angie: (persistent) Tell me what you mean.

Tammy: (pleading with her friend) Kim, help.

Kim: No. (pauses and looks at Tammy) Okay. When they heated the water for the tea, the heat made the water gas volume increase and so it came out through the tea pot spout.

We continued with the rest of the demonstration. I felt very uncomfortable; I wondered if I was facilitating the return of the science we created to the impersonal and abstract level. Although it seemed as if my students understood the gas law relationships inherent in these demonstrations, I felt the approach placed our personal experiences as secondary to "real

science." I felt that our experiences in the kitchen and elsewhere (most of the students are women who talked about cooking activities to explain the gas laws) were being replaced with laboratory experiences. I also think that I was more aware of those dynamics because as a woman who does more cooking and less of the mechanical fixing at home than she would like to admit, I felt a bit intimidated, at least uncomfortable using this abstract equipment to re-explain (to validate, as if personal experiences and theories of the world need to be validated by abstract lab equipment) my (and their) personal understandings of the gas laws. I wanted at this point to make these relationships between us in science and with science problematic with my students. I wanted somehow to begin to reposition ourselves within science.

Because I somehow felt distanced by our conversation and by the science content and process taking place, I retreated from facilitating a whole class conversation. Instead of doing the experiments with the students in front of the class, then following it with a discussion, as I began to do with the first piece of equipment, I changed my plan midstream. I encouraged them to work with each other in smaller groups, to play with the equipment and to explain to each other what they observed. Among the students there was talk about what they thought they saw and any obvious gas relationships. There was also talk among the students about the equipment itself: What was it? How did it work? There was also talk among some of the students about nonschool related stuff. I wonder if the nonschool talk seemed obvious to me because there was more people than equipment and they did not want to work in groups that were larger than normal or if it is because they were getting bored with pressure, volume, temperature and amount, or if they felt disconnected from these demonstrations.

After fifteen minutes I brought the class back together into a large group discussion. My intent was to talk about how the lab equipment demonstrated the formal gas relationships—I wanted to make sure that the use of the lab equipment did not remystify their understanding. I also wanted to express my discontent with my decision to use this equipment, so that if there were other students who found their experiences marginalized in science, as I had my own, by the use of the formal lab equipment, there would be a place for these feelings in class.

Angie: Who wants to share an idea about the gas laws related to these experiments?

Bill: Well, the syringe experiment shows that pressure and volume are inversely proportional.

Angie: Okay, what do you mean?

Bill: When you press the syringe in, the volume in the syringe decreases, and the pressure increases.

Angie: Okay, lets hear from some other people in response to Bill or something else.

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Linda: The experiment with the metal ball wasn't that clear to me. I understand how pressure and temperature are related, but I couldn't see how the experiment worked. Can you explain it?

Angie: Well, who has some thoughts related to Linda's question?

Gloria: This is just what I don't like about science. They always take ideas that are mostly understandable and explain them in ways which mean nothing to me. I would rather talk about popcorn than weird metal balls.

Sol: Its true, we do not use these things everyday, except maybe the syringe, so I don't think that they help that much.

[after Gloria and Sol shared their ideas many of the students are nodding or vocalizing their in agreement. Some students are laughing, I think at Sol's comment about the syringe].

Angie: This is very interesting to me. You know, when I got out this demonstration equipment for you to work with, I had this nervous feeling. That's because I was so happy with the ways you described the relationships between pressure, volume, temperature and amount with your own everyday experiences that I did not want to try and re-explain them with fancy lab equipment. So maybe I shouldn't have gotten this equipment out. Or maybe its a good thing because this gave a chance to talk about this. What do you think?

Sol: Who bought this equipment anyway?

Angie: The department.

[Most of the students laugh.]

Sol: Can't you tell them to buy something different?

Angie: I think I will mention something. Lets finish talking about the different gas relationships, but we will go back to our own experiments. Juan what do you think? Were you able to draw any connections between what the groups talked about earlier and these experiments?"

Juan: I can see how the metal ball worked, it was like filling the car tire with air. It does make more sense that way.

After Juan's comment, several other students echoed this previous when called on by suggesting that the formal gas laws (Boyle's, Charles', etc.) and the experiments performed to illustrate these laws were not very meaningful to them. They wondered out loud why the laws were useful if they were not realistic. We finished class that night with a discussion about the various gas relationships, comparing how we understood them in the contexts of our lives and with their formal presentation in western science. I told the class I wanted to write on the board some of the ideas that we developed, and then I would introduce some terms that connect their ideas back to the information in their text book.

As the students shared with me their ideas about what they had learned, I wrote them on the board. In the process, I organized them in a table [refer to Figure 9.10]. I wrote out their ideas with words. Next to the words, I wrote their examples as well as a mathematical formula. I had grouped the students ideas so that matched the accepted formulation of Boyle's , Charles's , Gay-Lussac's, and Avagadro's Law, and so I then defined their ideas by western science, by telling them the gas laws that they knew.

Relationship	Examples	Formula	Textbook connection
pressure increase, the volume decreases. Pressure decreases, volume increases	whoopee cushion	$P_1V_2=P_2V_1$	Boyle's Law not mentioned in text: Laura Bassi
Temperature increases, the volume increases. Temperature decreases, the volume decreases	tea pot, spaghetti, rice, popcorn, car tires	$T_1V_1=T_2V_2$	Charles Law; no one else mentioned in the text. Unable to locate any further useful historical info.
Temperature increases, pressure increases. Temperature decreases, pressure decreases.	Spaghetti, popcorn	$T_1P_1=T_2P_2$	Gay-Lussac's Law not mentioned in text: Josephine Gay-Lussac
Amount increases, the pressure increases. Amount decreases, pressure decreases	squirt gun	$n_1P_1=n_2P_2$	Avagadro's Law

Figure 9.10
Gas Law Relationships

After I did this I was not very happy because again I was afraid that the students' ideas might be perceived as secondary to western science. Even though we had used the complexities of our lives and hence our stories about gas laws to understand and critique science, I was afraid that this summing up activity would undermine all that we had done earlier. But, I did it because I was torn: Torn between valuing my students' lives, theories and critiques of science, and ensuring that they had the language and confidence to participate in the community of science. This leaves me wondering if an authentically inclusive science is possible.

After I finished grouping the students ideas, I then shared with them, that they, on their own, came up with the same idea that these historic chemists had been credited for and that they had done so in more authentic and realistic ways. I also told them that I thought their ideas were "better⁵⁰" than the chemists because they did not deny the complexity in the world.

⁵⁰I hate this term. Oh well.

I tried to share with them a brief history behind the development of these laws, which included the people who are not mentioned in their texts, either because their gender did not allow their work to be recognized, or because their gender or race did not allow them the opportunity to engage in such work at all. Just as I did in the gas laws during the spring semester, I shared with the students the story of Laura Bassi and how her work critical of Boyle's was ignored. Telling this story saddened me though because Bassi's work was ignored because she was a woman and because it did not deny complexity. Was I telling the students (and believing myself) that our work too would be ignored because of our existence as women, working class and minority people and because we also chose not to deny complexity?

I then told them the story of Gay-Lussac's wife and how she never received credit for her collaboration with her husband (and how historians note that over time Mr. Gay-Lussac's lab notebook handwriting changed so much, that in his later years that it was identical to his wife's!⁵¹ hmmm). I wanted to have time to have a discussion with the students about these stories, but we had already gone several minutes overtime and the students were becoming very restless (I cannot blame them at 9 p.m. on a Thursday night!). I knew this discussion would have to wait until Monday. I also knew that somehow I also needed to help the students draw connections between their theories and atomic and molecular theory. Maybe connections is not the right word: We needed to look more closely at these theories (ours and western sciences) and talk about why they are different and what they both mean for our lives in chemistry at GCC. I ended class by sharing with the students that we would take up these issues the following week. As we prepared to leave, I expressed my belief that there was one thing that they did much better than any of the people given credit for these laws:

...But, there is one thing that I think you did much better than the people given credit for these laws, these laws which you already knew even before this class

⁵¹"The tender sympathy subsisting between Gay-Lussac and his wife (Josephine, "Madame Gay-Lussac") during forty years controlled so completely their actions and even their habits as to extend even to their handwriting and in the end it was impossible to distinguish the manuscript of a memoir copied by Madame from the original as it proceeded from the hand of her famous husband" (Holmyard, 1931, p. 31)

just because of the things you do in your lives. You kept your ideas in context. For example, when we talked about the popcorn or when I talked with the small groups about making spaghetti or filling car tires with air, you were able to think about how not just two ideas went together, but more than two ideas. Like Boyle's experiment, he only talked about pressure and volume. Well, you all showed us first of all, how you already understood that relationship, how you did not need Boyle to tell it to you. But you also showed how unrealistic his work is. You showed us how we probably would encounter more complex situations, even in kitchen, then Boyle set up, and so how you need a more complex understandings. Its just like the story of Laura Bassi that I just shared with you briefly. She could not get Boyle's law to work in her lab because of the humidity in her lab. Yet, the chemistry community did not want to recognize the fact that situations are really complex because it messes up their neat little perfect laws. I think you all did a great job.

As I cleaned up after class, I wondered what messages my students left with. Did they leave with "Boyle's, Charles, Gay-Lussac, and Avagadro's Laws on their minds? Did they leave with a conceptual understanding of gas thermodynamics based on their lived experiences? Did they leave with the critique of western science because of the importance we placed on lived experiences? Did they leave with a new sense of self in science because we challenged the canon of western science from the standpoint of our lives? I ask these specific questions because these are the mixed, enlightening, empowering, yet troubling and oppressing ideas with which I left class.

CHAPTER 9

Don't you tell me whose science to learn! Reinventing (relationships with and in) science

In the last chapter I shared large pieces of two class sessions which highlighted my attempts to construct a feminist liberatory teaching and learning setting in chemistry. These class sessions were important because, as I wrote in Chapter 7, "Planning to teach the gas laws: Critically rereading personal experience", rereading my teaching and learning of chemistry with the help of my students changed my vision of feminist liberatory education. The series of lessons on the gas laws were one of my first real attempts to enact this new vision. The series of classes were also important to me because, as the students and I lived them out and as I reflected on them, my students taught me about the nature and purpose of feminist liberatory education in science as much, if not more than, I was helping them to learn chemistry. My students helped me to rethink both my understanding of gas thermodynamics and my own relationships with and in science. They helped me to embrace the notion of our lives as our theories for understanding, critiquing, and revisioning science. They helped me to fully acknowledge the political intent of my teaching. Finally, they taught me "the difference between education as the practice of freedom and education that merely strives to reinforce domination" (hooks, 1994, 4).

This chapter takes a closer look at the two classes that made up our study of the gas laws during the summer semester. This analysis reveals that my knowledge of science, the students, and feminist theory helped me to engage in a teaching practice that involved students in creating spaces in science which value the positional knowledge about and relationships in

science with which we bring to class. Many of the students were able to challenge traditional, taken-for-granted relationships with science and to create new knowledge in and about science from the standpoint of their own lives. Yet, as I hope to show in this chapter, this is a complex and uncertain process because each of us brings different lived experiences and different subjectivities to making sense of science and of our relationships with science. This is also particularly difficult and problematic because some of our lived experiences are validated by science and some are not. Some of our lived experiences reinforce the kinds of oppression I hope this teaching works against, and some are silenced or reshaped in their retelling.

In this chapter I also suggest that challenging traditional relationships in science allows moving relationships to come alive, and that living moving relationships are critical to creating a feminist liberatory science teaching and learning setting because they allow for and require, a new, different, and moving body of knowledge in science to be constructed in science class. This would be a body of knowledge where our lives become our theories. This reflection on the relationships that teachers and students have with each other and with science in class is different than posited in other social constructivist literature because of the critical stance the participants take to creating new relationships and new knowledge.

Therefore, in this chapter, I will explore the series of lessons previously presented in three ways. First, I walk through the story to point out how my knowledge of positionality and its connection to feminist liberatory education guided my teaching thoughts and actions. Secondly, I look for aspects of these lessons which are characteristic of feminist liberatory education (as well as what is not). In this second section, I look at how we (teacher and students) used our lived experiences as our knowledge in science, as locations from which to critique the knowledge base of western science, and from which to redefine our relationships with and in science. Thirdly, I join the previous two strands of thinking together by sharing what have I learned about teaching-researching, students, and science positionality and feminist liberatory education as a result of teaching the gas laws in the summer.

Gas laws Phase I - Beginning to think about gases

In this phase, my intent was to prepare the students ready to think about the gas laws. To do this we would generate a set of common ideas about gases and then explore and theorize about the gas laws and our own lives. I felt like we needed a common thread from which to make meaning across our lived experiences and personal connections to gases.

I was uncomfortable with my teaching in this first phase for several reasons. First, I chose to engage the students in thinking about gases through an historical exploration which problematized how the idea of gases was constructed. I believed that this was different than the spring because I started (rather than ended) with a problematic story. Furthermore, my intent was not to get the students to a prescribed piece of knowledge as I did in the spring (Boyle or Gay-Lussac, for example) but for the students to work through some idea about gases and how the evidence available for how these ideas could support multiple theories. In theory, I thought this approach would start us on our own study of gases with a questioning and critical mind. In practice I realized our learning in this phase was based on ideas prescribed by western science. The very fact that we were talking about gases, that we were "socially constructing" this knowledge on a set of experiences conducted by two wealthy European male scientists, rather than our lives, and that we were critiquing that knowledge with philosophical elements which were not necessarily rooted in our lives, made me feel as though these ideas were completely imposed on the students. While I taught this class in the summer I felt as though I had reinforced traditional relationships in science, even though I had presented the idea of gases problematically. I felt as though I was repeating what I considered "mistakes" in feminist teaching that I had made when I had taught the gas laws in the spring.

In this "first phase" of teaching and learning about gases, I needed to reacquaint the students with the concept of the gaseous state, as well as with various terms used to describe the thermodynamics of gases (pressure, volume, temperature, amount). I considered this portion of the unit an introduction, as if getting to know the characters in a play—not just their names

(scientific definitions), but who they really are and how they came to be (a social, cultural, and historical examination of their existence). Despite my best intentions to contextualize critically the knowledge base of chemistry as it pertains to the gaseous state, I started this unit with a raw feeling in my gut. I felt I had already "violated" one of the most passionately expressed tenants of feminist education—starting with the lives of the students (Fine and McPherson, 1993; Maher and Tetreault, 1994). I knew I had to teach about gases. I knew I had to teach the gas laws. I knew that most of my students expressed discontent with chemistry, a discontent which helped them believe that chemistry was not a part of their lives or their dreams. No one in my chemistry class had expressed an overt interest in learning about the gaseous state, never mind the gas laws. I knew that this was going to be a forced learning experience, no matter how much I believed I could help the students use their experience to build their knowledges and a critique of those knowledges.

I started our discussion about gases by sharing with the students the story (an "historical" account) of the "discovery" of the gaseous state. I told the students about van Helmont's desire to prove the Greek's wrong, his methods of analysis, his results and conclusions. I then shared with them the story about how Boyle conducted the same set of experiments, during the same time frame, in the same continent (although a different country). I asked the students to pick the story apart, to determine what information was important, what it had to say about gases, and to think about why the same set of data could be used to construct very different conclusions.

In reflecting on this phase of the lesson with the knowledge of what happened later, I recognize that some of the students' efforts were more helpful in our attempts to construct and recognize moving relationships in science class than I had originally believed. This conversation helped some of us to challenge and change science because we, in ways more subtle than our later efforts, began to make explicit and even problematic the unspoken boundaries of our taken-for-granted relationships with science. For example, when we were talking about why van Helmont and Boyle used their evidence to support different theories, Rita responded

to Sol's claim that "maybe his results were not exactly the same" by suggesting that "we really don't know what they each did." This comment was important because it questioned (I think) a tradition of accepting that recorded science work contains are pertinent and appropriate information such that it can be repeated. Rita was suggesting that this might not be the case. I chose to play with Rita's comment in order to challenge the class, by saying that perhaps we did not really know what each did because their stories were recorded with a slant—a bias. Bill was the only person in the class who responded—outside of his comments there was noticeable silence. Although not all of the students participated in this part of the conversation, in retrospect, I can see how this portion of class was setting the stage for some of us to challenge particular relationships because I began to push certain boundaries of our relationships in science class.

With this framework, a closer look at the introduction to gases can be read as an exploration into several (although not all) defining boundaries in relationships with science. In this introduction, I began to make explicit to the students the pieces which define our relationships in science; the pieces which are held in powerful positions—the knowledge, and the pieces which are buried deep in the institution of science—the social and political structures which made that knowledge possible. By introducing the gaseous state through an historical perspective on the work of van Helmont, we explored the historical, social and cultural influences on the construction and interpretation of that knowledge. I pushed the students to think about how those in power in science (scientists, media, funding agencies) had worked hard to make science appear disconnected from its social and cultural heritage, making it appear abstract and infallible, at least not subject to the weakness of human emotions and values. By exploring that aspect of the knowledge base of which we were about to learn, I was trying to help the students to critically peer over, and even "transgress" (hooks, 1994) the falsely constructed boundaries in science education.

For example, when I introduced the concept of gases through the work of van Helmont and of Boyle, I simultaneously introduced the notion that all scientific work, including

"rigorous" work is subject to the wants, needs and desires of its creators. Van Helmont and Boyle, as I shared with my students, conducted similar experiments and obtained similar results, yet the two scientists produced conflicting interpretations of the results.

By exploring this conflict with the students I believed that Rita, Linda and Bill began to make problematic the notion that one could uncritically accept ideas about gases. This occurred in two ways in the course of this segment of our discussion. First, by asking the students to look at van Helmont's and Boyle's data to determine what they thought was important about gases, I had required that the students work from the premise that there exists multiple interpretations for experimental data. This made possible the recognition that data collection and interpretation is contextually dependent. Second, the discussion about how everyone brings their own "slant" or personal bias to a situation—slants which can be influenced by sources of funding and other power wielding devices—implied that science must be understood through whatever slant it was constructed. This notion of personal bias was evident when Bill and Linda (with my insistence) questioned the motives for large and controlling funding agencies (government):

Angie: Yah, that's true. All I know is what I read, and that probably, well not probably, it does, have its own slant on the story. But think about it. That's a really good point. The stories that I have read have their own slant on the issue, so couldn't the scientists have their own slant. Who wants to respond to that idea?

Bill: Its what we have been saying all along in this class, that there are political reasons that control science.

Angie: Are you saying that there are political reasons controlling van Helmont's and Boyle's science?

[some students laugh at my question.]

Bill: I don't know, I wasn't there and I have not read anything about it, but it could be the case. You don't know who they were working for. Didn't a lot of scientists work for the nobility?

Angie: Well I think a lot **were** the nobility, but I bet that some worked for kings and queens, just like scientists today work for our government. Who would like to respond to that idea? [pause, then with growing frustration] No one? Come on, I know some one has to have an idea, or at least a question.

[silence]

Angie: Doesn't that idea seem sort of heretical? What do people think? [pause]
Linda, what do you think?

Linda: I work for the government, so I know what kind of pressure that can be. I never thought about it that way. I don't know.

This small segment of classroom discussion also illustrates that through our discussion on the nature of gases I began to push the students thinking about the boundaries of the objective nature of knowledge. When Bill and Linda questioned the role of the nobility or the government in defining the kinds of science which can happen, or the kinds of results that are needed, the question of the subjective nature of knowledge was subtly posed. By introducing this conflict, the authority of science often assumed to be natural became unsettling and in many ways unacceptable.

This particular transgression (although not grounded so much in our lives as in the philosophy of science) was important because in traditional science and education circles, and most certainly in general society through the media, the abstract and objective nature of science imposes an authoritarian stance in its relationships with others. This can be seen in court where empirical and theoretical scientific evidence ("expert" testimonies, finger printing) is rarely challenged as subjective, unreliable, or "without character," where as the testimony of a value-laden individual—for example, a prostitute who witnessed a drug trade or a single mother who was brutally raped—is often called into question because the witnesses, the prostitute or the single mother, "lack character" or are simply unreliable. In health care centers (at least the office that my grandfather⁵² visits), many patients' stories of their symptoms and personal diagnoses are devalued against the judgment of the medical

⁵²This may not be the case at all medical institutions. My grandfather never made it past the eighth grade. He was a bar tender then custodian for the local school in a working class town for many many years until his health forced him to retire. In institutions where more educated and maybe more wealthy patients are treated, there may in fact be a different standard. Although, I can say that in my own experience, as an educated woman, I have encountered situations very similar to my grandfather, most recently last fall where the doctor refused to listen to my symptoms, telling me that it was just a cold, until I was very sick from a thyroid infection.

professional. Granted, the medical professionals have devoted a great deal of their life to studying the human body; these experiences should not be devalued. But, as human beings, we each live with our own bodies, learning to recognize its idiosyncrasies, and accordingly, are quite able to diagnose when it just does not feel right. By calling into question the foundation for this authority of science, whether it is in courts, in health care centers, in schools, or in personal lives, we can begin to transgress that border of our relationship with science.

Other boundaries I pushed the students to explore critically in this short episode in class are those which define who can do science. Through casting the construct of gases through an historical slant, I had asked the students to explore who was allowed to do science and who was allowed to have their knowledge valued in science. By problematizing the notion that we were only talking about two wealthy European men and by wondering out loud (although not knowing) if others had worked (wanted to work) in this area, I questioned the assumed hierarchy for participation in science. Although student responses did not go beyond the fact that "well, at that time society did not allow women and minorities to go into science" at least the topic was raised. I think that because our conversation was located in science, philosophy and my questions at this point (and not our lives as was the case with many of the oral histories conversations or later in this class period with gas laws) the students probably could not really see or work beyond this semi-uncritical critique (knowing science is bias and that society was unfair, but so what?) to either become critical or to envision a science of the future. In this part of class, I do not think we really challenged any relationships we personally have in science class. We only challenged theoretical relationships (yes, science is unfair, but that doesn't bother me). However, I do think that we began to explicitly delineate the boundaries of science—boundaries which can be used in power relationships to define our science and our lives with and in science.

Phase II - exploring personal experiences with gases

Phase II was very much different than Phase I which was very teacher driven. I shared some historical stories and pushed the students analysis of the stories in the ways I thought were important. The conversation was awkward and slow. During phase two of teaching and learning about gases, I asked the students to share with their groups personal experiences and knowledge of the relationships between pressure, volume, temperature, and amount. This activity (which lasted about an hour) was structured insofar as I had prescribed for the students that they work in groups in order to think about how they understood the relationships between pressure, volume, temperature, and amount in their lives, and to construct relationships between the variables based on their lived experiences. I also prescribed for the students that at the end of the hour I expected them to have thought through the relationships between some of the four variables, and that they would be expected to have a manageable plan for sharing their ideas with the class.

My intentions for structuring the activity this way were twofold. First, I wanted to help the students construct a setting where they could begin to make their own science theories from the standpoint of their lived experiences. Second, I wanted the students to experience the social construction of knowledge. I thought that these combined ideas would give us a chance to bring our full positionalities into our relationship with science, to interrogate traditional relationships with science so that we could create new ones.

Lived Experiences

A critical piece to my feminist liberatory agenda was to help students reconstruct their relationships with science through challenging the norms which structure those relationships. Through sharing their personal theories of the gas laws constructed through a life time of

experiences, many of the students began to use their own lived experiences to define science, both in practice and in content. Because of the kinds of stories shared and the group dynamics, the ways in which this influenced relationships were different. The students' stories took many forms and encompassed many kinds of activities not usually discussed in science class or even considered to be scientific. For example, Linda talked about making spaghetti; Bill talked about cooking rice; Maggie, Lisa, and Holia talked about baking bread and making popcorn; Rita and Gloria talked about whoopee cushions; Juan, Sol, and Becky talked about squirt guns and car tires. As the teacher, I wanted to hear all of the students' stories, why they chose these stories, what the stories meant for each of the students in terms of their definition of science and their relationship with science, and how they managed to learn and work in their own situations. These stories were important to me because they provided information about the kinds of experiences that the students have had (and have not had) with the gas laws, how they interpreted the relationships between pressure, volume, temperature, and amount, and most importantly, how they used their own lives to construct their own theories about the world. If I wanted to help my students struggle to define their own knowledge and their relationship with that knowledge on their own terms, then it was critical that I help the students work through their experiences without any more intrusion by western science⁵³.

In some cases, it appeared that students explored the relationships between pressure, volume, temperature, and amount based on what they had learned outside of class doing everyday activities. Linda's story about making spaghetti is a clear example. She shared with the group how an experience in the kitchen provided a knowledge base about gases and their physical properties. Yet because she had never defined this knowledge as science—it was "only common sense cooking"—it appeared that she was beginning to define her own knowledge of science. Because her own experience defined what was important to know in the

⁵³Western science was already a part of the conversation—we were using the terms gas laws, pressure, temperature, volume, etc.. We were deriving the gas laws. If that is not an intrusion by western science, I do not know what is!!

case of cooking spaghetti, and because that knowledge was contextualized with her values and views of the world, as well as with the complexities of everyday living, I also see this as a situation where Linda began to reinvent her relationship with science. This seemed to be a relationship that did not take for granted the authority of science over her own experiences. I believe this is critical in a liberatory science class because science for many women, is an oppressive experience because women have traditionally been marginalized in the process of defining science and defining ourselves. Women learn to view science and science teachers, not ourselves, as the authors of our experiences. Women often come to know the world in ways that are not always supported by traditional education and science processes.

It is harder to say how the other members in Linda's group—Kim and Rico—felt because when I sat down with the group, these two members were rather silent. Although they visibly and vocally engaged in the ideas that Linda and Bill presented through laughing and asking questions (not science questions *per se*), I did not really have much of a chance to hear what they had to say. I did hear the beginning of Kim's story about making tea, but I was not there long enough to hear how and why she picked that story.

I think that Rita and Gloria also brought their own lives to making sense of gases and thereby creating new relationships with science for slightly different reasons. For example, in retrospect, what is interesting about Gloria and Rita is that their use of the whoopee cushion was an act to push on the boundaries of what counts as science, but NOT because they were intensely interested in exploring the world in ways which are more meaningful to them. Rather, I think that part of their decision to bring in the whoopee cushion was to challenge the authority of science to define what is official, and to challenge my own authority as teacher of science to label what is official. The physical presence of the whoopee cushion and its artifacts—the laughter, teasing, and repulsive behavior associated with its sounds—criticized and made a mockery of the official social order and ideology of science.

Still, in other cases, the group dynamics were such that I wondered if students constructed ideas about science through their experiences but did not challenge traditional

ideas. I believed this was the case with Maggie and her theory of the popcorn. In listening to Maggie's small group conversation, I felt that she was trying to impose her prior knowledge of the gas laws on what she and her classmates did outside of science class. This reminded me of what happened when I taught the gas laws in the spring; the students tried to take their science understanding and mold their lives around it. This kind of situation made me wonder if I needed to provide more guidance so that the students could claim their own knowledge instead of having science define their lives.

I also believe that this may have been the case with another group of students—Becky, Juan, Sol, Maria and Sarah—for slightly different reasons. The members of this group seemed to be developing an understanding of the physical properties of gases, but the men seemed to control the conversation, and only certain ideas were explored in depth (i.e. the car tires were explored seemingly by Sol and Juan even though it was Becky's idea, and Becky's idea of rice was not taken up). Even though the women in the group may have understood the examples, I wonder if they were left silenced, and therefore unable to challenge and change their own relationships with science.

Social construction of knowledge

I also wanted to provide students with an opportunity to work through the social construction of knowledge. In these group settings, students shared stories. Some parts of some stories matched, some parts conflicted. I hoped that the question "How will we make sense of such discrepancies?" would surface, and I hoped it would parallel our recently addressed question, "How did the scientific community make sense of the discrepancies between Boyle and van Helmont?" Through the process of sharing personal stories, and having to construct a reality out of a diversity of experiences, I had hoped that the social construction of knowledge would become an explicit lived reality, thereby uprooting the mystification which looms over the seemingly abstract mathematical relationships known as the gas laws. Although I am not sure if the parallel to van Helmont and Boyle was made by any of the students, I believed this

process of socially constructing knowledge to be a first and important step in the process of debunking the position of science in society, a position which assumes that science is objective and fair, and believed to promote equity (because it supposedly avoids bias in its means and product). This process would eventually begin to entangle science (or rather those who promote the existence of an objective and meritocratic science) in the production of an inequitable society with blinders raised to divisions across race, class, gender, and sexuality lines. For example, Linda began to uncover the notion that science was not so out of reach or so "abstract" when she realized she could deduce the same principles as Boyle through her common sense about cooking. Later in class Linda would use this emerging critical understanding to question the authority of science. When Rita and Gloria could not decide between several theories for their whoopee cushion (because they all seemed to work depending on how one chose to set up the explanation), these two women began to notice how theories can be shaped to fit particular needs.

Although the importance of recognizing the social construction of knowledge had been emphasized a great deal in science education research over the last decade, my concern with such research efforts is that such recognition is only to help students develop conceptual understandings of scientific concepts. My intent in engaging students in this process is to build contexts in which students can explore the cultural and political nature of science in order to begin to uncover assumptions made by the scientific community in their own process of constructing knowledge. For that reason, I felt I needed to rely heavily on the lived experiences of my students to accomplish such a task because many times their experiences serve as window on the margin looking in on science. I often cannot provide my students with that window because my experiences as a scientist and my privilege as a white person have clouded my vision.

I felt that the focus of my efforts in this second phase of teaching about gas laws were fundamentally different from my efforts in the spring. At the end of the spring semester, reflecting on my teaching helped me to articulate my struggle between valuing western science

and valuing my students lived experiences. I developed an awareness of how my teaching efforts maintained in many ways the status quo in science. Even though I had invited critiques of science into our learning of subject matter knowledge, and even though we had created a space through the oral histories to critique our own experiences in science, when it came down to talking science, the canon and all its ideological bias maintained its centrality.

My efforts to start a conversation among the students about qualities of gases through the context of their lived experiences was an attempt on my part to value the knowledge that students bring to science class and which reflects their complex and multiple lives. It was an attempt on my part to invite into the science conversation ideas, values, beliefs, qualities traditionally considered nonscientific, unimportant in science. The intent was more than to "empower" students by showing them that they actually already "knew some science" or "did science already in their lives." The intent was to push at the boundaries of how valued knowledge and habits of mind are defined. I did not want to redefine the students experiences in science but I wanted to redefine science through their experiences. This difference, although clear in my mind, is very subtle. I do not think that it was obvious to the students until later in class.

Phase III - Sharing personal experiences

In this phase, my objective was to create an opportunity for the students to share their own personal knowledge of the gas laws. This was important to me, because as Paulo Freire (1989/1970) writes,

[The oppressed] call themselves ignorant and say the "professor" is the one who has knowledge and to whom they should listen. The criteria of knowledge imposed upon them are the conventional ones. "Why don't you" said a peasant participating in a culture circle, "explain the pictures first? That way it will take less time and won't give us a headache." Almost never do they realize that they too know things that they have learned in their relations with the world and with other men [sic] (p. 49-50).

In this phase of teaching the gas laws the students shared their experiences with gases with the entire class. This created a place of study where I hoped we would challenge western science through our lived experiences; the students' lives were the theory for our own gas laws.

This phase of teaching the gas laws, was an extension of phase two: It moved the small group conversation to a larger and more public setting. This is an important distinction. In science class, when working in small groups, it seemed easier for the students to bring in personal experiences and other "nonscientific" talk. But once the students were responsible for sharing their ideas with the rest of the class in order to teach the rest of the class something important about gases, the emphasis shifted. For example, the dynamics of the whole class conversation were different from the small groups. Because I moved from group to group, I did not hear all of the conversation in every group, but from what I heard the students talk about, the emphasis in some of the small groups was on telling stories about things that they had done in the kitchen, garage, work, things that involved gases. Creating the science out of those situations, although central to the activity, in most groups, seemed secondary. For example, when Linda, Bill, Rico, Kim and Tim were discussing gases in their groups, Linda told a story about learning to cook. Bill engaged her in that conversation by sharing his own attempts to learn how to cook. They were focused on their attempts to learn to cook. It is this valuing of the personal lived experiences as a theoretical base for science which I believe is critical to revisioning science.

Yet, this kind of emphasis was difficult to maintain in the large group. I felt pressure to make sure that I helped each group focus their conversation so that the students learned something about science, and I think the students felt pressure to share what they knew about science rather than tell stories about their lives. As a result, in the large group discussion the emphasis was different than in the small group. I wished that the students would focus more on their experiences rather than the science in their experiences. In moving from small group to large group in science class the emphasis moved from personal relationships to presentation and content. Therefore, pushing the students to keep the focus on how they know something about gases through their lived experiences in the public setting of the whole class was an effort on

my part to redefine science through their experiences. As an extension of the previous phase, I saw the whole class sharing as a way to intensify the role of lived experiences in developing a liberatory science.

Phase IV - drawing connections: Making our lives our theories for science and a critique of science

I entitled the last chapter, "Teaching the gas laws: Our lives are our theories are our lives," because I remember leaving class with a feeling rooted deep within me that somehow, what had transpired during the course of the two classes had changed fundamentally our relationships with each other and with science. And, that "somehow" was nestled in our lives—our lived experiences. It was a recognition that who we are as women, working class, minority, nontraditional students (and teacher), is important, valuable, worthy of voice, worthy of theory. Centralizing our complex existence to explain ideas in science powerfully illustrated what it takes to begin to build a liberatory science in class. bell hooks (1994) writes,

When our lived experience of theorizing is fundamentally linked to the process of self recovery, of collective liberation, no gap exists between theory and practice. Indeed, what such experience makes more evident is the bond between the two—that ultimately reciprocal process wherein one enables the other (p. 61).

This fourth phase of teaching and learning the gas laws was the most exciting for me as a teacher with a liberatory agenda, because many of the events and interactions which unfolded in this part of class were unexpected, but expressed in a living way the notion of moving relationships better than I think anyone could ever write. In this phase of the gas laws, the students had just finished sharing their stories of how they understood the relationships between pressure, volume, temperature, and amount because of their lived experiences. I felt positive with how the two previous phases went because many of the students seemed to develop a conceptual understanding of the relationships between the four variables, and many had done so in a way which valued their individual and culture-specific

experiences and knowledge, although there were students who had done so in a way which embraced the complexity of their lives and their visions of valued knowledge. They had not done so in a way which promoted the authority of science to name their experiences. My intention for the fourth phase of class was to invite back into our conversation western science through demonstrating the various (pre-formulated) gas laws, to show the students that their ideas and experience had a place in science, and were equally valued in science. I hoped that my actions would show the students that they were capable of deriving theoretical ideas in science, and that they do not need to reformulate their experiences just to learn science. What I had hoped would not happen would be for the students to rename their experiences in the language of western science.

As I shared with the students some of the experiments that demonstrated the prescribed gas laws, there was an overwhelming feeling of frustration in the classroom. I was frustrated that my decision to use the formal lab equipment to show the "real" definitions of the gas laws to the students suggested to the students that even though I seemed to value their ideas, they were still not as good as western science. The students appeared to be frustrated because they seemed to feel as though they had just spent a great deal of time learning about the gas laws, (which made sense to them), and now I was requiring them learn the gas laws again with some equipment which just did not make sense. (Well it was not that it did not make sense for all the students, but rather that it seemed like a waste of time because it was not helping them learn the gas laws any better. If it was doing anything, it was reminding them what it was they did not like about science). It was at this point that a discussion ensued (initiated by the students--Linda and Gloria) where the students began to critique traditional relationships in science:

Linda: The experiment with the metal ball wasn't that clear to me. I understand how pressure and temperature are related, but I couldn't see how the experiment worked. Can you explain it?

Angie: Well, who has some thoughts related to Linda's question?

Gloria: This is just what I don't like about science. They always take ideas that are mostly understandable and explain them in ways which mean nothing to me. I would rather talk about popcorn than weird metal balls.

Sol: Its true, we do not use these things everyday, except maybe the syringe, so I don't think that they help that much.

After Gloria and Sol shared their ideas many of the students are nodding or vocalizing their in agreement. Some students are laughing, I think at Sol's comment about the syringe.

Angie: This is very interesting to me. You know, when I got out this demonstration equipment for you to work with, I had this nervous feeling. That's because I was so happy with the ways you described the relationships between pressure, volume, temperature and amount with your own everyday experiences that I did not want to try and re-explain them with fancy lab equipment. So maybe I shouldn't have gotten this equipment out. Or maybe its a good thing because this gave a chance to talk about this. What do you think?

Sol: Who bought this equipment anyway?

Angie: The department.

Most of the students laughed.

Sol: Can't you tell them to buy something different?

Angie: I think I will mention something. Lets finish talking about the different gas relationships, but we will go back to our own experiments. Juan what do you think? Were you able to draw any connections between what the groups talked about earlier and these experiments?"

Juan: I can see how the metal ball worked, it was like filling the car tire with air. It does make more sense that way.

As the transcript above indicates, Linda, Gloria, Juan, and Sol used their theorizing of the gas laws from the standpoint of their lived experiences as theoretical locations from which to critique western science. And because these locations are in their lived experiences, they changed and shifted as they began to reread science from their experiences, as they reread their experiences through science. I believe that rereading science through lived experiences was initiated by the students was critical to a feminist liberatory education. It is one thing to help students conceptually understand science from the standpoints of their own lives. It is quite another to help them use that personal knowledge to understand, then critique a powerfully long-standing and excluding discipline. I think some of the students had learned to

make their own science from their experiences. They learned that science does not need to be abstract, reductionistic, and separate from their ways of thinking about the world. When confronted with the alienating realities of contemporary science, they rejected it. This was a slightly different kind of rejection than at the beginning of the year—the I don't like science so I am not going to participate. Rather, theorizing about the world through their lived experiences had given Linda, Gloria, Sol and Juan a language and a reason to reject science. This recent rejection was highly political and gave form to the students feelings about science. Furthermore, it served as a knowledge source for further critique of the science and science education practices we were subjected to.

Before this discussion the students had developed scientific knowledge out of their interests and backgrounds, which are highly individual and culture-specific (Lemke, 1995)—cooking, child care, mechanical work. Working in groups, students theorized about how they have used their knowledge or understanding of the relationships between pressure, volume, temperature, and amount in an intuitive sense at home or work. They publicly shared with each other the ways in which their own set of lived experiences have provided them a context in which to name the gas laws, in ways different than (or, in some cases similar to) chemistry. The students used their lived experiences to suggest that science was not and should not always hold the place that it does and that their experiences are valid. Central to constructing new knowledge in class about the gas law relationships was the opportunity for students to articulate their own naming of the gas law relationships (with or with out the technical jargon). The "chemistry formulation" of these ideas was situated as secondary. We used these personal explorations to develop theories consistent with and connected to our personal observations, beliefs, and values. This starting point is important in creating an inclusive and liberatory science for all because it starts from the experiences of the students, and uses their knowledge to build a science of their own and to see the (dis)connections between that science and the traditional discipline.

I suggest that this is a good example of how moving relationships can play out in class for the following reasons: In phase two and phase three of teaching the gas laws, several of the students and I began to develop our own knowledges for the gas laws from the standpoint of the lived experiences of the students in the class. This act enabled us to give voice to our lives, our theories in science. By recognizing and valuing knowledge that we have constructed from our places, we were inviting ourselves into our relationships with science. These new relationships, though, were not explicitly talked about. When I asked the students to examine gases from a more traditional perspective, there was resistance on the part of the students. I think that this is because they experienced a changed relationship in science, and therefore did not want to go back.

Why is any (or none) of this feminist liberatory education?

The set of classes which are described here were very powerful for me as a teacher and a researcher, and I think as well for the students. By engaging in a conversation about socially and historically located interpretations of everyday events, several students were able to build a beginning knowledge critical of the identities, beliefs, and values traditionally attached to the roles we play within science class, as scientists and teachers and students of science. Through our joint efforts to begin our formulation of the gas relationships from the standpoints of our lives, we began to uncover and unfold the boundaries of ideologies which structure how we think about science and ourselves in science thereby imploding, or at least blurring, the insider/outsider dichotomies which structure and bound our relationships with and in science.

When we began to formulate ideas about the pressure, volume, temperature, and amounts of gases through exploration of our everyday experiences (not) in science, we⁵⁴ had an

⁵⁴I include myself because as I shared ideas with student groups, I too was trying to make sense of how I have intuitively understood the gas relationships which often seemed so abstract to me in class.

opportunity to reflect on our lived experiences in the context of science as well as an opportunity to reflect on science in the context of our lived experiences—we talked about decisions we made in the kitchen and in the car because of personal understandings of gas relationships. For example, Linda's story about cooking spaghetti led Bill and Kim to think about what they needed to know about pressure, volume, temperature, and amount to cook rice or to cook and smell tea. Becky's idea to think about car tires led Juan and Sol (and me) to theorize about what they needed to know about the four prescribed variables to keep their car tires in driving condition. Even Holia's knowledge of bread cooking led her group (Maggie and Lisa) to question the complexity of everyday activities, and later to questioning the importance and even the validity of controlled experiments (at least for their own practice).

We also had the opportunity to speak semi-publicly about the connections, contradictions and parallels which we felt existed between our selves and the chemistry we were in class to learn. A few students critiqued the formal presentation of the gas laws because it seemed abstract and disconnected from our own experiences and observations in the world. In other words, making connections between "scientific ideas" and our experiences—making the relationship between ourselves and science open for discussion—meant exploring assumptions we hold about ourselves, each other and science. As Linda talked about her experiences cooking spaghetti, she began to construct new relationships with and in science. She had thought of her knowledge in the kitchen as "common sense cooking," but by talking through those ideas and her experiences to a small group of students who shared similar experiences, she began to use her understanding of herself and her knowledge of her world to decenter the claims of a positivistic ideology in science and their place in her life, in order to allow other dynamics to shape her vision of science and her identity in that science.

Role of the self in science.

As a teacher and a researcher, the changes I made in my approach to teaching the gas relationships in the summer—attempting to build with the students a theoretical explanation

for gas relationships grounded in our experiences—took on multiple significance when pitted against my memories of enduring the gas laws as a student and later as a teacher. References to the traditionally feminine activities in our world as methods for explanation were rare (actually nonexistent) in my coursework as well as in the textbooks required then and required now⁵⁵; most explanations and formulations of these laws are based on adjustable pistons cylinders filled with gases which, with few exceptions, either remain unnamed or are the kind of gases which exist only in the world of chemical laboratories. Furthermore, most of the textbook problems and exercises and most of the standardized exam questions involve the same cylinders and unnamed laboratory gases.

To illustrate how the gas laws are explained in text in ways discontinuous with the students' and my own lived experiences I present a quote from our textbook author's explanation of Boyle's Law and Gay-Lussac's Law (Peters, 1990)⁵⁶.

Robert Boyle in the seventeenth century, investigated the quantitative relationship between pressure and volume of a fixed amount of gas at constant temperature. A modern laboratory experiment finds this relationship with a mercury-filled manometer such as that shown in Figure 13.6A. A graph (Fig. 13.6C) of pressure versus volume measured in the experiment suggests an inverse proportionality between the variables. Expressed mathematically,

$$\text{pressure} \propto \frac{1}{\text{volume}}$$

$$P \propto \frac{1}{V}$$

Introducing a proportionality constant gives

$$P = K_a \frac{1}{V}$$

Multiplying both sides of the equation by V yields

$$PV = k_a$$

⁵⁵In the course I teach, the department chair has selected a single chemistry text for use across all of the introductory courses.

⁵⁶ This is the author's entire discussion for Boyle's Law. All bold and italics are his original emphasis unless explicitly indicated.

Within experimental error, PV is indeed a constant (Fig. 13.6B).

Boyle's Law, which this experiment illustrates, states that for a fixed quantity of gas at constant temperature, pressure is inversely proportional to volume. Equation 13.6 is the usual mathematical statement of Boyle's Law. Since the product of P and V is constant, when either factor increases the other must decrease and vice versa. This is what is meant by an inverse proportionality.

From equation 13.6 we see that

$$P_1 V_1 = k_a = P_2 V_2$$

or

$$P_1 V_1 = P_2 V_2$$

where subscripts 1 and 2 refer to first and second measurements of pressure and volume at constant temperature. Solving for V_2 , we have

$$V_2 = V_1 \frac{P_1}{P_2}$$

In other words, if the pressure of a confined gas is changed, the final volume may be calculated by multiplying the initial volume by a ratio of pressures—a pressure correction. The inverse proportionality between pressure and volume leads to one of two possibilities: increases or decreases (pp. 307-308).

The calculations in the text intended to illustrate Boyle's Law include:

Example 13.3

A certain gas sample occupies 3.25 liters at 742 Torr. Find the volume of the gas sample if the pressure is changed to 795 Torr. Temperature remains constant.

Example 13.4

1.44 liters of gas at 0.935 atmospheres are compressed to 0.275 liters. Find the new pressure in atmospheres.

To explain Guy-Lussac's Law, the author of our text writes the following:

Figure 13.7 illustrates an experiment performed in a Stanford University laboratory. Temperatures were recorded in Celsius degrees, but both Celsius and Kelvin are shown on the graph. A straight line graph that passes through the origin is the graph of a direct proportionality. This shows that $P \propto T$ where T is that absolute temperature. This can be written as an equation by using the proportionality constant k_b :

$$P = k_b T$$

Equation 13.9 is the mathematical expression of Guy Lussac's Law: The pressure exerted by a fixed quantity of gas at constant volume is directly proportional to absolute temperature. Dividing both sides of the equation by T gives

$$\frac{P}{T} = k_b$$

From this it follows that

$$\frac{P_1}{T_1} = k_b = \frac{P_2}{T_2}$$

or

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

where the subscripts 1 and 2 again refer to first and second measurements of the two variables. Solving for P_2 we obtain

$$P_2 = P_1 \times \frac{T_2}{T_1}$$

Thus, if the temperature of a confined gas is changed at a constant volume, the final pressure may be found by multiplying the initial pressure by a ratio of absolute temperatures—a temperature correction. Again, there are two possibilities, this time dictated by the direct proportionality between pressure and temperature: final temperature is greater, final temperature is less (pp. 310-311).

The calculations in the text meant to illustrate Guy-Lussac's Law include:

Example 13.5

The gas in a constant-volume pressure exerts a force of pressure of 1.88 atm. at 19°C. What will the pressure be if the temperature is raised to 52°C?

In choosing not to use the decontextualized experiences of the four named male chemists (or male chemist textbook author) to define our own knowledge of gas laws, and by choosing to start from the lived experiences of the students (and their related intuitive understandings of the gas laws), we approached these gas relationships in quite a different way. For example, doing chemistry meant talking about and exploring the physical world in ways which were meaningful and personal, rather than in ways which were prescribed. Moving towards defining chemistry through our own understandings of the gas relationships, we had the opportunity to build on the traditional duties and roles of female and working class students (This is dangerous

to say I know. These labels occupy specific social and historical locations, and thereby continually undergo personal and social transformation—especially as we leave them open for interrogation in class (Orner, 1992)). We talked about how we made decisions about these sorts of events in our lives based on our knowledge of gas laws before we encountered gas relationships in science class. We also had an opportunity, when confronted with the demonstration equipment to critique the ways chemists and chemistry educators choose to talk about and make sense of the gas relationships from our own experiences, beliefs and values.

Rethinking our understanding of science as well as our relationships with science seems critical in light of recent ethnographic work involving gender, race, and class. As Spender and Sarah (1980) and their ethnographic study of the girls in England, Gaskell (1992) and Connel (1988) and their respective studies of Canadian working class girls and Australian students, and Patthey-Chavez (1993) and her study of Latinos in California point out, female, working class and/or minority students may understand, at least implicitly, that schools affirm white middle class masculine culture to the disqualification of their own views of the world. Consequently, despite the best intentions of teachers, many of these students resist the middle class, white, masculine ways of schools in favor of the world in which they have experienced—working class, minority, feminine.

Lived experiences for revisioning science

It requires something more than personal experience to gain a philosophy or point of view from any specific event. It is the quality of our response to the event and our capacity to enter into the lives of others that help to make their lives and experiences our own (Goldmann, 1972, p. 388).

In the lessons on the gas laws the scientific knowledge developed in this class has grown out of the students' interests and backgrounds, which are highly individual and culture-specific (Lemke, 1995)—cooking, child care, mechanical work. Working in groups, students theorized about how they have used their knowledge or understanding of the relationships between pressure, volume, temperature, and amount in an intuitive sense at home or work. They

publicly shared with each other the ways in which their own set of lived experiences have provided them a context in which to name the gas laws, in ways different than (or, in some cases similar to) chemistry. For example, what was interesting in this part of class was that none of the students derived any of the gas laws⁵⁷, but all of the groups had derived some version of the gas laws consistent with the physical qualities of gases. I am sure that this is because in their lives, they observed and made decisions about how to do things such as cook or take care of children which are complex. Their intuitive understandings of the relationships between the physical variables of gases was equally complex. For instance, it is not often that in secretarial or domestic duties, one would have the opportunity to deal with pressure and volume decontextualized from temperature or other physical characteristics.

Using our experiences as a theoretical location (shifting with experience) for understanding chemistry and for critiquing the knowledge base as well as the discursive practices of western science, helped me to understand how my own positionality masks my assumptions about what it means to know, do and think science. (For example, I had been structuring my ideas about feminist liberatory science education on the bipolar logic perpetuated by positivist science). Listening and watching the students recount and enact their experiences at home and at work helped me to draw connections between the structure and content of formal school science (as depicted by our text, by my experiences, and by meetings with the department) and how the insider/outsider positioning in science is in part built up and maintained by close monitoring of the language (i.e. the technical jargon) and uses of as well as participation in chemistry.

I do not believe that our use of home and work ideas to make sense of scientific knowledge was all that radical or liberatory, even though it provided us with a way of making sense of a set of physical properties. However, critiquing the science from that standpoint was radical. This critique occurred at two levels: Explicitly re-naming science from our voices and

⁵⁷the relationships between: Pressure and Volume; Pressure and Temperature; Temperature and Volume; Pressure and amount.

perspectives so that our own perspectives and voices became our science and re-naming our relationship to the traditional content and process of science. Many students in our discussions following the gas laws talked about how and why they felt so apart from and so much like outsiders to chemistry. And a lot of these feelings connected with the students' feelings of either "being in" or "being out" and to the idea that chemistry takes our everyday experiences and renames them in incoherent, abstract ways which are discontinuous with our experiences. This last point was really brought out strongly when Gloria commented during our discussion about the lab equipment, "This is just what I don't like about science. They always take ideas that are mostly understandable and explain them in ways which mean nothing to me. I would rather talk about popcorn than weird metal balls." When I think about the students standing up to science through their critique of the lab equipment, I am reminded of the words of Paulo Freire (1989/1970),

It is only when the oppressed find the oppressor out and become involved in the organized struggle for their liberation that they begin to believe in themselves. This discovery cannot be purely intellectual but must involve action; nor can it be limited to mere activism, but must include serious reflection: only then will it be praxis (p. 52).

The students were able to label science as the oppressor. Although continuously throughout the semester I had worked through several critiques of science with the students, I had not introduced that notion into our talk about the gas laws. I felt uncomfortable sharing the formal lab equipment with the students, yet I had not even mentioned that to them. Through their theorizing about their lives and using that knowledge to break down the authority of science, the students had engaged in a struggle for liberation.

Although my writing makes this process appear easy or unproblematically accepted by students, it was difficult and slow, and oftentimes painful for the people in our class, including me. What I have not included in this story are many interactions the students and I had with each other and with science earlier in the semester. The series of classes described here occurred two thirds of the way through the course. Had it been the first week, or even the fourth week, I do not think the students would have been so open to challenging the science they

believed they came to learn and the people they had to be in order to learn that science. Had we not spent almost an entire week earlier in the semester thinking about what it meant to reconceptualize atomic theory and the periodic table of the elements and then try to actually carry out those ideas in the space of our classroom, we may not have even understood the possibilities for the changes in the curriculum, and the influence these changes can have on our understandings of science, of ourselves, and of the pervasive nature of the ideology of western science in all of our relationships within our class.

Moments of resistance as locations for theorizing about feminist liberatory education in science

The gas laws story also sheds some light on what it might mean to use our locations of radical resistance productively to create a more liberatory science learning setting. For example, because we started our study of the gas laws by valuing our gendered and cultured experiences and the complexity inherent to those experiences, we were able to build a complex understanding of the physical world. Yet, our understandings were different from western science because we valued the complexity and contradictory locations of our lives. Because I shaped the classroom conversation in a way that would use the students' experiences to develop their own theories about that natural world rather than using the students' experiences to validate the science prescribed, I was not seeking to categorize their experiences according to the tradition of the gas laws. I wanted to let the students' theories stand for themselves. If there was enough evidence to contradict the prescribed categories of the canonically accepted body of knowledge in science, then we would need to seize that opportunity to make explicit the divergences between such theories, and to change the science in our lives.

In pushing our understanding of these discontinuities we were faced with the implicit decision of silencing our complexity in acknowledgment of the authority of science, or defining and practicing our lived theories in opposition to the standpoint of science. In choosing this space of resistance—in choosing to recognize publicly that we were speaking from and about our subjectivities—we had theoretical standpoints with which to rethink and rewrite our own

experiences in science. Explicitly locating these divergences, we had the chance to reread the science in our lives, and our lives in science. These spaces of radical resistance gave reasons and contexts in which to disrupt the neatly packaged hegemonic reality in and of science. The creation of these spaces pushed on the boundaries of western science, and as a result, as a community, we were able to begin to decenter the traditional power arrangements in science and the traditional knowledge base of science. We were able to reposition ourselves in science. Gloria reflects this stance when she said, "Yah, I know what she is saying. The metal ball, it wasn't like it was part of me and I spend my days working with equipment and working with the guys so that's not it either. Its hard to explain."

By engaging in a conversation about socially and historically located interpretations of everyday events, we were able to build a beginning knowledge critical of the identities, beliefs, and values traditionally attached to the roles we play within science class, as scientists and teachers and students of science. Through our joint efforts to begin our formulation of the gas relationships from the standpoints of our lives, we began to uncover and unfold the boundaries of ideologies which structure how we think about science and ourselves in science thereby imploding, or at least blurring, the insider/outsider dichotomies which structure and bound our relationships with and in science. When we began to formulate ideas about the pressure, volume, temperature, and amounts of gases through exploration of our everyday experiences (not) in science, we had an opportunity to reflect on our lived experiences in the context of science as well as an opportunity to reflect on science in the context of our lived experiences.

Making connections between positionality and feminist liberatory science education

As I have tried to show in this story, several students and I were able to create moving relationships in science class by pushing at the boundaries of the bipolar logic which structure our relationships in science as well as ideas about the nature and content of science. We began to suggest that the traditional insider/outsider structure was inadequate for who we were in

science, and our experiential understandings of scientific principles. One thing I find very interesting here was that the students each challenged the science in their lives differently—most likely because when rereading science from our differences has different meaning for everyone involved. For example, Maggie, Holia, and Lisa all connected to science differently despite the fact that they are all women and were working together in the same group. This is in part because their lived experiences are vastly different. As I described earlier, Maggie comes from a highly educated family and is taking this course while she is home from school over the summer. Holia, on the other hand is taking this class on 4 hours of sleep each night while she tries to raise her young son alone and work. She is taking this course because she wants somehow to fund a better life. Lisa is in the nursing program at the community college. Although it is her first time in college for ten years, she has said to me that she feels very comfortable in schools.

The conversation surrounding the lab gadgets was particularly powerful in helping me draw these connections because it had been informed by the ideas we, as a class, had constructed about science earlier. It suggested that students and I were using our awareness of our positionalities to challenge our relationships with and in science class. We were creating new understandings about science and ourselves in science because we were able to critique the power structures in science education which perpetuate ideas about what science is and who can do science. For example, we talked about the gas characteristics and how the lab equipment only served to mystify and abstract the relationships for us. Furthermore, we talked about how using the more traditional lab equipment in very subtle ways defines what is science and who can do science.

Central to making positionality a critical piece of learning science is reflecting on moving relationships in the context of the situated nature of teaching. Also central to this task is understanding how these relationships require the teacher to continually re-articulate her epistemological and political agendas. For example, as I learned more about how my students and I have constructed ideas about science through exploring lived experiences in class, it

became necessary that we use our lived experiences as places from which to critique and revision science and our relationships with science. Previous to these experiences with my students, my political intent was to use feminist theory, in the abstract, as our theoretical foundation. I can see now how this approach can be equally alienating, especially when many of the feminist critiques of science have emerged from a white middle class academic feminine perspective. In our class we were not all white middle class academics: The students were primarily working class, culturally diverse and very much on the fringe of the educational process. The differences from which we began to reread the science in our lives allowed a much richer vision of science as well as the possibilities for new relationships.

As we shared our lived experiences and ideas about gases, we pushed at the boundaries of what was acceptable in science; we created new ideas about science and new relationships with and in science. We talked about things that we do in our lives that are not traditionally valued in science. Valuing lived experiences, created spaces for relationships with science to be resituated—the positivistic ideology of science in some cases was displaced as our experiences became valid and valuable parts of science education. By recognizing the moving nature of our relationships, we could begin to articulate the changes in the ways we perceive ourselves and each other and in science. Our knowledges about self and science became resituated; having an awareness of the positionality that we bring to relationships we also had a better understanding of the power arrangements involved in such relationships. These events have helped me as a teacher-researcher to see that positionality is more than being white, being female, being a teacher, being a student, being a scientist, although these identities play central roles in the ways I choose to make sense of events. But, these identities do not change as a result of relationships (I am still white, female, a teacher, a student, a scientist). What changes are the ways in which I understand how these identities are bounded by particular power arrangements in science and education, and the effects of these power relations, namely the dualisms. It is through such changes, that we (my students and me) can begin to reposition ourselves in science and education.

Rethinking positionality: Constructing new ideas for feminist education

Preparing to teach the gas laws this summer, teaching them, then reflecting on what happened was very much a turning point in my thinking. As I had thought about positionality in the context of science teaching and learning, I have most recently been thinking that I needed to explore the relationships with which we engage in class. I believed that much of what is oppressive in science class is a result of the power arrangements which are invoked in relationships. In terms of our science class, the institutions of science and education played a central role in our relationships, and their centrality had defined for us not only what science was, but who we could be in science through constructing a set of dichotomies: Insider/outsider; scientist/nonscientist; teacher/ student; self/other—dichotomies which clearly indicated whether we knew science or did not and whether we were a part of science or were not. I had been thinking that these relationships needed to be explored in class and challenged and critiqued if we want to rethink the nature of science. Teaching this unit, though, with help from the students, helped me to see how pervasive those power arrangements were. I had thought in the past how such power arrangements, which determine what science was and who could do science, manifested themselves through structures such as exams, lecture format, and fancy terminology, but I had not realized how the insider/outsider; scientist/nonscientists dichotomies were present in almost every structure in the classroom; they were certainly present in those two pieces of lab equipment. Using our lived experiences to question science helped us to re-position ourselves in such a way that when confronted with the centrality of an ideology that confines and oppresses, we were able to critique it.

I know after teaching the gas laws during the summer semester, I personally felt "good." I felt as if we had peeled away at a layer of our structured thinking about ourselves with and in science and what that meant as we tried to construct new relationships in science class. As I think about my teaching of the gas laws, the students in my class, and our attempts to name our place in science, I am reminded of hooks (1990) description of positionality as home:

Home is not just one place, but a multitude of locations, "enabling and promoting varied and ever-changing perspectives, a place where one discovers new ways of seeing reality, frontiers of difference. One confronts and accepts dispersal and fragmentation as part of the construction of a new world order that reveals more fully who we are, who we can become, an order that does not demand forgetting. (hooks, 1990, p. 148). Because of my own conflicting localities, I have come to know myself, others, and science from both center and margin. I think some of my students have also come to know themselves, each other and science from both center and margin. We all have come to learning, teaching and researching the gas laws from contradictory localities. As a teacher who is thinking about positionality in the context of teaching the gas laws, questions of the "realities of choice and location" (hooks, 1990, p. 145) become central to my thinking. How did the power arrangements emergent from the current structure of science, education and society center particular identities in our relationships in class, and how did this influence how we thought we could act, think and know science and each other? How did this influence what we thought we could challenge?

The first time I taught the gas laws unit, I tried to help students understand that scientific knowledge generated in the field of chemistry was molded within a particular social and culture milieu and was therefore laden with a corresponding ideology. Yet, my goal was to engage them in learning the science so that they would have a foundation on which to build a critique. At the time I thought that through learning then critiquing such knowledge, we would be able to locate our own voices in the process; we would be able to articulate our identities in relationship to that knowledge.

But as I reflected on what happened during the course of events in the spring unit on gas laws, I was confronted by my own new understandings of positionality. Because I chose not to acknowledge that positionality is emergent in relationships with other people and their institutions, and does not exist solely within the confines of my own personal experiences. I had allowed the power arrangements within science and education to shape our relationships with science. In other words, by keeping western science and its discourses and practices center to our

teaching-learning of the gas laws, as I did by making the learning of those gas laws the primary classroom activity, I also kept our relationships within science unchanged, unchallenged, and unrecognized. The discourses and practices of science and education, which are traditionally dependent on a systematic set of hierarchical oppositions (Gore, 1993) served as "transcendental signifieds" in our science class on gas laws in the spring semester, because these were the unchallenged relationships within which we engaged with each other and with science, and which stabilized the meaning of other words or identities. The dichotomies of insider/outsider or self/other in science class were assumed to be natural, seamless, and true by the master narratives (Orner, 1992) of science and education and by those of us who unobtrusively took the master narratives for our own.

Therefore, these reflections on my teaching over the summer semester have brought new meaning to the relationship between positionality and feminist liberatory education. I wrote this past spring that the "politics of positionality therefore begins with the question about choice and location, with the explicit identification of positionality, the potential space of revisioning." At the time, as is evidenced by my approach to the gas laws in the spring semester, I was interpreting positionality as existing outside of relationships. In this view, by virtue of a set of experiences, cultures with which to identify with, a particular family with a defined way of acting and thinking, as well as a defined social class and ethnicity, a gender, and whatever else, I "had positionality." In retrospect, I can see why this vision of positionality kept feeling inadequate to me. I was trying to understand a "world of multiple causes and effects which interact in complex and nonlinear ways, and which are rooted in a limitless array of historical and cultural specificities" (Weedon, 1987, p. 24) in a linear and structured fashion; I was going to pigeon hole all my reflections and interpretations into the neat little boxes which make up my positionality. By not challenging the nature of the relationships within which we engage in science class, I had allowed my positionality in science class to be partially defined by positivistic science.

By moving to understanding positionality in the context of relationships (for now anyway) is to put into the text of science class a life of experiences, interactions, and understandings of the world in order to challenge, or to make problematic, assumptions held about power and privilege, oppression and subordination. In this sense then, addressing the dualistic thinking which structures our relationships in science class requires all of us (students and teachers) to continually examine personal and public assumptions about our own positions, those of our students, our power to (not) facilitate classroom conversation, and our unexamined power to legitimate and perpetuate unjust relationships. In other words, without reflecting on and challenging the relational, and hence inherently contradictory nature of positionalities in science class, I am removing opportunities to make sense of my worlds and my understandings of the worlds of those with whom I interact, as "multiple sensually, passionately, rationally, without a break, without the splitting separation between the senses, emotions, reasons" (Lugones, 1994 p. 465).

Looking ahead

Without doubt, much of what we hope our students will embrace through feminist teaching and learning is the political potential of speaking out on their/our own behalf. (Lewis, 1993, p. 44).

I am reminded of the work of Max van Maanen (1988) in phenomenological studies. He writes of modern social science research in education as separating pedagogy from the child:

Can you find the child? Where does all this theorizing and research still connect with the lifeworlds of the children? Rather, teaching is to live our lives with children more fully, educational research so often seems to be cutting us off from the ordinary relations we adults have with children....In modern forms of human science research in education, children may once again be recognizably present, however, their presence betrays a lack of pedagogic commitment to them. The children may be there as objects of our human interest in them—but they are not morally present in that they force us to reflect on how we should talk and act with them and how we should live by their side (p. 439).

Although I do not teach "children" per say—I teach "adults"—I do not see adults as needing anything less than children in the science classroom. My intentions in theorizing as a teacher-researcher must include the lives of my students and myself to create in a public forum a living body of science that does not deny us our cultural heritage as complexity socialized and labeled people. In my own teacher-research efforts, thinking about positionality has helped me to understand that the importance of allowing our knowledge construction (scientific knowledge and critiques) to explicitly embody the complexity in our lives with and in science so that we can live and act openly and honestly in science. As Magda Lewis (1993) writes,

I am convinced that the struggle over pedagogy is not to fit women into the phallogentric model for social relations and work and family life, a project that will always "leave us on the short end of life" (words from a song by Arlo Guthrie). Feminist pedagogical practices are more than critique, just as they are more than making women historically and currently visible in the curriculum...We can not bring about social change from within those concepts and practices that have limited our possibilities (Lewis, 1993, p. 40, 42).

I did not want to use students experiences to validate the prescribed science. I wanted students to use their experiences to develop their own theories about that natural world. I was not seeking to categorize these experiences according to the tradition of the gas laws as I had in the spring semester. The students were constructing their own knowledge about the gas laws, and about what is important when they study the gas laws. Their knowledge was generated, at times, in opposition to the hierarchical scientific tradition, which labeled their everyday experiences as unimportant, and trivial. The students labeled their experiences with gases as important and more complex than science could describe. The students (and I) were openly struggling against the power of the dominant culture (in science) claims to truth, to descriptions for the world. I pushed my students to be critical of the texts they were reading because those texts denied their reality. As, Chinosole, one of the professors in Maher's and Tetreault's study of feminist classroom suggests,

We create the knowledge, and just because our creations are not in places where knowledge is held, which is in the textbooks, that doesn't mean we didn't do it...When you talk about Black women's lives from a [white] feminist perspective you really don't read about our mothers, our aunts, our sisters, all the women we know (quoted in Maher and Tetreault, 1994 p. 65).

Chinosole described the knowledge generated in her ethnically diverse wild women in music and literature course. This also describes some of the changes made in my own attempts at a feminist liberatory education in science. In the spring I had hoped to help the students work through a conceptual understanding of western science (which by leading the learning of science automatically categorized and named our experiences for us). I then hoped to help the students critique that knowledge and begin to revision a new science. Yet, I based our classroom critique of science on my own knowledge of critiques in science (very much a white feminist interpretations of the limitations of science). In many ways I was afraid to let the experiences of the students form the body of course, the body of the critique in science. As a result in the spring semester, I had not really provided the students with the opportunity to create a science that was outside their textbooks, or outside the authority of science. Even when I promoted a critique of science, it was often (but not always) informed by a white middle class academic feminist perspective (myself and the literature that I have read). So even when the students set out to critique the knowledge base of science formally (outside the oral histories), their experiences were not really a part of it. I began to see that our real critiques of science and our lives in science grew out of our oral histories conversations rather than the formal critique I presented to the students, because it was in the oral histories that we were part of the critique, that our experiences became part of the course. I began to see how this was truly needed in the actual learning of science.

So, as a result, in the summer semester, the students reshaped the science radically so that we could respect each other's ideas, wants, needs and beliefs. In order to value the experiences and ways of knowing students bring to class, the prescribed science—formal gas laws—was replaced with a modified version—namely exploring the connections that students perceive between the gas laws and their lives. If I was going to help all of the students participate in science, including the students who have felt alienated from the traditional practices in science, then I needed to find ways to value the diverse ways of knowing brought to

class by the students. I needed to value a revisioned science which emerged from finding intersections between their ways of knowing science and formal science.

Feminist literary criticism urges women to be "resisting readers" (Fetterely, 1976). I wanted my students to be resisting readers of science and resisting practitioners of science. I wanted them to embrace, yet distrust the subjective knowledge of science. I wanted them to read and practice science in ways which would value personal (autobiographical) knowledge, knowledge emerging from their lives as inscribed yet agentic people rather than to let their knowledge of science rest in the abstract and intellectual science. I wanted the students to "combine their subjective reactions with emerging tools of analysis, and then to form a more broad-ranging set of connections with feminism and literary theory....to construct a knowledge that was useful to them" (Maher and Tetreault, 1994, p. 71).

PART IV. LOOKING BACK AND LOOKING AHEAD

Part IV (Chapter 10), although the last chapter of my dissertation, is only a pause in my journey where I try to bring together the ideas I fleshed out in this dissertation. It is a moment where I look back on my teaching and researching from a new vantage point and begin to see more clearly old patterns, and to ask new questions.

CHAPTER 10

Revisionings

Because I believe that we only ever end with beginnings, it is on these beginnings that I want to reflect as I come near to completion of this work (Magda Lewis, 1993, p. 181).

Journal August 9, 1994

It is the middle of August. I am sitting in my office at GCC preparing to turn my students' grades into the administration. I have the last official word about which of my students knew chemistry and which did not. By the time my watch chimes 5 o'clock, everything my students and I talked, laughed, and wrote about, as well as resisted, will be officially reduced to a number that will be recorded in the data banks at the community college.

I am taking my time with this process even though there is not much to do. Most of the students already know their grade, because we discussed them individually. In these cases I presented to the student my idea for a grade, and then opened our conversation to negotiation. Students have known since the beginning of the semester that they can play a role in determining their grades if they like through personal learning projects and discussions with me. I take a slow approach to grading because the very act of defining our work together through a decontextualized number, signifying academic achievement in the department's chemistry program, leaves me feeling like a disembodied abstraction, scattered in fragments across a bubble sheet score card.

I am also working slowly because there is an awful thunder storm moving its way across campus. I'd rather not walk out to my car until the storm has passed. In many ways I think that this storm is symbolic of our summer semester as well as my dissertation teaching-researching-writing. It stormed on several class nights, so that many of my students and I would stand together by the door facing the parking lot sharing stories as we waited, slowly getting up the nerve, one by one, to walk or run out to our cars, bikes or bus stops. Rarely did these conversations focus on chemistry.

I have always associated storms with power and uncertainty: The thunder, the lightening, the possibility for tornadoes. I also think of storms as a sort of communal re-emergence of life, of possibilities. After the storm has passed, I notice the exposed earth worms, the singing birds, and the people moving freely outdoors.

This is much of the same way that I feel about teaching and learning right now: Power, uncertainty, and possibility. I am reminded of yesterday afternoon. I

spent the afternoon in office hours. We are "required" at GCC to hold one office hour a week, but I usually hold more to make sure that the students have a chance to see me, if they want to, given that the students I teach have rather diverse schedules. My schedule is demanding, and so if I do not have office hours, I am typically not even on campus. This week, I also wanted to make sure that any student who has not had the chance to talk to me about their grade would have an added opportunity.

Late in the afternoon, Tammy came to my office. Tammy was a quiet student during the summer. I recognized her shyness immediately at the time, and as I write my stories about teaching during the summer, I am reminded of it as I hear her voice very little in the tapes I made of class—usually only when I call on her. When Tammy entered my office, I was a bit surprised because we had already discussed together her grade, so I thought that perhaps she wanted her copy of her project back. She had done a really interesting piece where she created a game centered on atomic theory (I think she knew that was my favorite topic in class). She had created questions that were intended to help players think about the different pieces of atomic theory as well as the historical development of the atomic theories. What I found most interesting was that her game had no winners or losers. There were special steps built in for whole group work when an individual player could not work through an atom problem alone.

When I began to tell Tammy what I really liked about her project, she quickly thanked me and said that the real reason she came by was to thank me for the course. She then opened her backpack and pulled out a little bag, handed it to me and said she felt that for the first time she had learned something in a science class. When I asked her what she learned, I do not remember her naming anything in particular, but just feeling like she had not been mastered by science. After she left I opened the bag and found a loaf of apple bread, a bag of coffee beans and a card. The inscription on the card read, "Thank you teacher!" In the card, Tammy had written, "Thank you Angie for your hard work. I hope these coffee beans help keep you awake as you try to finish your Ph.D. I know you will do great!"

Power, uncertainty, possibility...

It is summer again. Four semesters have passed since I started my dissertation project; four semesters of searching for ways to help create a meaningful science in the lives of my students, to bring the meaningful lives of my students into science. My students from these past semesters have moved onto activities other than introductory chemistry at the community college, and yet their lives in that class—their learning, their writing and their thoughts—have been abstracted as data for my project (Middleton, 1993 p. 147). With the aid of science—tape recorders, computers, transcription machines—I inscribed our voices onto disk. I moved from file to file and cut and paste pieces of transcripts, journals, interview notes into this

chapter and that. I used my power to record and transcribe as well as my power to interact comfortably and unproblematically with science to write a story about feminism, liberatory education, and science. I am scared by this power.

Scared, but not alone, I am determined not to be paralyzed by the contradictions and tensions inherent in a life committed to (but not always successful at) feminist transformative praxis. Attempting to deconstruct the power and authority in science in the same breath that I use science to promote my own power and authority threatens to paralyze me. But, fighting off paralysis, I return to the questions which guided my dissertation study: What does it mean to create a liberatory and inclusive science education when the teacher-student and the scientist-nonscientist relationships are built on hierarchical power arrangements in which the teacher/scientist is considered the knowledge giver, and the student/nonscientist, the knowledge receiver? What does it mean to create a liberatory science education when the discourses of science and education are guided by a discourse that does not include the complexity our lives as gendered, raced, and classed students and teachers? What does it mean to create with all students a science that is not oppressive in its content, process, language, or privilege?

In this chapter, I summarize but also explore further what I have learned about my dissertation questions. Two themes ran through this dissertation: First the feminist theme of positionality, and how positionality can serve as a helpful lens for constructing a feminist liberatory chemistry teaching and learning setting. The second theme has been about my journey to create a liberatory setting for my chemistry students. I would like to share the learning that grew out of living and writing these themes. But I need to preface "the lessons learned" with my concern and contradictory feelings about writing and sharing such conclusions.

Writing conclusions for a feminist teacher research project

Typically the last chapter of a book or dissertation is titled or subtitled "conclusions and implications" or something along those lines. In writing this chapter, I felt pressure to share with my readers some sort of argument or outline marking the major ideas presented in my thesis as well as some sort of generalized recommendations. Maybe this is not so much the case in education, but after having authored research reports in chemistry, I know these are the expectations in "real science".

I created a text which I want to be accepted as a dissertation and which details my struggle as a feminist teaching chemistry. As author, I claim the authority to describe reality—to claim that something worthwhile has happened. Through my teaching and research practice I argued that science and scientific research is epistemologically and politically contextually dependent. My conversations with students and my struggles to make the gas laws something other than someone else's theory that had to be learned to gain credentials showed me how much our lives are shaped by our theories and moving relationships. Our lived experiences and the ways in which we learn to articulate them through complex and shifting power arrangements locate our understandings of ourselves and our interactions with the world (and therefore science). We live, we have new experiences, our lives change, our locations change, our knowledges change, our theories change.

My teaching, researching and living suggest to me that with each new experience, and with each new re-reading of my lived experiences, the meanings constructed by me about this dissertation will change. "Knowing" this (which itself is problematic because it suggests that there is something which is uncontextually knowable) makes writing anything called "conclusions and implications" problematic. It implies a sense of finality and a vision of an acceptable reality to my text which I do not believe exists. So, as I write this last chapter:

I hope that none of what I've said here is viewed as either didactic or universal. If nothing else, I've come to learn that teacher-research relies on ever-evolving sets of circumstances and that each person's experiences as a teacher-researcher should serve as the basis for her own development and change. So, while my experiences represent a personal history, I hope it is a history that may strike some chords for others as they realize moments of recognition as they read through the text...[P]erhaps the changes I've made in my own history as teacher-researcher might be seen as evocative rather than as representational, a reflection of the musings and adaptations of one teacher-researcher, a teacher-researcher whose understandings will expand and grow (Fleischer, 1995 p. 64).

While writing this chapter is problematic, I feel a responsibility to share with the reader how this work has informed my efforts as a science teacher, science education researcher, and feminist theorist. I am also committed to share what I believe are important connections to the larger science education community. I use the majority of this chapter to own up to these responsibilities by reflecting on (but not providing answers to) the following two questions:

- What did I learn from researching my science teaching about teacher research, liberatory education, positionality and feminist theory?
- What can the educational community learn from teacher research, liberatory education, positionality and feminist theory?

What did I learn from researching my science teaching about teacher research, liberatory education, positionality and feminist theory?

In the first chapter I wrote that I often felt alienated from science, because the science I was supposed to learn did not always connect with my experiences and intuitions about the world. I felt scared and intimidated by a culture and a content that did not adequately connect with my experience, and I felt I did not have the knowledge base, the language, nor the confidence to challenge either science or my feelings. Yet I also wrote that by probing into the nature of science and critiques of science, I began to draw connections between some of my feelings towards and beliefs about science. Feminist critiques of science opened up new imaginings about science. I began to understand that it was legitimate to have feelings in science, that I did not

have to be able to separate myself from my object of study. I learned to characterize and make explicit the values embedded in my own scientific theorizing and that scientific knowledge, by its very nature, was made stronger, more objective, through such explications (Harding, 1991). I felt liberated from feelings of intellectual deficiency and fraud (MacIntosh, 1980).

Throughout my teacher-research study, I tried to create situations where my chemistry students could experience a similar kind of liberation. Of course I knew theirs would not be the same liberation as I experienced, because each of us brings different life stories to the study of chemistry. But I believed that there would be common elements. Through the process of exploring this teaching struggle, from a feminist perspective and through the lens of positionality, I learned that to engage students in an understanding of science which did not assume a particular cultural framework meant taking seriously the lived experiences of students. It meant allowing those lived experiences to shape and form the science and the critiques of the science we do in class.

Through sharing with me their lived experiences in and out of science, my students helped me to interrogate how my own positionality as a feminist teacher originally shaped my intent for a liberatory science class. My students' intervention helped me to recognize that our lives are our theories for science—that we can reread our lived experiences to create liberatory science education.

Rereading our lived experiences for a liberatory science education

We know things with our lives and we live that knowledge, beyond what any theory has yet theorized (Catherine MacKinnon, as cited in Lewis, 1993).

Making this theory is the challenge before us. For in its production lies the hope of our liberation, in its production lies the possibility for naming all our pain (bell hooks, 1994).

Within the last five years there has been a growing attack on the feminist notion that the personal is political (Giroux, 1992b; Mercer, 1992; Rutherford, 1990). Giroux (1992b) summarizes much of this debate when he writes that "one has to now genuflect before the

discourse of "authentic experience" in order to be taken seriously...the politics of experience is questionable on any number of grounds" (p. 312). He argues that to accept the authority of experience uncritically is to forget that identity is complex, contradictory and multilayered. Additionally, he suggests that using the personal as political results in a form of "confessional politics."

Using personal experience to rethink science has been central to my efforts to construct a feminist liberatory science education, and in my attempts to "research" my efforts towards those teaching goals. Although this route has caused me to share parts of my life with the reader and with my students, I do not see that as a "confession" on my part.⁵⁸ It is a way to make clear the power, limits, and partiality that inscribe my own sense of identity in science and education, my relationships with these institutions and the people acting within, and my own visions for change. Central to making this work is the process of embracing our experiences with a critical eye. What is the point of rethinking science from our experiences without being critical of the latter? Science has done this all along; it is objectivist and positivistic. The science community has successfully attempted to depoliticize cultural differences by inserting itself in a power-neutral discourse. The very act of recognizing that our experiences are embedded with social values and locations makes our efforts to rethink science inherently political and radical. For me, positionality in feminist liberatory education is about critically rereading lived experiences, and interrogating science and our experiences through connections to our lives.

⁵⁸Growing up Catholic I feel I have some insight into this metaphor. Confession is a time to reflect on your actions in order to locate times when your actions worked against the mission of Christ. It is an admittance to doing something *essentially* wrong—an action, thought, conversation that denied social justice or social transformation for the "greater good." It is a "mediated" conversation with God as a way to semi-publicly admit fault and semi-publicly to receive forgiveness (although we are all taught that God forgives even before we commit any sinful acts.) The personal as political—although a reminder and a source for the deconstruction of our own actions—is neither a pleading for forgiveness nor an admittance to a life of sin. Rather it is a political standpoint that our lives are wholistic—that everything we do informs the other and cannot be ignored.

Reflecting on my personal and teaching experiences helped me to understand how my privileged location allowed me to unintentionally mask many of my assumptions about what it means to know, do and think science. For example, when I began to teach science feministically, I used western science in its content and practices as a "foundation" for my feminist teaching (e.g. the gas laws during the spring semester). I taught the canonically accepted science first (through progressive teaching techniques), then expected students to be critical of it and to revision it. By approaching the learning of science this way, I automatically categorized and named our experiences for us. I limited our opportunities to rethink science because I had imposed "The Way" to think about and rethink science. My actions suggested to the students that there was a knowledge base out there to be learned that would bring meaning to their lives. In many ways I had fallen prey to the same tempting ideology, power relationships, and colonizing practices perpetuated in the practice of a positivist science.

In many ways I was also afraid to let the experiences of the students form the course. Perhaps I was not sure I could. As a result of these beliefs in the spring semester, I had not really provided the students with the opportunity to create a science which was outside of their textbooks, or the authority of science. This is not to say that we did not do "household chemistry" type experiments. We did those because I said we should and because they connected the students' lives to western science. For example, in our study of the gas laws during the spring semester, I intentionally did the experiments with marshmallows and bicycle tires because I knew the students were familiar with these items. But, I used students' experiences to legitimize western science. In the summer I explored something different. Student experiences were not used to validate a prescribed science. Instead, students used their experiences to develop their own theories about that natural world. They did not require the validation of western of science in order to be acceptable. When enough evidence existed to contradict the prescribed categories of the canonically accepted body of knowledge in science, then students seized that opportunity to critique science and even to change science. In our study of the gas laws in the summer semester, we created a more complex understanding of the gas laws.

Although the physical relationships we established between pressure, volume, temperature and amount were similar to the accepted relationships, they were constructed and connected through the lives of class members.

When I began to promote a critique of science in chemistry class, it was often informed by a white middle class academic feminist perspective (myself and the literature that I have read). So even when I required the students to critique the knowledge base of science formally (outside the oral histories), their experiences were not included. Our more personally relevant critiques of science and our relationships with science grew out of our experiences. This was why the oral histories in the spring had more power than any of the chemistry we studied.

In the summer semester, after I had begun to value more deeply the significance of lived experience, I allowed the students to reshape the science radically, so that we could respect each other's ideas, wants, needs and beliefs. In order to value the experiences and ways of knowing students brought to class, I allowed the prescribed science (formal gas laws) to be replaced with a modified version (an exploration of the connections that students perceive between the gas laws and their lives). I believed that if I was going to help all of the students participate in science then I needed to find ways to value the diverse ways of knowing brought to class by the students. I needed to value a revisioned science which emerged from finding intersections between their ways of knowing science and formal science. Listening and watching the students recount and enact their experiences at home and at work helped me to draw connections between the structure and content of formal school science (as depicted by our text, by my experiences, and by meetings with the department), and our own experiences. It helped me to interrogate a bit more deeply how we are each positioned within the larger chemistry community. Searching for connections and divergences also helped me to see possibilities for revisioning.

Using students' lived experiences as locations for revisioning science does more than validate their personal experiences, although I believe that to be a very important act. Because personal experiences occur within and are reconstructed through social frameworks,

students' experiences should shape the social and political dimensions of our class conversations. I can legitimate particular ideas about and experiences in science which challenge long-standing power arrangements in science and education. This kind of valuing of lived experience in science class complexifies individual and collective images of specific science content as well as overarching visions of science. I believe that these images of science and each student's developing relationship with science are more important than "mastery" of particular scientific concepts.

This dimension of lived experiences is central to what happened in my attempts to teach the gas laws in the summer semester. The students constructed their own knowledge about the gas laws and about what is important when they study the gas laws. Their knowledge was generated sometimes in opposition to the hierarchical scientific tradition, a tradition which labeled their everyday experiences in cooking, playing with children, and working on mechanical gadgets as irrelevant. The students found their experiences with gases as important and more complex than science could describe. We openly struggled against the powerful claims of the dominant scientific culture of true descriptions of the world.

Helping students reconstruct their relationships with science through challenging the norms which structure those relationships is a critical piece to my feminist liberatory agenda . I hope that the students, through the process of naming their own experiences in science, can begin to reinvent their own relationships with science, and in the process reinvent their own science. Through sharing their personal theories of the gas laws constructed through a lifetime of experiences, science students could use their own lived experiences to define science, both in practice and content.

Feminist liberatory education and teacher action research as pushing the boundaries

My training in science has taught me many things, one of which was that professors and other scientists have all the answers. I know that I am exaggerating. I never believed that my chemistry professors had "all the answers," however I did believe that they understood their

subject quite well and understood everything they told us about in class or asked us on exams. Connected to this, I also believed that every question had an answer: The answer might not be known, but it could be "discovered." And so, when I learned about social constructivist theories for the world and what these theories have to say about scientific knowledge, I had to—I wanted to—put my well-ingrained beliefs about the nature of science to the side, because the social constructivist theories made more sense to me. Because I had been trained so well in the positivist paradigm, much of my beginning thoughts about teaching a feminist liberatory chemistry were only partially located in a social constructivist framework. I "know" now that many of my ideas about teaching a feminist liberatory science were also located, contradictorily, in a positivist framework. I believe that the overwhelming positivist framework in science and science teaching helped to promote this perspective on my part.

For example, I was stuck in theorizing a revisioned science for much of the spring semester: I knew the generalized feminist critiques of science well, but every time I tried to "do" a revisioned science in the spring semester I did not know how to convert generalized theoretical ideas into practical chemistry. This very kind of thinking positioned me within a positivist framework—I had the answers, and I needed "to construct" this "liberatory and social constructivist" vision of science for my students.

Reflecting on the oral histories projects and having the summer conversations with my students helped me to understand this contradiction in my teaching beliefs and actions. For example, in the summer conversations, Tracy and Gene talked about the political nature of science education and how we are all a part of "power relationships". They also talked about how these circumstances have an enormous impact on what we do in our science classes. Being able to articulate how we are all so caught up in such power relationships is a big reminder for me of how we are defined in terms of these power relationships—as teacher and student, scientist and nonscientist, men and women. It also reminds me of how these definitions impact the ways in which we think we can talk and be inside and outside of chemistry class.

Tracy's insight into our actions during the spring semester and the connections she drew to her personal life, helped me to see how valuing our experiences pushed on these power-relationships. I had to find more ways to allow the students to shape our class and the science in our class through their wants, needs, and beliefs. Tracy's and Gene's ideas about who holds knowledge in science and society suggest that a feminist agenda goes beyond pushing the boundaries of power relationships in class to also helping students become aware of the power relationships in science as well.

As should be clear by now, one subtext which permeates this dissertation is what I refer to as "pushing the boundaries"—of what it means to know and do science, to teach and learn science, to research and to be a feminist. Some of my friends have looked at my project and shared their enthusiastic belief that I had embarked on an incredibly ambitious yet needed project. Some of my friends have argued against me that the scope of my project is too large, that I am trying to tackle too many things at one time, that to revision science, teaching and research methodology creates too many variables or that it is not the job of science educators. It is a messy project.

I think that despite the ambitious nature of my project, there is really no other way to do it. Yes, it is messy. But then again, my life and my students' lives are messy. The lives of the people reading (and not reading) this dissertation are messy. None of us ever asked to be born into a world full of power relationships which derive their strength from racist, sexist and classist practices. We never asked to be born into a science and education guided by an excluding and silencing ideology. But we were. And in my intellectually and emotionally guided passion to subvert these tendencies in science education, I view my actions as teacher, researcher and scientist, as intimately connected—in constant interplay. Without challenging all of the factors simultaneously, I am boxing in my chances to change the other factors.

To learn science in a "liberatory way," I asked the summer semester students to rethink their visions of school science—of western science—and to articulate their questions and needs for science. I asked them to see how their questions came from their personal and lived theories

of acting and interacting in the world. By exploring science this way, many students had a space to explore how their ideas compared to the acceptable theories promoted by the institution of science and those who work to uphold its traditions (scientists, teachers, etc.). Many students' ideas differed from western science, and many saw their own ideas reinforced by western science. I asked the students to value their own questions, arising from their current life situations rather than relying on answers to generic science questions from other experts' investigations. Because this approach was different from many of their usual experiences of science or school, I asked them to deconstruct, readjust and clarify their senses of education, science and self in learning and living science (Hollingsworth, 1994a p. 200; Lather, 1991; Greene, 1988).

An issue this raises for me connects to the authority that I hold as teacher and scientist—as validator or silencer of student ideas. My experiences as white, middle class, female, scientist, teacher have helped me to read gender into classroom activities and into science. I find it easy to locate classroom discourse within the realm of "learning science" as well as in the realm of "learning gender roles." I painfully witness many of my female students, such as Shellie or Laura, giving up their ideas because Dave or Bill had "better and more official" explanations for why things happened in chemistry. I painfully witnessed many of my female students declare their incompetence in chemistry, their fear of the math involved in solving problems, and their struggle to locate meaning in chemistry concepts while many of the men suggest that they "like chemistry at its core" or patronize the women for feeling dumb.

In reflecting on my own teaching-researching actions from both the spring and the summer, I believe that I have problematized gender in the teaching of chemistry. I also believe that my attempts to problematize the middle class academic values in science by valuing and using the working class experience of my students to rethink science—many of their experiences in manual labor, domestic duties, and alienation from the culture of school—were good beginning points. However, I also see my treatment of race and ethnicity as highly inadequate and I need to think deeper and harder about how to theorize and practice race and

ethnicity issues in science class. Part of me recognizes the paralysis I felt as I worked to push on the gendered relationships in an overwhelming patriarchal practice—that it took a great deal of attention, energy, and courage to confront this aspect publicly with my students and department. Yet, part of me knows that I relied on my white privilege in class to keep a sense of comfort, a place of familiarity.

My husband and I talk about how my teaching is often a practice in helping students get out of their comfort zones—to confront their own oppression and privilege so that they "know" how they have been inscribed in science class and can then move forward to actively construct new relationships. This kind of teaching also forces me out my comfort zone: Admitting my oppression and privilege to students and sometimes to other faculty violates the traditional and assumed positions of teacher and scientist. I feel vulnerable and afraid. I know though, that in my future efforts to teach chemistry, I will need to work harder to create spaces for us to read race and ethnicity into science. I need to push harder on those boundaries for my own understanding of science and for my teaching practice, as well as for my students.

I believe that there are no answers to these difficult questions, however this does not make me lose hope. The creation of a critical awareness of science in our lives in science class is an evolving thing, and we need to continue to read gender, race and class into science and our practices in the classroom if we want to continue to push on the boundaries of what it means to know and do science.

The evolving nature of feminist praxis and feminist liberatory education

Positionality is a messy way to think about teaching science. Through this study, I have found that articulating my own position among and within various groups, the understandings I have because of these positionings, and how these influence my relationships in science class helps me to develop a critical awareness of my own personal beliefs and values about science and education. Because examining and articulating a teaching practice through

positionality is self-reflexive, it helps me, as a teacher-researcher, to rethink continuously the values, knowledge and practices which go into teaching a liberatory science.

The reflexive relationship between articulating and critically examining positionality is also a location of transformative praxis. By locating my research methodology as a subjective political act for social change, I am creating an evolving form of transformative feminist praxis. A political commitment in research to change and be changed is a form of feminist praxis, because it "encompasses both reflection and action as a form of inquiry that promotes a better, fairer, more humane world" (Miller, 1990, p. 13). For example, as a teacher, I draw on my knowledge of science, the students, and the larger social context of schooling in order to promote the kinds of teaching and learning I feel is appropriate in introductory chemistry. I know certain things about my students, chemistry, education theory, feminist theory, and liberatory education. I also know that my ultimate goal is to help students build a relationship with science that does not deny their lived experiences, is critical of the ability of science to speak for people, and also interrogative of personal and communal values. Part of this relationship is knowing how to interact in and with the culture science. This is important because it requires a knowledge of the scientific culture and a knowledge of the connections and divergences between a "home" culture and the culture of science, in order to interact with science.

These ideas played out in my teaching-researching. Laurie, Tracy, and Gene, as well as my summer semester students taught me that feminist praxis is, by its nature, evolving. Part of doing feminist praxis as a science teacher is finding ways to help all of us use our agentic positions to challenge ideas, beliefs, relations in science that silence or oppress our lived experiences. The process of sharing stories of our lived experiences in the summer conversations and in class during the summer semester, highlighted the agency we all have in changing the science in our lives. By creating opportunities in science class to understand how knowledge is constructed through experiences, we learned how such knowledge reflects subjectivities, and how it relates to power, privilege and oppression. We were able to interrogate the assumptions

of scientists and society. For example, by having the chance to rearticulate and give new meaning to our experiences in the study of the gas laws, we developed a better understanding of how the power arrangements influence our relationships with and in science.

I hope that my dissertation shows how my ideas about feminist liberatory education and about praxis have changed slowly over time through the course of teaching-researching. I believe that allowing the stories of the lives of my students to intervene in my own life, and in my teaching and research, has taught me that any sort of liberatory learning setting in science requires an examination of lived experiences in science. Because our lives are our theories for science and our interactions with science, how can a feminist liberatory education (and praxis in science class) be anything but evolving? I will never know how my students' lived experiences will locate them in science or locate the science in their lives without creating a setting within to explore that issue together. I can know science as my own life has allowed me to interact with it, and I can develop a growing knowledge of how my present and past students' lives will have interacted, but these can never serve as a fundamental understanding of how my future students will interact with science. Even if they could, I am constantly changing, so my interactions with students are continuously altered. For these reasons, feminist liberatory education can never be certainly defined; it is constantly shifting.

The need for moving relationships in science

My dissertation is a reflection on my journey as a feminist teacher-researcher. As I have struggled to make sense of science, teaching and learning, and feminist liberatory education, my ideas about what counts as learning in science have been shaped by my reflections and my students' lived experiences and ideas. Critically rereading our lived experiences gave me insight into how the students and I are positioned in science and education and the kinds of relationships we have with each other and with science. This is a different interpretation of positionality than my efforts at the beginning of my dissertation teaching-research because it

emphasizes how our positionality—and awareness of our positionality—shapes and moves our relationships in class.

Teaching a feminist liberatory science through "moving relationships" emphasizes the relational nature of knowing, thinking and doing in science class, and how all of our knowledge about science and about ourselves in science is wrapped up in our relationship with science. These relationships evolve over time and reflect the power arrangements established by a patriarchal, capitalistic and white society. This is important because by pushing on the boundaries of our relationships in science, we can develop new relationships in science and a revisioned science. In other words, by challenging how science is defined (positivistic standpoint) and how science defines us (through hierarchical dichotomies and inscribed identities), we can value the complexities in our lives and read science from the standpoint of these complex lives. As assumptions about what it means to know and do science, and about who can do science are challenged and changed, relationships move, science changes.

This was and is a very complex and emotional process for several reasons. First, we had to constantly reform new relationships with science and with each other because of the issues raised by the on-going oral histories conversation, as well as my attempt to value the students' lives in our study of various topics. Consequently our relationships in class were always "unsettled." This is a very uncomfortable place to be, because certainty and assumed traditions in science education were not guaranteed. Even students who actively resisted this process were always engaged in it to some degree, because of those who kept making lived experience in the class an issue (especially me).

Second, because each student brings different lived experiences to class and because of my feminist goals, I would not always understand or value each student's lived experience equally as locations for revisioning science. Even though I try to value all lived experience as a text to be reread with a critical eye, and as a way to articulate instance of privilege and oppression in science and connections and diverges with science, I know that I do not always succeed.

For example, I think the case of Maggie, a student from the summer semester, points towards the complexity of feminist liberatory education. Maggie, a woman, comes from a highly educated family and is highly educated herself. She was home from a prestigious four year college and had enrolled in the community college over the summer simply to learn. I believe her education and family culture have shown her what ought to be valued in science. Being a "good girl" and a good student, she had successfully learned that her lived experiences were not all that important in science. I remember very clearly her struggle throughout the semester with the subjective-objective nature of science. She shared with me several times that she understood why I felt it was important to raise with the students historical and philosophical dimensions of science in class, but that ultimately it was not important. In the end, back at her school and in her potential career as a scientist (biologist), it is her command of the subject matter knowledge, not the history or philosophy of science which was important. As she wrote in her journal, "I find the history of science very interesting. I believe that science is not objective or positivistic. But, that does not change the fact that a mole is a mole and an atom is an atom!"

To say the least, our relationships with each other and with science are messy. My intent is to help my students recognize the boundaries of these relationships and change them so that our complex lives are valued. Therefore, I pushed the students to be critical of the texts⁵⁹ they were reading because those texts denied their reality. I believe that by inviting our lived experiences into science class in a way that emphasizes the students' (and my own) complex construction of the world over the neatness of science, I allowed us to challenge and change our relationships with science. Because many of us challenged and changed our relationships with science, our assumptions about what it means to know and do science and about who can do science were shifted. For some, science was shifted.

⁵⁹I intend a double play on this word: the textbook and the more general text of science and science class.

What can the educational community learn from teacher research, liberatory education, and feminist theory?

As I finish writing this dissertation, I am also preparing to teach TE 402 during the summer session for post baccalaureate students at the university, so that they can begin their teaching internship this fall. TE 402 is a "progressive version" of science teaching methods for preservice elementary school teachers. It is progressive in that the purpose of the course is to prepare students to teach science at the elementary school level, but not to teach them a prescribed formula for doing so. As I reflect on this story I have tried to tell in my dissertation and what I am going to teach this summer, I wonder what, if anything, my dissertation has to say to anyone teaching science or preparing to teach science. What, if anything, does my dissertation have to say to me and people like me who are preparing teacher education courses?

Although I believe that my dissertation joins in the conversations on teacher learning, student learning in science, feminist readings of science education for "all," and feminist teacher-research, I would like to address the last two conversations only. I chose these two conversations because one of my original goals as a researcher was to examine the possibilities of teacher research as a space for theorizing about and practicing an inclusive feminist liberatory science education. I direct my reflections here to teachers and teacher educators who are interested in similar issues.

Science for "all": Interrogating the all

The stories I have written in this dissertation reveal the experiences and theoretical standpoints I have developed as I have been shaped by and have tried to shape what it means to be a feminist women science teacher-researcher. Since I embarked on my dissertation, my purpose has been to explore positionality and feminist liberatory science education. I wanted to create a different version of a "science for all" than is promoted by current national reform initiatives (refer to Chapter 2). What I discovered along the way was that this dissertation is about much more than positionality and feminist liberatory education, that it is also about my

students, science, and me, and how we all struggle together to find meaning in science class. I did not discover this alone. My students, through sharing their stories with me, inside and outside of class, pushed me to rethink my practice as a teacher-researcher-scientist and to interrogate my own vision of positionality and a feminist liberatory education. They have taught me to consider what it means to teach a feminist liberatory science differently by sharing their lives with me. By listening to their wants, needs and desires for the science in their lives (which some of them would still not want to call it science). I began to understand the complexity in bringing the "all" into science. I began to build new ideas about the purposes and goals of a feminist liberatory science education.

Revisiting the spring and summer semesters: Recognizing the exclusiveness of feminist master narratives and what it means to value all lived experiences?

As I recognized through listening to and trying to value students' lived experiences, my students are positioned differently than me in science and education. My choice in the spring semester to determine what they needed to know was reworked in the summer. In teaching the gas laws, I moved from one set of goals (teaching students the acceptable science, then critiques of science with the expectation that this knowledge would enable us to revision science) to a new set of goals (allowing students to construct their own science about gases through their experiences, and using these experiences to interrogate the acceptable science, and our relationships with science).

In the summer, I allowed the students' lived experiences to be the curriculum in our learning of the gas laws. However, I also recognized that not all students' lived experiences were equally valued or legitimized in our class. There were several competing factors and power arrangements which ensured that this was the case. When I teach chemistry, I impose my feminist values and political agenda on my students and their learning. The values I enacted through my agenda were formed from my own lived experiences and reflect my interactions with a variety of often times competing groups. In other words, as a white

academic feminist and a chemistry teacher, the knowledge that I bring to making sense of what goes on in the classroom is often full of contradictions because I have been socialized to view the world as white woman, scientist, student, teacher, feminist. My personal values often come into conflict with each other (such as wanting to help students see the beauty and the horror in science) or come into conflict with students who come from different backgrounds and histories (such as the conflict inherent in valuing a student's idea which may be oppressive to me or other members of the class). Not only do these conflicts exist because I impose my agenda on the students or because the department imposes its agenda on all of us, but also because the students impose their values and agendas on each other and me. What I think is important in science class is sometimes in conflict with what the students assume is important or want to make important (i.e. Maggie and Bill). The students and I interact within inscribed roles and relationships (Luke and Gore, 1992). Finally, there are the values which science has been imbued and the values promoted by the society in which all of this takes place.

In my dissertation I have tried to interrogate through my teaching-researching the "all" in thinking about the popular idea of science for "all." I have learned how conflicted this "all" is, and how deeply entrenched meritocratic visions of science are in schools. Through this work I have learned that a science for all requires that science be changed in order to be open to the multiple experiences that "all" bring. For me, teaching a science for all has partially come to mean that it is important to create spaces for students' lived experiences to be articulated with and against science. Creating spaces for students' lived experiences helped me in my search for ways to uncover the grand narratives which structure learning in science class. It has also helped me to reflect on how feminist theories can help my students and me to create a science teaching and learning setting that seeks to help us understand, critique, and revision science, and our relationships with science, from our multiple and lived perspectives, and to create a science education which invites and supports diverse experiences and participation in science, in an effort to inform the goal of "science for all Americans."

Questions, concerns, and contradictions in liberatory science education that have arisen in writing this dissertation

Teacher research is critical to feminist research agendas because it helps to identify and address ideological concerns in the teaching and learning of science. In order to come to a greater understanding of how a feminist agenda can be lived in the classroom by teachers and students, it is necessary to understand how a teacher's actions and reflections can be informed by underlying assumptions about science and school. I know that my own personal reflections on what it means to bring a feminist agenda to science education have made it obvious to me that the ways in which I act upon my own feminist teaching agenda are contextually dependent. I make sense of my feminist teaching agenda in connection with my understanding of myself and the world, the understandings and experiences which my students bring to class, and my interpretation of those experiences, and my beliefs about the content that I teach. This reflexive thought in teaching can move science teaching towards its liberatory potential.

Throughout this text I have highlighted some tensions and contradictions in feminist liberatory science education, alluded to others, and unproblematically silenced others still. So, I use the space of this next section to revisit these tensions and to raise new contradictions in liberatory science education. I then reflect on each dilemma without offering solutions, because I have none. I hope that these reflections express a sense of agency, because my sincere belief is that even though these contradictions exist in my own thinking about liberatory education in science, I still believe that the act of raising them is important and ought not be paralyzing.

Locating possibilities: Learning the anti-official science

Science is a pervasive force in this society. It plays a significant role in shaping society's view of valid research methodology and valuable knowledge. It also shapes our physical lives through transportation, communication, nutrition, and health. I do not hope that all people choose a "career" in science, or that any of my students do so. However, it is my hope that our science does not dampen any person's agency to work for social justice or anyone's

ability to imagine a world without social-power hierarchies. My intention as a feminist teacher working for liberatory science education is to work with students to create spaces where their lived experiences, their hopes, dreams and fantasies, are part of their exploration of the world and its mysteries—including, but not limited to science.

Tim Lensmire (1994) writes about Bakhtin's description of carnival, a medieval cultural event where people had "the right to emerge from the routine of life, the right to be free from all that is official and consecrated" (Bakhtin, 1984, p. 257). Lensmire describes this right to emerge from the routine of life as people's "second life" which is "both unofficial and anti-official" in that the "playful, fearless spirit of carnival loosened the grip of established norms and relations and allowed alternatives to emerge in their place; anti-official because this same carnivalistic spirit engendered and supported the criticism and mockery of the official social order and ideology." (p. 373). Lensmire goes on to write that:

Carnival is life turned inside out and upside down. This disruption of life's routine, and especially the temporary abolition of power social hierarchies, allows participants to experience relations with each other and the world that are unavailable to them in everyday life (p. 373-4).

This notion of carnival dramatizes the importance and limits of theorizing about science through positionality and lived experiences in feminist liberatory education. The very act of teaching students the culture of science, or the ways of being in science, is an explicit suggestion that there are certain ways of acting and being in science which are right and certain ways which are wrong. There is no room in the routine of science to place science inside out or upside down. There is no room to explore alternatives to the power hierarchies which attempt to bound and categorize our social and physical existence. There is no room to reposition ourselves, to shift the meaning of knowledge publicly. Therefore, part of my feminist agenda in science education is to create a learning community among students where we can explore ideas about science, ways to be in science, relationships to have in science which are continuous with and interrogative of our lived experiences. As I look back at my teaching over the past three semesters, I see instances where this happened, and I recall shifts in our understandings of

science and ourselves in science. These instances are important not just because the students may have learned something about the world around them, but because they and I learned something about our being in the world. We learned about and experienced new kinds of relationships in science, new kinds of social relationship with each other, new kinds of acting and talking in science class. Experiencing this positional way of knowing gave us space to bring new language to understanding the official and routine practices of science, a space to imagine what life could be like without the routines of science.

Gloria's and Rita's talk about the whoopee cushion as their way of understanding the gas laws is a powerful instance where the routines of science were turned upside down and inside out. Not only were they able to explore what they knew about gases in ways which connected to their lived experiences, but they also challenged the authority and status of science. I think that part of their decision to bring in the whoopee cushion was to challenge the authority of science to define what is official, and to challenge my own authority as teacher of science to label what is official. It was an attempt to make the antiofficial, official because the physical presence of the whoopee cushion and its artifacts—the laughter, teasing, and repulsive behavior associated with its sounds—criticized and made a mockery of the official social order and ideology of science.

Rethinking limitations

This study raised questions about the limitations of lived experiences for revisioning science. First, because we learn to think and act within social arrangements in society, many experiences we have (and the ways in which we interpret those experiences) do not challenge the traditional practices of science. In school, we are often taught that our ideas are a consequence of the ideas of western science, which becomes one of our lived experiences. How can we use experiences born of western science to challenge western science? Second, what if the experiences that students bring to class promote power hierarchies which are oppressive to members of the class or at least contradict the beliefs and feelings of other members in the

class? This happens all the time. For example, Sol's decision to use the squirt gun to shoot the dog as a way to express what his group knew about the relationships between the physical qualities of gases, was a violent act that hurt me and my value system. When I tried simultaneously to value his experience and share with him why I felt hurt by his actions, I think that both of us closed up. Neither of us learned from each other's experiences as we might have been able to if neither of us had felt so attacked.

Physical and ideological location of the community college

Another question that has arisen connects to the tenuous nature of my position in the community college. As an adjunct faculty member, I am employed on a semester by semester contract. If the college does not desire my services, then it is not required to provide me with a new contract. This makes it very easy for the college to control the nature of its faculty. Furthermore, the introductory chemistry course that I teach is meant to reach a large number of students each semester, and therefore requires a large number of teachers (usually 2-5 teachers per semester). It is set up by the department chair to accommodate a large turnover of teachers. When I first started the course, I was given the textbook, syllabus, and three exams. I was asked to create three exams on my own, but was assured that within two years, the department would prepare all six texts. It seemed clear to me that the department chair viewed me in a similar light as the students: A body to be moved into its proper place, given its proper assignment and the physical tools necessary to complete it, then left alone. I was viewed as a *replaceable automaton*, although I actively resisted that label.

My location in the community college raises other interesting and contradictory questions about the purposes and goals of science education, and liberatory science education as well. The community college holds a unique place in the education system. It is often considered the "bridge" between high school general education and the more specialized knowledge and rigorous work of various professional schools or colleges. It is supposed to serve

as an extra bit of support which some students may need to develop confidence in their academic abilities or to develop skills in particular areas needed for further study.

I have found this notion of the bridging course to be highly problematic in my own interactions at the community college, primarily because the science department bases its authority on the intellectual tradition of science. That is, I see the science department at GCC as practicing and promoting the long held view of science as an intellectually demanding discipline in which only the best and the brightest can succeed. This rings true in the history of Chemistry 125 which I taught and which has a tradition of high drop out rates, low average scores, and a focus on abstract decontextualized knowing. All of this seems rather ironic given its mission as a bridging course.

In many ways, GCC is better described as a holding place where students go waiting to get the "okay" to move on. Students at community college are waiting to get the word, the validated certificate, which allows them to move on and up. The current structure of Chemistry 125—a prescribed knowledge base to learned, a prescribed set of exams to define the proper mastery of that knowledge base, a goal that 70% is the average achievement in the course, a high drop out rate, the lack of room for teachers to shape the course to their students (unless they do so problematically in the eyes of the department)—clearly defines the qualities needed to cross the bridge. The most obvious quality needed for successful crossing is conformity to the routine of school and science.

An important question is then raised for those who seek a feminist liberatory education in the community college: Will the students who have learned to construct a relationship with science which decentralizes the authority of science contribute to their own oppression because they refuse to conform in science? Will they therefore not receive the appropriate credentials? I would like to believe that this is not the case. I would argue this position with Gene's ideas: There is both ignorance and intelligence. I do not believe that the sole purpose of education in science is to propagate the scientific knowledge base by herding students from pasture to pasture. This is knowledge with ignorance. If the knowledge base of chemistry can be discussed

in class through productively locating differences, then students can choose their own pastures, and there may be less ignorance, at least on the part of the "masses."

I am reminded of Patti Lather's reflections on the work of Lentricchia, when she writes that "Lentricchia's pedagogical strategy uses deconstruction to help students create subject positions such as a kind of new person who's not going to be satisfied with the usual canonical things" (p. 122). I believe that education in science is important only in that it teaches students how to (de)constructively deal with the science in their lives intellectually and politically. Education in science has traditionally pushed students and teachers into totalizing categories (and I have contributed my fair share). I believe that if an education in science values the multiple and contradictory sites from which we all engage each other as well as science in the material and intellectual space of science class, then science class can be viewed as a fluid social setting requiring but also promoting changing agentic selves (Lather, 1991).

Labeling and categorizing students' identities

Another issue I've struggled with is how I ought to label students as female or male, white, Hispanic, or African-American is to impose an essentialized way of acting and relating to each other in class. It imposes definitions of self and other which deny the complexity in our lives, complexities which are a result of positionality. It also conjures up (both consciously and subconsciously) a master narrative hierarchy of acceptable ways of being. Thus, the social positioning of these identities (due the ways in which they have been constructed through hierarchical dichotomies) applies a value judgment even before the student (or teacher) has a chance to live their own life in my classroom.

Yet, my experiences as a white middle class woman in science have taught me there are real consequences due to these identities. Society has constructed these identities, and enacts social practices through them. I want to help students to become aware of how this may shape our understandings of science, as well as the kinds of relationships we have constructed in science. How can I use these categories productively so that they exist as locations from which

to deconstruct our understandings of science and each other, but so that their locations are not so fixed that we use them to bound our notion of who we are?

Political agendas and the "apolitical" nature of schools and science

Moving (out of ones place) we confront the realities of choice and location. Within complex and ever-shifting realms of power relations, do we position ourselves on the side of colonizing mentality? Or do we continue to stand in political resistance with the oppressed, ready to offer our ways of seeing and theorizing, of making culture, towards that revolutionary effort which seeks to create space where there is unlimited access to the pleasure and power of knowing, where transformation is possible? This choice is crucial. (hooks, 1990 p. 145).

This reality highlights some of my biggest concerns in feminist teacher action research: Is the point of feminist research only to document as "objectively" as possible, what goes on in schools, classrooms, and learning environments, or is it part of feminist research to use what we learn to enact change—to do action research? Because of the conception in our society that schools are "apolitical," it is difficult to engage in feminist research (and teaching) and make our political agenda explicit without getting an angry group of parents who do not want this agenda thrown at their child, or an angry department chair who disagree with the goals and the purposes of a feminist agenda or with "being political." How can we acknowledge the political intent of our research and teaching without being dismissed, having our classes, and our research time, and money rechanneled or reassigned?

Feminist theory has challenged me to explore how it is that I use my position in the classroom, and whether that leaves room for students to explore their own positions. It forces me to begin to question what right I have, as a teacher, to bring my political agenda into the classroom with the expectation that students will take it seriously. I am left wondering if my attempts to construct a more liberatory teaching and learning setting through the exploration of positionality as teacher, student, woman, and man, in science is an act on my part to force my own agenda "down their throats."

Retrospective writing of a teacher-researcher

Inherently problematic to this dissertation is the fact that I have written about my teaching actions and reflections retrospectively. Although I kept a teaching journal and copies of my responses to students' journals which give evidence to my thinking and teaching at a particular time, I write from the perspective of a teacher-researcher who holds evolving knowledge of teaching, science, students and self. My reading of what happened in the spring semester is shaped by what happened in the summer semester, and in my later thinking and writing. New insights into feminist theory and science education shape the interpretation with which I read my past teaching-researching.

I do not view this inherently problematic situation as limiting. In fact, it has been through these rereadings that I have worked through limitations and other difficult spots in my reflections and in my teaching practice. Similarly, it has been through these rereadings that I have reworked practices which seemed helpful in my attempts to teach science feministically. Although I believe that it is important to acknowledge how this retrospective writing shapes my story, I also believe there is no other way to write the story. How I currently read my teaching in the spring reflects the reality of my current beliefs.

Collaborative conversations

Collaborative conversation played an integral role in my teaching-researching. While entrenched in the discourses and practices the institutions of science and education, engaging in conversations with fellow teachers, researchers, and students. These conversations helped me develop a growing awareness of the practice and tensions I experience as a feminist science educator. Collaborative conversations also helped me to uncover some the assumptions I live, teach and research by. Through "collaborative conversation" (Hollingsworth, 1992) with students, my knowledge of self and of science was challenged, and in the process we created multiple opportunities to weave together our unique knowledge of science, self and others. In

this sense, conversations helped me and several students to create opportunities to deconstruct and reconstruct lived experiences, and helped to nurture instances of re-vision.

The most moving and transformative aspect of my own teacher action research process occurred in allowing the lives of my students to enter into my own life in deep and personal ways, and to allow myself to be changed by those interventions. For example, one of my students, Tracy, initiated a long term conversation with me which focused on our lives as women, and on ideas which were raised in the chemistry course I taught: What does it mean to be a woman in science? What role does the elitism in science play in our own science education, and from where does that attitude receive its energy? How are the values of dominant society imbued in the knowledge we construct about science in our classroom, and what are those values? In a critical, yet caring way, Tracy helped me to understand my own feminist liberatory agenda from the perspective of a working class student who has boycotted formal science courses for a decade. I have initiated similar long lasting conversations with other students in my courses.

The questions and issues that I raise here connect to Sam Hollingsworth's (1994a) work with collaborative conversation and the idea of positionality as it has been worked and developed by Maher and Tetreault (1993; 1994). My developing attentiveness to the lives of my students shaped my teaching and my research in ways that I had not expected. By inviting students to assist in the analysis of the course, it was not so easy for me to impose alien constructions on their experiences. It required me to re-interpret my reading of our chemistry class and the nature of feminist liberatory education. These conversations became more than a casual interaction; they became an intervention by me into their lives and by them into mine. This kind of transformative praxis moved me towards a more collaborative construction of reality, helped me to construct new interpretations of my prescribed research questions, and transformed my vision of feminist liberatory education.

But now I know a great deal about my students, and they know a great deal about me. In the process I believe we have created new ideas about science, ourselves in science, and feminist theory in the classroom. I believe that we have created new personally relevant theory

through examination of our lives. I have seen some of my students (and myself) make incredible changes in attitudes and beliefs and actions regarding science and society (and one person—a physical science teacher— even changed school districts because of the "elitism" in his district defining what was important in science), throughout the course of these conversations. Where does the feminist pedagogue begin and end her practice in (science) education? For me this question raises an ethical issue: How can I justify or even explain these decisions to the bureaucracy who in the name of white middle class masculine ideology names the beginning and the end of science education with the science itself? Although I do not credit our conversations for the changes in attitudes and careers made by my students, I do see them an important, supportive, and radical venue in which the participants could explore ideas that may not be accepted by status quo in science education or anywhere else for that matter. They therefore helped them and me to make such changes).

Looking ahead

For me, in many ways, this dissertation has expressed the complexity of feminist work in the 1990's in the United States. There are many interconnected, overlapping, disjointed, paralleling and contradictory pieces. Traditionally, writing a dissertation takes place within a specified format. There are allocated spaces for the literature review, methodology, data, and conclusions. It is supposed to be very "scientific": The researcher goes out and "discovers" some set of Truths for the education community to use in its pursuit for knowledge. The researcher has become an expert in a particular area and holds valued knowledge of something new and unique. This notion is modeled after the positivist theoretical framework traditionally used in science. Scientists "discover" knowledge which is useful and meaningful. Educating others in science traditionally follows the same ideology: Teach students the knowledge of science.

My convictions born out of my lived experiences and interactions with others, tell me that at no level—scientific research and writing, educational research and writing, and teaching—is objectivity possible, and that there is no method which can guarantee certainty or generalizability. At every level, our knowledge and our relationships with knowledge and others is contextually dependent. To make meaning out of contextual artifacts requires a constant rereading and an understanding of the multiple locations in which any interaction occurs.

I am reminded of how Sam Hollingsworth (1994a) writes about teachers and teacher action research and how an important piece of such a practice is to critically reread our own assumptions and attitudes about education, because "such attitudes also influence the epistemological philosophies that we adapt to frame our teaching" (p. 200).

For example, if I believe that public institutions of education, in their current forms, prepare all children to live democratic, healthy and pleasurable lives...my social attitude would be to approve of and replicate the current society through education. Changes in my practice would be those of improvement within the same epistemic framework. If, however, my social attitudes were more critical of the results of public education, I would have to deviate from that framework and imagine another way to educate socially critical teachers (Hollingsworth, 1994a, p. 200).

Along the same lines of reasoning, if I believed that science has been used to help the human race, to make our lives easier, and to help rid the world of inequities then I would work hard to teach students what they need to know to engage in the culture of science. I would teach them the discourses and the practices of science. I would teach them the history of the institution of science which is in power now. I would help students engage in science (as science is popularly defined) so that they could use science "meaningfully" in their lives.

However, through interrogating my own lived experiences in and out of science and trying to listen to my students' experiences and their own struggle to reread (or NOT to reread) them, I do not believe that science has been used solely to help the human race. I do not believe that science has helped to alleviate the vast inequalities in our country. Quite the contrary. I believe that science, although an incredibly useful and productive tool, hurts everyone to some

degree, and hurts some people quite a bit. I believe that science has perpetuated, and at times, intensified inequalities. For example, industrial waste dumps are more often found in low income and minority neighborhoods. Cardiovascular stress tests machines do not perform adequately on women because "breast tissue gets in the way". The list goes on: Laurie's family's struggle with cancer because of the use of toxic pesticides in her hometown of Andover; Val's struggle to be recognized as a human being rather than an object in the delivery room; Gloria's fight to be heard over the weird metal balls; Gene's conflict with the science department where he taught. I am critical of the results of science and I am critical of any educational process or method whose primary purpose it is to indoctrinate children or adults into the scientific community without helping them to develop a critical awareness of the uses and abuses of science in both its process and product.

My lived experiences, as a white academic feminist woman in science, have brought me to this point in my thinking. Science has not always been a source of freedom in my life, and I know that it is not always the source of freedom in the lives of others. Just as science has silenced and marginalized the complexity I experience in my life it has also been used to promote my agenda. The relationships we have in science are messy and complex, but if as teachers and researchers we value that complexity with students in self-reflexive ways, then we can begin to live a revisioned science.

Journal May 31-June 1, 1995

Right now I am high above the Pacific Ocean. It is dark out, as it has been since my plane left Auckland over six hours ago. I am not sure what time it is where I am, but I do know that it is 1:08 a.m. Thursday morning June 1 at the airport in Auckland where I departed, and it is 6:08 a.m. Wednesday morning, May 31 at the airport in Los Angeles, to which this plane is headed. This isn't my favorite or my usual place to write. As a matter of fact, this is only the second time I have flown over the Pacific Ocean—the first was last week on my way to New Zealand (Aotearoa).

I have to write this journal by hand and type it into my computer later because the batteries to my laptop computer ran out long ago. They are supposed to last two hours each, but they conked out after only 40 minutes. I think that the change in voltage between my home country and New Zealand might have been the cause. Then again, maybe it is the spirits which lurk above the earth. We just hit

some turbulence, the pilot says. Maybe the spirits quivered when I invoked their names.

I write this journal entry because I have been thinking about Rose, whom I met on my trip to Christchurch, a small city on Aotearoa's southern island, where I visited the University of Canterbury. Rose is a vibrant Maori woman who, as an educator, teacher, researcher, and community activist, draws heavily from feminist theories and native Maori writings to find ways to bring Maori voice and customs back into New Zealand education. Rose tells me that Maori people came to the islands of Aotearoa (New Zealand) many years ago. They are the "indigenous people" of the island. The Maori, as were the 500 tribes of North America were dominated—colonized and missionized—by English settlers several hundred years ago. Since that time, the Maori have worked hard to keep their cultural heritage. As Rose tells me much of the Maori oral culture has been lost over the last three centuries as the settlers have engaged in a successful campaign of cultural assimilation.

Rose also told me that the Maori have their own system for explaining their world based on their own observations. The "ways of knowing" Maori bring to the world are different from western science. For example, they strive to always look at the whole. This is evident in the Maori medical practice where there is no word for health or healing, but only one word, the meaning of which extends beyond health and healing to include the material existence of the person. She told me this story because she said she was very much interested in my work. She said she was interested not only because it could create spaces for the white Pakaha way to be decentralized in the western schools that Maori children often attend, but also because the process of sharing lived experiences in a critical and supportive community allows the participants to reread their own ideas about science.

To me, Rose expressed the power, uncertainty and possibility for liberatory science education. Rose's comments remind me of the power and authority I have as a white academic feminist, teacher and researcher to choose which lived experiences in my class to value, as well as to tell others that they ought to incorporate their own and their students' life histories into their courses so that "the everyday world" and positional knowing becomes problematic (Smith 1987). Her comments reminded me of the uncertainty in revisioning science. It will never be discovered, never be complete, but always partial and changing as we work to make our understanding of the world more inclusive of multiple ways of knowing and being. Finally, her comments speak to the possibility for liberatory education in science. I do not claim to have worked through the layers of hegemonic practices which guide my teaching-researching. Yet, I know that critically rereading my understanding of science and science teaching through the lives of my students has helped me to begin to picture a science education I had never considered possible. Rose's stories of the Maori spoke to how much more we all need to learn about western culture, about oppression and colonization, and about the politics of inclusiveness.

The sun is starting to rise ahead of the plane. It is now 3:00 a.m. Aotearoa, 8:00 a.m. Los Angeles. My muscles feel cramped from riding in this crowded plane, but I refuse to feel trapped. There is much work to be done in the politics of decolonization of my own mindbody and of science education.

APPENDICES

APPENDIX A

Collaborative Conversations

I would like to share an excerpt of conversations that Constanza Hazelwood and I shared through email. I share this conversation because I wanted to highlight how the role it has played in my thinking. Constanza's reactions to my interpretations of what goes on in my class and my theorizing in feminist theory and science education pushed me to reconsider my own ideas and assumptions. Her insights have helped me to uncover many ideas about ethnicity and about students which I had let uncritically guide my thinking. I chose not to interpret this conversation for the reader because the conversations have been sources of questions for me. Each time I revisit what we've talked about, I take away new insight, and so to me this conversation, like the knowledge I construct from it, is constantly changing.

Constanza

Angie, you mentioned how you are always aware of the effort I make to communicate in English just because you can't speak Spanish. You also told me that you were playing tapes in the car to learn Spanish. You remind me of a conversation between Maria Lugones and Elizabeth Spelman where Maria says:

No quiero hablar por ti sino contigo. Pero si no aprendo tus modos y tu los mios la conversacion es solo aparente...Por eso no me debes dejar que dicte tu ser y no me dictes el mio. Porque entonces ya no dialogamos. El dialogo entre nosotras requiere dos voces y no una. Tal vez un dia jugaremos juntas

y nos hablaremos no en una lengua universal sino que vos me halaras mi voz y yo la tuya. (Lugones and Spelman, 1984, p.19).

The thought of you trying to learn my language is enough to open a door for us to communicate. I enter a conversation when I am certain that people will take the time and put in the effort to understand what I am saying. I believe this is true for many people whose intention is to communicate with others. However, the goal of being understood is particularly relevant when you are speaking in a foreign language. As one who needs to put her thoughts in a language other than her mother's tongue, I find it necessary to know that the Other person is willing to give me a chance to speak with an accent, with my own idiomatic expressions, my own style, but also to learn how to relate to my experiences.

I guess you could look at our conversation as an unbalanced situation where you are home, speaking your language while I have to translate my experiences. Some of this rings true to me, but not all of it. Learning a language is a very complex and intricate process. I have been paying close attention to it because my oldest child has been learning four different languages. I often ask: Which one is her mother tongue? And believe it or not, I sometimes ask the same question of myself when I write about my dissertation in Spanish and realize there are many things I know how to say in English but I don't have the language to voice in Spanish.

When we talk, we often use the language of feminist theorists that helps us identify and articulate our feminist agendas. We talk about patriarchy, master narratives and women's oppression in relation to common experiences. Although sometimes confusing and convoluted, we both find the language in feminist literature to be a source of inspiration and a liberatory force to inform our actions. This binds us together. And it is to this togetherness that we seem to pay more attention, sometimes ignoring the many different qualities that make each of us unique.

Angie

The language issue is a big one. As I think about teaching science and my desire to deconstruct the ways in which science and education have naturalized and essentialized the power arrangements in science class, I am reminded of another language struggle. How can I share these ideas with the students in my class the students who are primarily female and working class and ethnically diverse in such a way that would allow to come to some shared meanings. The books and articles I read tell me that these people are oppressed by the capitalistic (patriarchal, white)

system, that they are almost always the ones on the low end of the power relationship. My experiences tell me that, in many cases, this is true for women, for I have experienced that as a woman. Then if this is true, why do I have such a hard time sharing my liberatory ideas with them? Why is there so much resistance? Are they resisting the academic attempt to "strandify" (to make many strands) their lives and their experiences? This is where I need some help.

Tu eres mi amiga. Gracias para mostrarme que hay un lado oscuro de la luna.

Constanza

I told you there are dimensions of my Self I do not reveal in our conversations for fear of being misunderstood. Like the moon, I have a hidden face I don't show when we talk. The pieces of myself I offer to share with you often disconnect my gender from other dimensions of my identity that you do not know much about. For instance, we hardly ever talk about my ethnic background. Why don't we talk about ethnicity? By ignoring ethnic differences aren't we making white Anglo-Saxon the norm here?

I find it very problematic to portray myself as if I was made up of a total of unrelated pieces. This is also true about the way I think of the girls who participated in my dissertation. I keep talking about their ethnicity and gender as separate strands. This way of thinking is highly influenced by the separate bodies of literature on ethnicity and gender which deepen these conceptual divisions.

I am glad though to see us speak and think about our tendency to focus on gender as a category of analysis and a way to relate to each other. By bringing this up we are uncovering some of the power structures that make this conversation unequal, perhaps uneasy-as you point out. We are also examining the academic roots of our ways of seeing the Other to find out that we need other sources of knowledge to bring together those identities we have separated into different strands..

Angie

Did you notice the full moon last night? I teach chemistry on Mon./Wed evening and by the time I arrive at home, it is very dark, for I live out in the country where there are not many houses, there are no street lights, and there is very little traffic. I usually fumble my way up the stairs of my porch until I can get inside and turn on the light. But not last night. Last night the full moon was so bright that I had no trouble seeing. If half of a moon can give so much light, I wonder what would

happen if there was no fear or power struggles that kept the whole moon from shining.

Our conversation left me thinking about many ideas that I had consciously chosen to leave in the background: everything other than gender. And has raised some messy questions: how can we fully represent the identities of the people we study, including ourselves, without breaking things down into a zillion strands with barriers between the strands. Its like if you are not a white middle class European American male, then you are not complete, not connected. You must be classified and categorized in order to have your experiences understood. How can we begin to blur boundaries or work across borders without masking them?

Having the chance to share my fears with you about attempting to make ethnicity, class, and other isms problematic in class, has left me feeling uneasy: uneasy with my complacency, my privilege, and my power to establish norms in my class. I think you are right when you say that not talking about ethnicity makes Anglo the norm, just as I deeply believe that not talking about gender in science makes masculinity the norm. I know I have to try, even if I will make mistakes, because if I do not, then I am allowing my comfort a comfort based on a certain degree of power and privilege control how I define what is good and bad for my students. I am also left amazed at how much power I truly have as a science teacher and researcher. I have not thought about it so explicitly before. Thank you for pushing me on that issue, and thank you for not letting that part of our conversation be easy.

Constanza

Now that we are more aware of the presence of the hidden side of the moon, how do you think we can gain access to it? I am just wondering how I grabbed on to your suggestion of looking at the literature to bring together gender and ethnicity. I wish I can find enough written to help me bridge these identities and help me reveal others that I am not even acknowledging. But I am also wondering if the hidden side of the moon has been right in front of my eyes all along, but these eyes have learned to be conceptually blind to it. Will the "strandy" literature leave me with anything but a schizoid picture of the Other? After all, it was the literature that created the conceptual lenses to divide people up into chunks.

What about looking at the moon from a different planet? Maybe if we think about re-positioning ourselves to gain a different perspective, we might begin to gain access to the pieces that we can not see from our present positions.

What does this mean in terms of getting to know the participants in my dissertation? If I re-position my self in the context of our conversation sessions, I think of Victoria, Domenique, Alejandra, Marisa, Selina, Lisa, Laura, Linda, Magdalena and Lupita. When I truly let them do the talking, meaning that I trust them to guide the conversation, and I trust myself to listen, I no longer see them through the lenses of my analytical categories.

As they spoke and I listened to their stories, I was thinking of them as whole persons, not just gendered, raced, classed , aged....individuals. When I spoke, on the other hand, and led the conversation, I tended to bring us back to my foci of analysis i.e. gender, ethnicity, scientific knowledge. The tension between my agendas and theirs could be typified in terms of this tendency to pull towards some overarching themes I believed to be central to my dissertation.

APPENDIX B

Interview Protocol

June 1994

Questions for Student interviews

1. describe yourself to me. Things you like/dislike. How like to learn.
2. What is science? What are some words that you might use to describe science? What are some words that you might use to describe chemistry? Does science share any similarities or does it have any differences with other academic disciplines?

Do you think before the chemistry class last semester you would have said the same thing.
(what changed; why/why not).

3. What do scientists do? How would you describe the work of a chemist? Do you feel like a scientist in chemistry? Why or why not? How do you picture yourself in chemistry class? Do you picture me (Angie) as a scientist in class? Why or why not? Do you picture the other students in the course as scientists? Why or why not?

Do you think before the chemistry class last semester you would have said the same thing.
(what changed; why/why not).

4. What is scientific knowledge? How would you describe scientific knowledge? Is different than other forms of knowledge (say, history or language)? Are there any similarities? Would you say that scientific knowledge is objective? Explain.

Do you think before the chemistry class last semester you would have said the same thing. (what changed; why/why not).

5. What, if anything, did you learn from CHEM 125 last semester? What messages were the strongest to you? How do these messages make you feel as a person, as a man/woman, as a scientist?

6. If there were more women and minorities in science in the past (from Antiquity to the present), but the total number of scientists remained the same, would science and/ or scientific knowledge look any different?

7. What scares you the most in science class? How did it make you feel in my class?

8. How do you feel about the elitist attitude of science? How did that make you feel about learning chemistry? About coming to chemistry class? Do you think that talking about this in class was helpful in your own development in chemistry? What other power structures in chemistry (i.e. the institution of science or the institution of education – GCC) make learning chemistry difficult or uncomfortable or boring, or nonfun, etc.

9. Do you like chemistry class? Why/ why not? What are some things that you think about when you are working in class? What goes through your mind as you are trying out the new ideas/problems? What goes through your mind when you turn in your exams, homeworks, journals, etc?

10. Has your experience in science at GCC (or elsewhere - specify) changed the way that you think about science, your self and the world (science high school or elsewhere)? In learning here, have you come across an idea that made you see science differently? or think about science differently?

11. What do you think that your life will be like in 15 years? Are there things that you would like to learn about chemistry that you do not think that you can learn at GCC?

12. Describe some of the feelings you have when you are encountering new ideas in science. Are these feelings different for when you encounter new ideas in class or on your own? Explain?

13. Does science ever leave you feeling uncomfortable? Describe a situation where you might feel uncomfortable. Does science ever leave you feeling comfortable? Describe a situation where you might feel comfortable. If neither of the adjectives apply, what might be some adjectives that would apply to the way you feel? Can you describe a situation for me?

14. What do you think about the language of science? Do you think that the language of science has an impact on the way you learn science? On the way you feel about science? Do you think that the language of science accurately depicts what is happening in the natural/physical world? Can you give me an example to explain what you mean?

15. Tailor this question to the person who is answering it!!!

Do you think that being a female/ male, white/black, has an influence on the ways in which you understand science? Can you explain your answer?

Do you think that because Angie is a white, middle class female that shapes the way she presents science to you?

Read the following quote made by someone else about science a few years ago and comment:

"In areas where the right answers are known, I think the experts should tell us what is right. But, in areas where there are no right answers, I think that anybody's opinion is as good as the other."

Possible questions to answer about the quote:

In learning something you really want to know, can you rely on the experts?

When is someone an expert? How do you know?

What do you do when the experts disagree?

Do you agree with this quote?

Do you think that scientists are searching for truths? Will they find it? How about painters or writers, etc.?

Is there anything else that you would like to share that might help me to understand your beliefs about the nature of science and scientific knowledge or about the language of science?

APPENDIX C

Mini Project - Oral Histories

Requirement: Each student is required to do an oral history of a person in the Lansing area who uses chemistry in her/his life. This may be a chemist or may be a person who is not a chemist, but who uses chemistry in their job/life. All oral histories must be preapproved by the instructor. Each student or group of students will present their project to the class in a short 5 minute presentation, and will turn in a 2-3 page paper on the oral history. I encourage you to do this project in groups of two students, but you may do the project alone if you wish.

Worth: The miniproject will be worth 50 points⁶⁰.

What is an oral history?

An oral history is really an interview or conversation with another person. For this project you will, either alone or with another student, interview a person in the Lansing area who uses chemistry. You will take what you learn from the conversation with this person and share it with our class.

1. Each student will select a person for their miniproject. This person must be approved by the instructor by [date]. You may find a person on your own, or you may ask me to give you a list of people you may contact.
2. Each student will present a 5 minute presentation at the beginning of class starting [date]. A sign up sheet will be sent around the second day of class so that students can sign up for a time.
3. Each student will contact their person and conduct an interview with them (interviews should last approximately one hour). Students ought to either tape record these interviews or take careful notes during the interviews. Interviews should be done in person, but if this is impossible, they may be done over the phone.
4. Before the interview each group of students should have a list of ten to twenty questions they would like to ask their person. The questions should relate to some of the questions or concerns you may have about what chemistry is, how people use chemistry in their jobs, what is it like to be a woman or minority in science (if applicable), how these people would change chemistry if they could, what excites these people about chemistry, etc. If any one

⁶⁰I was up front with the students that if they did their project, they would get all their points. I did not want to make the project a burden.....

has concerns or questions about the questions that they develop for the interviews, please feel free to see me before or after class or during my office hours.

5. The presentation can consist of a description of some ideas about what your person thinks chemistry is that are different from your own views or from the way that science gets portrayed in society, relating to the class a day in the life of your person, or a history of how the person got to where they are. You can use the blackboard, posterboard, pictures, or handouts if you wish, although this is not required. Use your creativity.
4. I am available before and after class and during my office hours to help you with this project.

Do not let this project make you nervous!! This project is a way to bring all dimensions of chemistry into the course. It is a way for you to share with us something that you have learned and find interesting that might not normally be a part of this class. I am not grading you on your presentation style (or other things that an English teacher might), but rather on the news that you bring to the class!

APPENDIX D

Conversation Pieces

Actual comments, journal entries from the students and conversation and interviews

with students in the fictitious conversation:

- Tammy: I never realized or actually thought about science as being all around me. From the road I drive on to the entertainment of fireworks enjoyed on July 4th (journal entry 7/12/94).
- Shellie: Through the oral histories, I found there are a lot of people out there doing chemistry, thinking of ways to improve our world, and those who are concerned with making our lives safer. As for me, I now know chemistry and science is so much a part of my life in ways I never knew. I found all of the reports fascinating (journal 4/25/94).
- Tammy: I now find myself looking at my surroundings and trying to related at least five items in each room of my house to science. I've read the labels on house cleaners and my make up and I understood some of it. Its fascinating, and being able to relate science to so many practical things makes me want to learn more (Tammy 7/12).
- Peter: The reports made me think more about how chemistry is all around and that many people use it in different ways. They haven't really shaped my beliefs about science. Science is a tough field and you to work long hours in the lab. That's why I am not going into science (Journal 5/9/94).
- Bret: The reports have given me a better idea of how chemistry has a role in the different careers. I don't think that the reports have reshaped my scientific beliefs at all. I don't think that science is any different that any other part of life, it has its ups and downs. It was fun hearing what people had to say, but so what, its like that all over life (Journal 5/9/94).
- Sandy: The projects have made me think more about science. At first I thought that the reports were a waste of time. We could have used that time to learn more chemistry, but then I began to think about some of the things we talked about. I didn't realize the political elite that takes place in science before this class. From the oral reports, it seems things are starting to improve some places as new, younger minds (and women) enter the field (End of the semester personal teaching evaluations).
- Tim: It make me feel better now that more and more females are getting into chemistry and taking credit for their work. It makes me wonder why women

were pushed away. I say that if it is an advancement, it doesn't matter who done it (Journal entry, 7/12/94).

- Tammy: I have been discouraged by the reports of women in science I don't desire to make Chemistry or Biology my career choice but its sickening to think about how many good things may not be happening because women are still not being taken seriously in this field (Journal entry, 7/12/94).
- Gloria: I think the most significant fact that has made an impression on me is the hopelessness of sexual discrimination against women in the field of chemistry. There are many careers that are discriminatory yet the company I work for, I have seen some small changes of acceptance of women. Several of the men in my department swore they would never work with women on their crew., These men are still going from the rules of the "olde school". After working with several competent women, many of these attitudes are changing. I'm not so sure that science industry will ever change, based on some of the oral history reports. That's sad (Journal entry, 7/12/94).
- Juan: When reflecting back on the oral reports, Megan's and Lori's reports both have to stand out in my mind because I really have a great respect for individuals who have a love for the science. And, if she or he can accomplish those goals through many years of education, their efforts ought to be applauded. So when a woman can come into the field and contribute to the field, it has to be a "sign of the times." (or so one would think). These oral reports have really raised my awareness of science. I really believe that science is life and life is science (as well as a few other beliefs). But then again, people are always people, and when their beliefs stand in the way of positive change and life it can really cause one to take a second look at things. My awareness was increased greatly but after hearing Megan's report my notion of clean, smooth running, equal opportunity Down Chemical Laboratory was changed drastically (Journal entry 8/9/94).
- Bill: The report from Laura who interviewed the chemotherapy RN struck closest to my experiences and focus. It did not really alter my conceptions of medical science, but only served to intensify my feelings. The message I kept hearing whether it be from the retail RPh or the chemo RN involved research, was the focus on economics for survival in the current science climate. Certainly I can't think of a report where it was not mentioned. Quite frankly for learning's sake, I'm disgusted by our cultures focus on economics. Learning for learning's sake or even for practical application to be second to the need for financial support regardless of whether the research is of practical value of application. And I find the inability to share research data and/or progress totally contrary to the who concept of research. C'est la vie (Journal entry 7/12/94).
- Rico: It is all about money. Big corporations will decide the roads that science will lead. The best way to live with that is to try to do a compromise with personal interest in science and BIG INTERESTS (Journal entry 7/12/94).
- Juan: Listening to the oral reports (especially Megan's) has really added more of a negative effect towards my attitude towards the scientific elite in the United States today. These elite don't just exist in the scientific and research communities but they are everywhere including my job. Its very sad to have such an obstacle because can always change your education status (bachelors,

masters, Ph.D.) but you can never change a persons discriminatory attitude. It is this attitude that excludes and deters a lot of good, bright, contributing people from the scientific and technical fields today (Journal entry 7/12/94).

- Lori: Caterina's report about the doctor who studied the animal's eye really got me curious about just how much science is unknown because of politics. I think I believe science is much more political now than before I started the class. I don't think that years of research should be put on hold because the government decides that it isn't important enough to give money to anyone (Journal 5/9/94).
- DeShawn: I guess it changed my way of thinking as far as not see it as being absolute, but a political and economically controlled endeavor. I never read about midwives in school as far as science was concerned, or any women for that fact. It showed me history has to do with science and still does today. Whoever has the power gets the credit. Just like in every other field such as literature, mathematics or history (DeShawn 5/9/94).
- Juan: It really makes me wonder about what kinds of chances minorities have in science just to have access to science. When my mother had cancer it took forever before she could get the medicine she needed. She would not have had to go through all that pain (interview 8/10/94).
- Linda: Its just like my friend I interviewed. She was promised that job at that chemical company and when they moved they took the job away and kept her husband. They never did find her another job (transcript of class 7/19/94).
- John: Not use the interviews. They are helpful but take up too much class time. Maybe use more examples and experiments that can be done in class. We need to be ready for CHEM 151 (End of the semester personal teaching evaluations).
- Shellie: I need to learn the material because I have to take 151, and I am so far behind everyone else. I have never had chemistry and I haven't been to school in 15 years (personal conversation). She said the hardest part for her [Lori, a biochemist] was there didn't seem to be a holistic kind of science, it was broken down into such small units that it didn't seem to have any humanness to it. What she is doing now, she said that she feels comfortable because she is looking at the whole. She wants to help try to change the approach to science. I'm like Linda, I don't want to be in science class if I cant connect to it (Oral history conversation 4/94).
- Janine: Listening to the oral histories gave me a lot more insight on science. They actually give you real people who use chemistry everyday. Not like people you read about in a chemistry book like Bohr or Dalton. The people from the reports seem more real. It has changed my attitude a little bit, now that I know that chemistry is more than chemistry (book). (Journal 4/25/94).
- Ron: If you want oral reports in CHEM 125 make the students explain concepts to the class with example of experiments and research, instead of tidbits of information on dead witches/ wizards, monsters and alchemists. These oral reports only increased my cynicism towards feminism because of the high woman content of choice (Journal 5/9/94).

- Angie: Ron, I am curious as to why you don't think learning about "witches/wizards, monsters and alchemists" is chemistry? Also you alluded to a "cynicism towards feminism" because of the high women content of choice." Would have you developed a cynicism towards masculinism if I had a high male content? Why is the large number of women problematic for you? Ron, another idea I find curious is that at the beginning of the semester I intentionally put more women on the list than men to get a reaction from the class. No one said anything to me at all – until now. How does that make you feel that I did that besides causing you to develop a cynicism towards feminism? But, there was also another reason why I did that. There are more men in science than women, overwhelmingly, and I thought I had three choices: 1.) make a list that truly represented science (which would mean including one or two women on it); 2.) make a list of 50% men and 50% percent women to each gender a fair shake (although remember this would not be an accurate representation of science); or 3.) make a list that allows us to read about people who typically are not given a voice in science (i.e. the women). (Written response to Ron's journal 5/10/94).
- Ron: You could have been more realistic. Its not my fault there aren't that many women in science. I didn't stop them from going into science. You are being just as unfair to the men. I thought you wanted a "just" classroom (Journal entry 5/9/94).
- DeShawn: Personally, I have always thought of science as very abstract. It had little to do with what goes on in everyday life. I believe that has a lot to do with how it was taught to me. The oral report about mid-wives I found very interesting. I guess it changed my way of thinking as far as not see it as being absolute, but a political and economically controlled endeavor. I never read about midwives in school as far as science was concerned, or any women for that fact. It showed me history has to do with science and still does today. Whoever has the power gets the credit. Just like in every other field such as literature, mathematics or history (Journal entry 5/9/94).
- Ron: Science works. Its proven itself. I bet next time you are sick, you go to a doctor. And, I bet if it was life or death, you wouldn't care if he were a man or a woman (Journal entry 4/18/94).
- DeShawn: Science is very political. Women had to learn by trial and error and weren't allowed in school. What we really know about science is controlled, and we are given what status quo wants us to know. I guess I feel that science is like many other areas that need disperated (sic) growth before they can truly be effective (Journal 5/9/94).
- DeShawn: You need to be more direct with Ron. Girl, don't let him jerk you around (Comment to me after class, cant remember the date).
- Marie: Chemistry is many different things to different people. You don't have to have a degree in chemistry to actually learn something. Some people learn by experiments on their own like with the plants (Note I think that she is referring to Beatrice Potter). Science is more than just school or complicated experiments (Journal 5/9/94).

- Mark: Beatrice Potter. There have been, there still are, bigoted morons in the scientific community (oops). Only "big strong white men can do science." Oh please! I think the situation is hopeless (Final exam 5/94).
- Penny: Everybody has a different view and it helped me to listen and take into consideration other views and learn by their definitions of chemistry (Journal 5/9/94).
- Karen: Chemistry change because of the time period. It showed me other outlooks on chemistry and shown me different attitudes and practices of chemistry in different time periods. The oral reports have made me realize chemistry isn't just solely working out problems, it has ethical and emotional sides (Final exam 5/94).
- Kelly: I like the fish one, and the one about the eye surgeon. I have shaped my ideas about science in a more positive way knowing that we really do need science to survive, but at the same time we create our own disasters due to science which in turn need science to come up with ways to reverse what we have already done (Final exam 5/94).
- Gene: Part of the reasons that science has emotional and ethical sides is that it is a human practice, it has a human side. For example, the oral report by the medical intern presented last week showed me how really important chemistry is in the medical profession. Somehow I didn't realize that everything you did in hospitals required chemistry of all sorts to function, serve and cure and heal humanity. People do science and people use science. It is human. I felt it was just books, methods in education and industry, but now I realized it can come alive and influence our survival as humans. Furthermore the injustice that women shared in the science/chemistry profession at all levels. That those men who share the elitist attitude are missing the point of science of the masses to appreciate. It is all our responsibility to change it (Conversation 7/94).
- Julianna: Prejudice has also been present in the development of science, but not many people know about what minorities go through to have their theories accepted. I feel that science, like any other area of society, needs a lot of revision. People, should not be ignored because of their culture. All people are capable of being an asset to the science community and should be allowed to do so (Journal 4/12/94).
- Gene: We have to find the courage to go against tradition and break out new methods and ideas to make sciences more relative to all, not just the few to understand and appreciate to learn. It's our responsibility to change it (conversation 6/15/94).
- Tracy: This man's attitude seemed to be very self righteous, egotistical and extremely elitist. His image didn't ruin my impression of science as a whole, but epitomized the white, good old boys network that I find incredibly frustrating and sickening. What I think of science was shaped a little by this attitude because for some reason I hadn't thought of the extreme sexism involved in science and this report just brought it to my attention. Full force – in the face! I wish I could remember the details of Laurie's report, but I can only remember my general feeling about this man, his monetary motivation and condescending attitude towards Laurie's questions. It went along with much of what you have

shared about your experiences in science and how your instructors or male counterparts have responded to you. These messages have only fueled more of the feminist activist in me. I cant stand the unfair treatment of people or the institutional discrimination! Maybe I should think about LIR, and law in addition to psychology! (Journal 5/94).

- Gene: The elitist attitude makes me feel angry at the injustice that attitude emulates to the every day spectator in uh regards to any type of knowledge, teaching, concept, philosophy and uh it holds, it bestows a false sense of superiority that the professor, elitist has and uh the anger I feel is that the student or the masses will have to feel insubordinate or can have an opportunity to attain the knowledge (Personal conversation 6/94).
- Angie: I am really interested because you are both a teacher and a student of science simultaneously. Now these ideas that you talked about, how do they make you feel as you move back and forth between these two roles? (Personal conversation with Gene 6/94).
- Gene: Tired! I tell you, tired! At the end of the day I was tired. There is really a hunger there that I can feel. There is also a frustration. I am trying to find ways of trying to use the methods and all of the concepts that you are talking about in my class. I couldn't because, it was really frustrating. I couldn't because there were all these barriers. I think the majority of the children that I taught have some sort of attention disorder. The only way that I could get some of them to understand is if I grab them like this (he illustrates with his arms and hands him grabbing a student by the shoulders and shaking them) and it was so frustrating how many times I had to repeat my self. (Personal conversation with Gene 6/94).

APPENDIX E

The parallel traditions of science and science education: Nomenclature

The third story is about how the oral histories influenced our teaching and learning of chemical nomenclature that occurred towards the end of the semester. In this story, Gene, Shellie, Sue, Jeff, and Gwen push on the elitism theme by questioning and critiquing departmental practice regarding the teaching and learning of nomenclature and other topics. By exploring this theme in the context of our educational practices, we had the opportunity to rethink our own actions in chemistry class. We recognized our (my) own acceptance of an oppressive science as well as our contribution to the continuing oppression of marginalized groups by science. Making this knowledge public through the language and knowledge created by the oral histories helped us to rewrite our science teaching and learning.

Nearly three-fourths of the way into the semester it was time to learn nomenclature. It was "time to teach" despite my own beliefs that learning nomenclature is an incremental task—developing an awareness and understanding of how compounds are named as we study the physical characteristics and processes of those compounds. It was "time to teach" because it had been prescribed by the department that we would teach a unit on nomenclature for the next exam (which was departmentalized). This was particularly frustrating, because teaching a unit on nomenclature made no sense and did not connect with the way I had structured the course thus far. Why should we learn about how to name oxyacids when we would not study them for another month?

Anyway, on the appointed day for this topic, I moved from Pete's oral history of Bob Raychild, a goldsmith, to chemistry by talking to the students about an exam they had taken a

week earlier. It was frustrating to return the students' exams because it was clear to me after reading through their work, that they did not "master" all of the scientific knowledge required by the department's objectives. I felt an incredible tension because I knew that I had altered my teaching style to make sure that we "covered" all the ideas in the last unit required by the department's objectives. For example, it is typical for me to construct chemistry lessons around the questions that students raise and around activities created to help students question particular scientific phenomena. But, in this last unit I compromised my teaching agenda so that I could begin to "catch up" with the rest of the department (I knew that the next unit was to be tested through a departmental exam). For example, instead of taking the time to discuss in class a take-home project that I had assigned to the students, I chose not to discuss it in class. It is not necessarily that the students needed me to help them get the ideas about bonding structure "correct", but they needed the time to talk with each other about their own ideas, and assigning this project without any student discussion precluded any such discussion.

As I handed back the tests, I said:

The tests, the tests the tests⁶¹. I will hand back the tests, they really weren't that bad. Here's the dilemma that I think we need to talk about as a class. I feel like, I feel really bad about rushing through chapter eleven. I feel terrible because I asked you to do your projects at home when I was gone and we are not going to take time to talk about them in class because there is not enough time. I feel really bad about that and I know that you all work full time and it is hard to study at night. When I was taking masters courses at night when I worked for Genzyme, it was really hard, and so I know that it is really hard. And I know that most of you are paying your own money to take this class too. I know what it is like to pay your own money to take a class and that is hard too. So I felt like when I was grading some of these tests some of you missed a lot, and I am not criticizing you, I am kind of criticizing me because I just should have

⁶¹Just a note about the tests: My department chair insisted that all students enrolled in general chemistry (5 sections -- I taught only 2) all take the same first test, as a way to measure student learning (and teacher teaching) across all sections. Further, he insisted that all students take his test—not because he did not "trust" that we could not (or would not) write "good exams" but rather because he had already generated a "test bank" for the first exam. He had written, over the course of two years, over three hundred questions that could be scrambled on a computer and thirty questions selected by random so that all sections would have "different but equal versions" of the exam. Besides the fact that the format of the exam was problematic for me—it was mainly multiple choice, fill in the blanks and simple fact memorization questions—it strapped me into teaching specific topics at specific times in the semester with specific sets of applications (ones that I found particularly abstract and only partially useful).

made sure that people were understanding the ideas. I just should have ignored what the department was telling me about how much we needed to get done and when.

There is this tension here. As I told you earlier, the department is telling me that I have to get through eighteen chapters by May 4th and I have to give you five tests, and I have to make sure that the average score on each test is a 70. I also feel like we should not have to go through eighteen chapters if we are not going to learn anything. I mean what a waste of time and money. And I also feel like we shouldn't have to take five tests and I also feel like the average shouldn't have to be a 70. If people know what they are doing then why couldn't the average be higher to reflect that? If the average is a 70, that means that half the class is scoring 70 or below. And, we are supposed to be satisfied with that? That is not acceptable to me.

We have choice. The choice is, oh one other thing that I wanted to tell you was that I felt like, when I graded your tests that some of you felt sort of alienated from chemistry and that bothered me because I want you to feel connected with chemistry. I want to spend more time talking about the ideas so that you can feel more comfortable. So that you don't feel intimidated or like you can't do it or like we are rushing through it. I feel all these things. I guess number one is that I want to know how you feel and two I want to know if you want to take our own pace and what we get done we get done and when we take the test it can be open book and we just won't tell [the department chair]. Or we can just go through the rest of the semester as is expected, at a very fast pace. But we would be doing it the way that the department would have us do it.

Now I don't mind engaging in acts of political resistance, because I have done it before. It's just my nature. I just want you to begin to feel comfortable in chemistry, to understand the ideas and concepts because if we just go through it really fast and miss a lot then we could be wasting so much time. I want to make a decision that our whole class feels comfortable with. If we deviate from the plans that the department has for us then I could get fired. But I would want to make sure that I was getting fired for a good reason.

I shared with the students my struggles as their teacher to try to incorporate their needs and my needs into the departmental agenda. I shared with the students my dilemma about whether I should continue to shape the class around the students' needs as I had tried to do throughout the semester, or to refocus the class so that we could cover the remaining six chapters before the departmental final exam in three weeks. As it was, we were nearly three chapters behind the rest of the chemistry sections because of our "detours."

The students were concerned that if they chose to deviate from the syllabus then they would get burnt despite the fact that they may learn something. Gene then shifted the conversation from requirements to learn to my position as the teacher by stating, "It seems to me

that the department is taking away your educational freedom." When I asked Gene to share with us more what he meant, he said,

Well, they do not respect your opinion about what your students need. They are trying to make decisions for you and your students without the knowledge that you have about your students. They are taking away your freedom to make decisions about what you want to do for your students. I think that it would be better, and I can only speak for myself, if you made the kinds of decisions that you felt were right. You know more about what is best for us as a class, then does the department.

Gene and Shellie used this opportunity to draw a parallel for the class between the elitist practices of the science community and the elitist practices of the chemistry department at the community college. As a result our class recalled the "weeding out" practices of the chemistry department, the dropout rate for the course, the fact that the course generally had the reputation on campus as being the "toughest course."

I shared with the students that "First I think that I don't want it to be just my decision. I want it be our decision because I think that you know more than I do about how you feel about the material that we have covered so far. But, I will take responsibility for the decision. I just do not want us to feel constrained by the schedule set out by the department so that we are too busy cramming, that we are not learning." The students continued to debate what they thought they needed to know by the end of the semester. For example, some of the students' comments were:

John: Well I know that for me, I need to understand the concepts before moving on. I work all day long with respiratory patients and the only time that I have to work on chemistry is in the evening when I am already tired. I find that when I do not have the time to really understand a concept I get really lost. I find that I have a difficult time learning new ideas when I am still lost with the old ones that we should have learned, and I get real frustrated. I would like to spend more time on the concepts otherwise they do not mean that much to me, and like I said, I get really frustrated. But, I think that overall everything so far is going pretty well. I feel like the time that we are devoting to issues in here has been helpful and I do not want to change that just to get through all of the required material.

Shellie: I feel like John does. I get real confused if I don't take the time to understand the concepts, and even if I am home studying I get real frustrated when it is just me and the book.

John: I find that the book sometimes confuses me too. When I look back to my notes, I find that I don't have any problems working out some of the exercises, but if it is not in my notes.

Sue: I am only concerned that we will not learn all that we need for CHEM 151 .

I decided with the support of the students to continue the course with our needs as the central focus and to risk not covering dutifully the departmental requirements. This conversation was particularly salient that day because according to the departmental syllabus, we were to start a chapter on nomenclature. I had my political and intellectual problems with this particular approach which I explored in a journal entry written a week before the class discussion described here:

Teaching Journal, April 1, 1995

The department chair expects that all sections will learn (memorize) the names of many ions (5 single spaced pages!). Some can be figured out by naming rules, some just need to be known. I am completely opposed to this practice. What good does it do to tell students that they are responsible for memorizing five pages of ion and other compound names? And have spelling count? I do not understand why the department feels so strongly about this. There are two chapters dedicated solely to naming compounds. I agree that to engage in chemistry one needs to be able to speak the language, but I do not agree that the way to go about it is to tell the students to memorize a bunch of nomenclature!! What a way to perpetuate the fragmented and "unsocial" nature of chemistry. Is this a power play by the institution to keep these students fearing, hating, and disconnecting with science? If so, it's working!

I am not sure yet how I will handle these chapters, especially because it will be tested on a departmental exam. I think I will share with the students how I believe it is important for them to become familiar with the rules of nomenclature so that they can learn why compounds have the names they do and also so that they can become proficient in using reference books. I find it problematic that students are expected to "memorize" (the department chair used this word) rules for naming compounds that we have not even covered in class. For example, we have not studied acids and bases yet. Why is it important for the students to memorize rules for naming acids and bases when they have not dealt with them conceptually?

The worst part of the whole thing is that we cannot even skip the chapter. This is the test that the department chair wrote and he will be heavy on the naming (and spelling).

Because we had decided to learn what and how best fit our needs, I no longer felt our class was constrained by the departmental syllabus (although I still felt constrained by the departmental objectives—especially because there were students who wanted (needed?) to

work through all of them). Consequently we decided that we would discuss the rules of nomenclature for the compounds we had studied thus far in the course (and leave those we hadn't studied until later in the semester). I also decided that the students would be responsible for knowing how to apply rather than memorize the rules. As a feminist attempting to teach chemistry I felt comfortable with this decision because it decentered the authority of science education to tell us what to learn and to prescribed the important pieces of our learning. Confronting full face the moral question of "now that I have made this decision what happens to the students next year when they will be given the same nomenclature handout and be told to have it memorized for an exam on the third week of classes?" Sue's and John's wants spoke louder in my mind: Will they have what they need for next year?

Several of the students, such as Tracy, Mary, Shellie, Laurie, Dave, John, and Gene, appeared to feel comfortable with the decisions we made about "engaging in acts of political resistance." Tracy told me in an interview that this was one of the first science classes were she "actually learned something and felt like [she] belonged". And, as Gene shared with me later in the summer:

Gene: I think by doing that you became a team member, you became a team member in the quest for knowledge and in the learning of how to do things and not an adversary of students efforts to learn and become successful. Many times in college, the elitist attitude tries to scare the student and be a hindering force towards the education of the mind and development. I think that anytime that they try to be [elitist] is an antagonist to the educational process. And I think what you did made you a champion.

Angie: Uh, do you have ideas of how we could have done that more in the class?

Gene: I think employing the teacher as participant rather than one who dictates, where the teacher and the student work together, and to me this is what you did, work together and work on the experiment and rather than become a dictator, you became a player, and I think that is really, I think that that is an advantage and an asset if you can find a common ground between the teacher and the student. And that basically is like a bond that can carry the student over a lot of spots that the student might be having. I am not talking about friend, I am not talking about friendship or palsy walsy or one of the good old girls or boys.

Yet, this decision, although unanimous, was not entirely unproblematic. In concert with the students, especially Sue, Jeff, and Bret, I worried publicly about what would happen to

them if they took the subsequent chemistry course where the rules of nomenclature are covered again and are expected to be memorized again.

I believed it was important to share these dilemmas about what and how to teach with the students. I felt that sharing my struggles would be a way for me to explain and justify to the students my teaching beliefs and actions and to give them a context from which to question me. In opposition to the culture of science and to the culture of the department in which we teach and learn, I wanted to share my subjectivities with the students: Just as the knowledge of science is not neutral, neither are my decisions. Everything is located socially, historically, and culturally. I also felt that it would be a chance for us to decide together if we agree with the department's authority to define how, when, and about what we needed to know in chemistry. I also chose my words very carefully: I used the phrase "acts of political resistance" because I wanted the students to know that if we chose a route different from the department, we had personal and political reasons for doing so. I wanted the students to have a voice in their education, and I wanted them to know that they could use that voice publicly to speak from and for their needs. I thought that if I did not make explicit what I felt we were doing, then our sense of agency—our ability to use our voices and our experiences to define our own science education—would remain hidden and unused.

Although committed to making a political statement with the students, I was also nervous about the language I had chosen. I was nervous about the implications and repercussions. I wondered during the very instant that I spoke it, if I had imagined all the connections that the students appeared to have made between power, knowledge, elitism, and science in my search for glimmers of hope present in my attempts at feminist teaching. But, as the rest of our conversation played out I learned just how strong and personal the connections were that the students had made, and just how tormented they also felt between this "new knowledge" and their prior knowledge of what it means to be a student of science. The same story that we had heard in many of our oral histories about contradictory experiences in science paralleled our own lives as students (and teacher) in learning science and experiencing science

education. Our understandings of our positioning in science and education emerged from our community built around moments of resistance (Welch, 1985).

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