

**RE-PRESENTING SCIENCE:
A STUDY OF ELEMENTARY TEACHERS' EXPERIENCES AND
UNDERSTANDINGS OF SCIENCE**

by

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Abstract

The purpose of this research was to document a group of elementary teachers' understandings and representations of science. The work sought to examine how life and educational experiences of these teachers influenced the perspectives they held about science, as well as shaped the way they viewed themselves as teachers and learners of science. In exploring the relationship between an individual's life history and conceptualization of science, the research identified influences that led to feelings of alienation from science, or likewise, contributed to positive attitudes towards science. The paper describes the science experiences of five student teachers and four practicing elementary school teachers.

The research is a qualitative study based on ethnographic principles. Interview responses from each participant together with the researcher's insights into the research process are central to the study. Combined, they emphasize three important features of learning science: the role of belief in science, the contextual nature of learning, and the importance of connecting science to lived experience. The teachers' discourse, in particular, captures the complexity involved in the construction of scientific knowledge.

For most participants, schooling played a critical role in fashioning the meaning, experiences and discourses from which they drew their understanding of science and the nature of scientific knowledge. It was here ideological representations were created, reflecting lived experiences as well as the viewpoints of teachers, administrators and policy makers working within and outside of the practice of public education. The words and views portrayed by the participants provide insight into the difficulties faced by many in the classroom. The learning of science involved an exploration of authority and a constant shifting and negotiation between what was lived, perceived, and valued.

The participants' narratives evoke as well the complex relations between education and the culture within which it occurs. Affecting learning was not only belief, but struggles of gender, class, and race. Despite public discourse on equality, gender discrimination proved

problematic for many participants in the study. The study suggests a need for further research on how experience contributes to individual understandings and social representations of science. It also suggests implications for exploring the historical, social and political issues surrounding science within the context of teacher education programmes.

Dedication

To my father, for always being there.

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Chapter 1

Introduction

Kids, especially in the elementary grades...really enjoy the science experiments especially if they are not labeled as science. The label kind of turns them off sometimes, whereas if you study living objects and study plant growth or something and don't label it as being science, the kids find it interesting and really enjoy it and learning about that kind of thing. For me too, sometimes the science label kind of scares me. It is like way out there and I don't understand. I think how can this work and it kind of scares me. (Susan, student teacher, January, 1996)

This quotation illustrates the complex relationship many elementary teachers have with science. Science is fun, but it isn't. Students will enjoy science as long as it is not called science. Science is the study of our world, but is felt to be different from other ways of understanding if referred to by name. Its label implies authority, rigidity, as well as knowledge that is not easily accessible. Experience has taught this teacher to be wary of science. She thinks of it as "way out there," often beyond her reach. Acceptance of its authority coexists with fear.

This thesis asks the question what does science mean to student teachers and those involved in teaching elementary school science? More specifically, it is a study of how lived experiences shape our relationship to scientific knowledge. I wish to examine how past experiences of elementary teachers may influence the perspectives they hold about science, as well the way they view themselves as teachers and learners of science. Using lived experience as the focus of my concern, I also hope to probe such questions as what is the structure of science experience? How does its discourse function in schools and educational practices? How is this translated into individual representations of science? Are there ways we can make science more accessible to students and teachers alike?

Education courses are based on the assumption that teachers bring understandings and knowledge to the program, yet they are still expected to put into practice the goals of the field. Science method courses are designed, for example, to introduce prospective and experienced

teachers to a variety of pedagogical issues about science teaching, science and children's learning. In keeping with current educational research, they are also expected to inform, influence, and possibly change, teachers' concepts or attitudes about science education.

Yet, a number of researchers argue that understanding the beliefs teachers hold about science is critical to improving and informing teaching practices (Abell & Smith, 1994; Proper *et al.* 1988, Wideen *et al.* 1992). They also contend that important links exist between teachers' beliefs about science and the way they teach. In a study of 74 student teachers, for example, Aguirre *et al.* (1990) reported that almost half regarded science as a body of knowledge consisting of facts and laws about the world. Many who held this view also conceptualized science teaching as a matter of knowledge transfer. In contrast, Shulman and Tamir (1973), Wideen *et al.* (1992), and Roth and Roychoudhury (1994) propose that if teachers view scientific knowledge as tentative, an ongoing process of concept development, greater emphasis may be placed on the interpretive aspects of science.

While studies have focused on teachers' beliefs about science, to my knowledge, very little has been done to document the life stories and personal experiences that have contributed to their views. In other words, teacher's beliefs about science have been explored devoid of context. As university educators attempt to establish a science culture in which change can be supported and enhanced, they require a better understanding of what experiences have shaped teachers' beliefs. This requires a close attention to individual voice. Although they did not go into detail, Gustafson and Rowell (1995) alluded to the importance of personal experience in shaping the science attitudes of preservice elementary teachers enrolled in a science methods course; "Regardless of the nature of preservice teachers' prior ideas, they all seemed to be rooted in past life experiences which had the power to 'outweigh' course ideas" (p. 600).

Modern sociology and philosophy of science maintain that science is a social institution, shaped at many levels by human values, beliefs, histories and commitments (Blumer 1969; Haggerty, 1995; Keller 1985). In this thesis I explore the notion that a teacher's view of science comes from an understanding developed over time. This notion

recognizes a social constructivist approach to learning and science education. At the heart of this epistemology lies the belief that knowledge does not reflect an objective reality, but is an understanding, interpretation and organization of the world based on personal experience (von Glasersfeld 1984). Teachers, like students, bring ideas to their courses which are derived from their own experience. These influence the meanings they construct, as well as the nature of further exploration. Indeed, teacher education studies confirm the power of preservice teachers' prior ideas. In an investigation of teachers' views on their approach to teaching, Raymond *et al.* (1992) found that experiences which precede pre-service teacher education not only shape early approaches to teaching, but also "act as lifelong references for a teacher's identity" (p. 150).

Building on a social constructivist framework, I seek to explore the science experiences of both student teachers and practicing primary teachers within their life histories. Are certain events or experiences catalytic in the development of an individual's beliefs and attitudes about science? How do a teacher's views inform the way she teaches science, or affect her own learning? Work by Berrill and De'Bell (1995) suggests that pre-service teachers have strong preconceptions about science, many of which are negative. Based on a questionnaire given to students taking a physics course for elementary teachers, they report:

We were surprised by their explicit mentioning of being "scared" by science. As well, we were reminded that these students already had prior experiences with science and that many of these experiences had not been positive ones. By the time they reach university, then, students do not necessarily present even a neutral stance toward science; rather, some of them have prior experiences which made them feel unsafe in a science context. (Berrill & De'Bell, 1995, p. 12)

Considerations of gender are also integral to this research. Despite the official discourse of gender equality, the under-representation of females in science persists (Haggerty 1995). Researchers have posited various reasons for this inequity ranging from differential socialization of females and males to cultural expectations to school influences (Acker & Oatley, 1993; Haggerty, 1991). Indeed, even within the school setting stereotypes still serve to characterize science as a masculine domain. From textbook materials to activities used in

teaching to curricular orientation, the image of science as “male” abounds (Roychoudhury & Tippins, 1995). There is little to counter the stereotype. It has become part of our language, permeating both individual and social representations of science.

Although I wish to avoid the pitfalls of essentialism, the reality is that the vast majority of elementary teachers are women. Further, many have experienced a culture that has traditionally disadvantaged girls/women in science (Acker & Oatley, 1993; Haggerty, 1991, 1995; Keller, 1985). Nonetheless, it is important to recognize there are many women who do not feel discriminated against by current science culture. Thus in exploring life histories, I hope to document those experiences that have contributed to the success of female elementary teachers doing science as well those that have caused alienation. Further, I do not wish to ignore the stories of male teachers. Certainly men, just as women, have experienced science in different ways. In contributing to the literature on teachers’ experience and beliefs about science, however, I hope to create a place for the individual and her story in teacher education.

Much has contributed to this research: conversations, readings, lectures, ideas remembered and acknowledged as well as elements tacit, unconscious or forgotten. But shaping the work in particular are two theoretical frameworks. The first, the sociology of knowledge, is “concerned with the relationship between human thought and the social context in which it arises” (Berger & Luckmann 1966, p.4). It attests to the importance of interaction in developing knowledge. It establishes that what we perceive as reality is the result of culturally and personally determined interactions between ourselves and existent representations. Knowledge is never acquired alone, but socially negotiated. I will also ground my research in feminist criticism of science. This work seeks to displace the traditional view of science as objective and value-free, but rather re-locate it in the culture that gave it birth. Feminist theorists also point to the invisibility of women and minorities within science. They argue that science is based upon adherence to a single patriarchal ideology, and as such, is incomplete. My immersion in these writings influenced my research vastly, both in the doing and the interpretation. The literature helped me to think about the disparity in science

education as more than a matter of participation. Rather, I began to look at educational access as one that deals with language, values, commitments, power and the political contexts in which science is situated.

Researcher as self

Postmodern strategy recognizes the reflexive character of research. As many authors have argued, the neutrality of the observer can no longer be upheld in either “positivist” or qualitative research (Alcoff, 1991; Anderson & Jack, 1991; Hammersley & Atkinson, 1983). Riessman (1987) quotes Oakley (1981, p.58) in saying: “The mythology of the “hygienic” research with its accompanying mystification of the researcher and the researched as objective instruments of data production must 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.” I concur that my view of reality is mediated through my own understandings and experiences. It is thus important I acknowledge at least some of the biography that I bring to the research.

I conduct this research as a white woman, first-generation Canadian of European ancestry. Although I have been involved in science for over 15 years (first as a research assistant, then as graduate student in zoology, and lastly as a medical/science journalist) my intellectual interest in science education really began when my first child entered school four years ago. I was dismayed to see that science was taught in a very structured way (an adherence to text book science with little hands-on activity) or not at all. The lack of science activity was particularly striking in that we live in a town located on the Howe Sound. With the ocean virtually in our front yard, and the mountains at the back, the opportunity for hands-on “rub-in-the-mud” science is vast.

Conversations with Deborah Berrill, director of Trent-Queen’s Concurrent Teacher Education Program, focused my attention on teacher development and gender. She remarked that the large percentage of elementary school teachers are female, who have social sciences

and humanities backgrounds. Her own informal surveys indicated that elementary teachers' lack of comfort in teaching science is caused primarily by their lack of science participation and knowledge (Berrill & De'Bell, 1995). I found many of her statements were echoed in discussions with teachers at my daughter's school. One teacher told me that she did not feel comfortable with science, therefore she did not teach it. Another said her own schooling had reinforced the notion that science is only for boys. She had never overcome that sense of alienation. As I had been thinking about returning to university for some time, these women's words provided a focal point for inquiry. Does an individual teacher's past experience affect the way she views and teaches science? Do science method courses adequately address the needs of the teacher/student taking into account their varied histories?

In pursuing this research, it seemed appropriate that I undertook a qualitative study with person-to-person interviews forming the core of the work. Although not an ethnography in the strictest sense, I wished to investigate how different teachers viewed science and whether particular experiences/memories/histories contributed to their views. I did not see this work as a search for a unifying "truth." Rather, I wished to delve into the complexities of science and how people come to view and interpret science in their lives.

My past experience also came into play in influencing the type of method I selected. I remembered as a graduate student in zoology wishing to have a "Journal of Negative Findings." Although at the time I would not have identified it as such, I felt uncomfortable with a scientific tradition that maintained only positive findings had meaning. This became evident to me during my fieldwork when I tested a hypothesis that did not yield a change with respect to the system studied. My supervisor told me to discount the findings. Because my hypothesis and subsequent experimentation did not lead to a positive event, seemingly the research did not add to knowledge. Negative findings were considered a void. Yet as a graduate student, I felt these negative events were as important as positive findings in contributing to our understanding. It gave my work much of its texture, yet I was told to dismiss it.

As I began a new area of research, qualitative methodology afforded me the depth that quantitative did not. It permitted negative findings, as well as the positive, to enter the research realm. It also invited me, as the researcher, to be part of the discourse rather than pretending invisibility.

In pursuing any kind of research, Emerson, Fretz and Shaw (1995) state it is important to examine the methods we choose and why we choose them. The data were collected using semi-structured interviews. In discussing an individual's life history, interviews enabled me to explore situations that could not be directly observed. More importantly, however, I believe the interview allowed me to gain an understanding of the meanings the participants give to their experiences. As Anderson and Jack (1995) put it: "Oral history interviews provide an invaluable means of generating new insights about women's experiences of themselves in their world" (p. 11). They also allow for greater flexibility to attend to unanticipated concerns.

Like many qualitative studies, however, this work is hardly complete. The results do not permit generalization but are limited to the situatedness of the work. However, a number of authors have argued the aim of qualitative research is not generalization of results (Gore, 1993; Merriam 1988). Rather, it is the extension of understanding that may allow others to make sense of similar situations. In discussing case studies, Kilbourn (1990) puts it this way: "Each new case contributes to our repertoire of understandings and skills for dealing with future cases. Within this context, generalizability of specifics are not required" (p. 112).

Interviewing, like any other form of data collection, has its strengths and limitations (Merriam, 1988). Although interviews may allow insight into an individual's perspectives, the researcher may not always "hear" what is important to the speaker. The lack of shared norms can create a barrier to understanding, or else the researcher's agenda may override the real concerns of the participant (Reissman 1987, Anderson & Jack, 1991). The interview is limited by the sensitivity and integrity of the researcher (Merriam, 1988). In doing this work, I tried

to be attentive to the participant's concerns. I also returned the original transcripts and the analyses to them for their critique and verification.

Another limitation of the study is that it does not include any observation of the participants' teaching. Some researchers have documented discrepancies between teachers' espoused views about science pedagogy and the way they actually taught (Wideen *et al.*, 1992). It is possible the perceptions held by the participants in speaking about their science teaching or their relationship to science differ from their actions in the classroom. Direct observations would have given greater insight into how their thoughts and words interacted with practice. Observation may have also revealed concerns or issues that did not arise in the interviews.

Organization of the thesis

This thesis is arranged in six chapters. Following this introductory chapter, chapter two presents a review of the literature which helped shape the conceptualization of this study. It selectively examines the literature on teachers' beliefs and conceptions about science and science teaching; the sociology of knowledge; and feminist critique of science. In chapter three, methodology is discussed. Chapter four offers a narrative account and interpretation of the life experiences of nine teachers (five student teachers, four experienced) with respect to science. Chapter five presents further analysis and categorization of themes emerging from the narratives. The final chapter summarizes the understandings gained in the study and attempts to extend their implications to teacher development.

Chapter 2

Literature Review

It is rare for scientists to feel the need to reflect on their presuppositions; the success of their enterprise does not, at least in the short run, seem to require it. Some would even argue that the success of their enterprise requires that they not reflect on the matters that would merely enmire them in ancient, fruitless disputation. Let the data speak for themselves, these scientists demand. The problem with this argument is, of course, that data never do speak for themselves. (Evelyn Fox Keller, 1985, p. 129)

This chapter examines the literature on a variety of intersecting fronts. I begin by exploring teachers' beliefs, concepts and world views about science and how they may relate to an individual's pedagogy about science teaching. Because our beliefs are acquired and mediated through socialization, however, this leads to another level of inquiry in which I examine the importance of interaction, language, and social representations in learning and construction of knowledge. A selective review of feminist critiques of science adds context to this discussion by looking at the history, culture and assumptions underlying traditional science and scientific knowledge. The implications of these critiques are then assessed with respect to science teacher education.

Throughout the readings, I found authors used the terms beliefs, concepts and views interchangeably. The following definitions, although condensed, are thus given to clarify the meanings of each term as well as to show their overlap. They are taken from the *Oxford English Dictionary*, 2nd edition (1989).

Belief: Mental acceptance of a proposition, statement or fact as true on the ground of authority or evidence. In modern use often simply equals opinion or persuasion.

Concept: A thought, idea. Disposition, frame of mind. Imagination, fancy. Opinion.

View: An aspect or light in which something is regarded or considered. Opinion, ideas or theories of an individual or speculative character, held or advanced with regard to some subject.

According to these definitions, belief, concept and view are similar in meaning sharing the same synonym “opinion.” Beliefs are distinguished from views, however, in that they imply consensuality or social acceptance of particular understandings whereas views are presented as personal or individual interpretations. Concept refers to a more abstract relationship between an idea and event. I would argue that all three constructs are comprised of affective and subjective dimensions, drawing their power from previous events and grounded in social understanding. In other words, beliefs, views or concepts are located within the tensions of lived experiences. They are shaped by practical experience and form the lenses through which we perceive and interpret our world. In agreement with the current literature, I use the terms interchangeably.

Science beliefs

In 1949, Michael Polanyi wrote:

The beliefs which men (sic) hold are mostly imparted to them by their early education. Others they acquire through professional training and through the wide variety of educative influences which infiltrate our minds from the press, from works of fiction, and through other innumerable contracts. These beliefs form far-reaching systems, and though each of us is directly affected only by one limited part of them, we are committed by implication to the pattern of which this is a part. (p. 61)

In recent years, university educators have argued that important links exist between teachers’ beliefs and the way they teach science (Abell & Smith, 1994; Proper *et al.*, 1988; Shulman & Tamir, 1973; Wideen *et al.*, 1992). They suggest that teachers’ beliefs about the nature of science are likely to affect the way they understand it, relate to it, present science to their students as well as learn science themselves. For example, if science is viewed as a body of knowledge based on proven facts and absolute truths, the teacher may be more likely to approach science teaching as the direct transmission of these truths (Roth & Roychoudhury, 1994). The scientific method is presented as objective, the most legitimate way of knowing reality and beyond human influence. Within this framework, education is characterized as “a

need to control what is learned and how it is learned” (Dunne & Johnston, 1992, p. 516). Science becomes a directive.

If the teacher views scientific knowledge as tentative and a continuous process of concept development, however, more emphasis may be placed on constructivism. Implementation of this pedagogy means that students would be asked to draw upon their own understanding and experiences to make sense of a scientific phenomenon (Wideen *et al.*, 1992). Teaching would emphasize an approach to learning in which students construct knowledge that is viable for them. Learning is characterized as process. It is thought to result from conceptual change generated by activity, as well as through the social process of communicating and internalizing the knowledge and practices of the scientific community (Driver *et al.*, 1994). Obviously, teachers’ views of the nature of the discipline can influence not only how they teach, but their students’ conceptions of the subject (Abell & Smith, 1995).

A number of investigations have attempted to elucidate teachers’ views, beliefs and epistemologies about science. In a study of student teachers, for example, Aguirre *et al.* (1990) reported that 40% appeared to hold a naive conception of the nature of science. The student teachers portrayed science as an activity which provided unequivocal explanations about the world, rather than a socially constituted activity shaped by the human mind. Many who held this view also conceptualized science teaching as a matter of knowledge transfer. Hewson and Hewson (1987) reported similar findings in an earlier study. They found that preservice teachers held a variety of conceptions about science teaching. Teachers whose views conflicted with a constructivist approach to science, however, did not take into account students’ prior knowledge in influencing the learning of new science material. Rather, they perceived teaching as the transfer of knowledge from teacher to student despite having taken a science methods workshop which promoted a view of science teaching as conceptual change.

Proper *et al.* (1988) investigated world views projected by science teachers. They defined a world view as a “person’s set of beliefs, held consciously or subconsciously, about the basic nature of reality and how one comes to know about it” (p. 547). Using Pepper’s

classification (1970), they observed that teachers projected world views through classroom dialogue most often consistent with formism, or mechanism.¹ Physics and chemistry, in particular, were presented in mechanistic terms. On the other hand, discourse reflected a plurality of world view presuppositions about biology. For example, descriptions of ecology and interdependent biology systems reflected organicism or contextualism, whereas mechanism tended to be projected in genetics.

In a more recent study, Ogunniyi *et al.* (1995) found that science teachers may have multiple or conflicting world views about science. Born out of experience, these world views are tenacious and often take precedence over educational instruction. They write: "Science teachers may have entered and left schooling with several different understandings of the nature of science which coexist and compete with, rather than replace, their world view presuppositions" (p. 822). Indeed, a study by Bloom (1989) showed that anthropocentricity in definitions and purposes of science dominated a group of student teachers' conceptualizations of science. Misunderstood notions of theory added further confusion to their understandings. Many teachers equated theory with fact. Another study examining preservice elementary teachers' conceptions of science revealed that most student teachers failed to realize the social or creative dimensions of the discipline (Abell & Smith, 1994). They believed that scientific knowledge exists in the world, and "that students must receive or discover it" (p. 484).

Similarly, Gustafson and Rowell (1995) found that few preservice teachers who took a science method course saw science as tentative, but rather regarded it as a body of knowledge "separate from us and waiting to be 'discovered'" (p. 598). Prior school

¹Pepper (1970) developed six world hypotheses to represent the way people interpret reality. Four are relevant to science teaching in particular. Formism addresses the form of things; it is based on an investigation of selected characteristics looking for similarities amongst objects or events. Mechanism takes machine as its root metaphor, revolving around questions of how things cause, influence or correlate with each other. Contextualism focuses on the event or entity in its context; and organicism refers to integration of themes, reflecting a preoccupation with wholeness or synthesis.

experience, individual learning preferences and practicum experiences played a large part in the formation of their scientific beliefs. The university course, which emphasized a constructivist approach to science, had little influence on the students' ideas about learning, teaching science or the nature of science. Gustafson and Rowell (1995) commented:

Past experiences seemed particularly vivid and convincing to the participants, and the approaches used in our education courses seemed to have only a modest effect on these personal, and persistent, ideas about teaching and learning... Integrating new ideas into conceptual frameworks seems to demand much more than the relatively brief encounter with a constructivist approach to learning science offered in these courses. (p. 603)

Munby (1984) also observed that teachers may hold beliefs about science or science teaching of which they are unaware. These beliefs, although tacit (Polanyi, 1966) in the sense that they are not articulated or examined, can still affect teaching practice. His interviews with a science teacher revealed, for example, that she considered hands-on activity and laboratory work critical to students' understanding of science. When asked to explain why she approached science teaching in this manner, she was unable to say how she developed her reasoning.

Sociology of knowledge

From the previous discussion, it seems that a teacher's beliefs shape her relationship to scientific knowledge. To further explore how beliefs, views or concepts relate to and inform practice, however, requires an examination of knowledge and the ways in which it is produced. It also requires a consideration of how cultural myths and norms structure what we consider science to be.

Berger and Luckmann (1966) regarded social interaction to be at the core of knowledge. As people interact they create their realities, and it is from these interactions people derive meanings about events in their lives. They asserted that the creation of knowledge entails a constant interplay between subjective and objective meanings. The reality of life may be described as objective in that it is comprised of an "order of objects" that are

independent of a particular individual. However, individuals experience everyday life with “differing degrees of closeness and remoteness” (p. 22), internalizing and forming their own subjective meanings of events. Each informs, shapes and is shaped by the other.

A social stock of knowledge is constructed when subjective meanings become objectified and are shared through discourse and interaction. Language, an objective sign system in itself, serves as an index for subjective meanings. It objectifies experience, making it available to the shared community. As Berger and Luckmann write: “Language bridges different zones within the reality of everyday life and integrates them into a meaningful whole” (p.37). Language allows the same body of knowledge to be transmitted within and between generations. But neither language, nor subsequent social knowledge, is neutral. They can be only understood within the social context and location in which they are shaped. Deborah Britzman addresses similar concerns in her book, *Practice Makes Practice: A Critical Study of Learning to Teach* (1991):

Words and their meanings carry the intentions and contexts of historical subjects - ideas that precede but do not preclude the speaker. Our words signify communities of discourse that realize language as social. These communities - authoritative and personal- are always in conflict. (p. 23)

Flick (1995) extends these ideas around the theoretical framework of social representation. This theory advances the concept that individuals encounter knowledge in everyday life as socially distributed. Social representations include a system of values, ideas and practical experiences that allow individuals to orientate themselves, interpret their world, and communicate about it with others. Beyond the individual, a group shares social representations. “More generally, this is the social process of constructing realities - through knowledge and social processes” (Flick, p. 75). Historical, cultural and social factors constitute and delimit social groups and thus particular representations that ensue.

Referring to the writing of Moscovici (1984) Flick discusses objectification as one of the critical components in social representation. He defines objectification as the process by which something new is integrated into everyday knowledge usually through the use of

concrete images [objects] or symbols. Which images or objects are used “depends on the social, historical and cultural context in which the objectification takes place.” It is the result of an interactive process. Once these objects/images enter everyday knowledge, they have the power to change and extend existing ways of thinking with new concepts.

While Flick emphasizes the fluidity of social representation, Berger and Luckmann discuss how some social meanings can become fixed. Institutionalization occurs when certain actions, activities or situations are habitualized and shared by a particular social group. Institutions imply “historicity and control” (p. 52). History precedes the making of an institution; the latter is its product. Institutions control human behavior by defining patterns of conduct and constructing the roles to be played within its purview. Over time, institutional knowledge acquires the status of anonymity, detached from those who produce it, implement it or the situation in which it is applied. No longer are institutions seen as humanly produced, and legitimized by living individuals, who have specific social locations and social interests. Rather, the knowledge or rules that govern an institution are perceived as objective reality and the meanings involved become embedded as routine in social stocks of knowledge. In the words of Berger and Luckmann (1966):

The institutions, as historical and objective facticities, confront the individual as undeniable facts. These institutions are *there*, external to him, whether he likes it or not. He cannot wish them away. They resist his attempts to change or evade them. They have coercive power over him, both in themselves, by the sheer force of their facticity, and through the control mechanisms that are usually attached to the most important of them. (p. 57)

A similar theme is central to Richard Lewontin’s discussion of science as an institution of social legitimization. For an institution to claim that it offers the most legitimate explanation of reality, Lewontin (1991) maintains that it must possess several features. First, it must appear to be separate from socio/economic/political forces. Secondly, its ideas and rules must project a truth that transcends human compromise or error. Lastly, the institution must have a “mystical and veiled quality so that its innermost operation is not completely transparent to everyone” (p. 7). This quality is often conveyed through an esoteric language which requires

translation and interpretation by experts. Lewontin asserts that science has achieved this position, indeed replacing religion as the chief legitimating force in modern society. The assumption of priority and privilege are connected to its institutional status.

Feminist critiques of science

How do these theories about the sociology of knowledge contribute to an understanding of science? How do social representations of science affect the way we approach, learn or teach science? How is it that science, a social institution, renders itself as objective, true, apolitical and above ordinary human relations?

Arising from a number of disciplines, critical inquiry poses a direct challenge to dominant science tradition and its claims of political neutrality. Historians, philosophers, sociologists and feminists alike have sought to dislodge the representation of science as objective truth (Blumer, 1969; Fox Keller, 1985; Haggerty, 1995). Rather, they maintain it is social enterprise, “reflecting and reinforcing the dominant values and views of society at each historical epoch” (Lewontin, 1991, p. 9). Science is the name given to a set of practices, understandings and knowledge. As a social institution, it rests on particular assumptions which reflect the interests of those who produced it (Fox Keller, 1985). Tradition has established a view of science as objective, neutral and distinct from human experiences. Indeed, this omnipotent view of science has become part of our culture with many believing that scientific methodology can eliminate cultural, political or even personal bias. Society has also come to claim that the products of science are apolitical and have a transcendent truth. In challenging the belief that science is value-free, Ruth Hubbard (1989) points out, “facts aren’t just out there. Every fact has a factor, a maker” (p. 119). She and other feminists argue that what is needed is a view of science that is much more holistic; a view of science that locates research in its social, cultural and political context and that does not put objectivity and subjectivity in opposition.

In her work, *Reflections on Gender and Science* (1985), Evelyn Fox Keller identified the 17th century as the birth of modern science. It was during this era that the British Royal Society was founded, and with it the idea that knowledge that could be gained through observation and experiment. Its members embraced a mechanical approach to science, one which “sought to divorce matter from spirit, and hand and mind from heart” (p. 44). Themes of power and dominance, coupled with sexual imagery, entered the discourse on what science should be. Fox Keller quotes Francis Bacon in describing his vision of science as a “chaste and lawful marriage between Mind and Nature” that will “bind Nature to man’s service and make her his slave” (p. 48). Nature was to be conquered and subdued. “For you have but to follow and as it were hound nature in her wanderings, and you will be able, when you like to lead and drive her afterwards to the same place again” (Fox Keller, 1985, p. 356). Fox Keller argues this view of science as masterful and dominant has affected scientific practice ever since. For many, the scientific process is still perceived as one of battling obstacles.

Coupled with themes of dominance came the view that science is impersonal and value-free. Early modern scientists advanced the belief that knowledge and objective “truths” could be derived from observation and accumulation of evidence. Their reasoning was based on the assumption that natural phenomena exist in fixed relations with each other, and that these relations can be discovered and known in consistent ways. They defined science by a series of dichotomies: rationality as opposed to emotionality, objectivity versus subjectivity, and truth as distinct from culture, society or politics. Even scientific language helped eliminate the personal by dropping any reference to “I” or “we.” By stripping away cultural specificity and socio-historical context, it was taken for granted that the laws of science could speak for everyone. Scientific method supposedly demonstrated the highest intellectual achievement by providing a defense against superstition, political and personal bias. Sandra Harding and other feminists argue this practice of devaluing context leads to distorted perspectives and “leaves partial understandings of nature” (Harding 1991, p. 198). She writes: “There are social as well as intellectual reasons why ‘master molecule’ theories gain ascendancy at one moment in

history and interactive models at another” (Harding 1989, p. 122). Lisa Heldke puts it another way:

Boyle’s law is useful and successful, and that success is rooted in the fact that it describes a set of actually experienced phenomena. But those phenomena were selected by Boyle and his scientific tradition to be relevant ones. They did not present themselves as the only candidates; rather over time, they came to be the candidates of choice....So it is not at all a matter of claiming that gases “don’t behave that way” - or that of course they behave that way because we make them do so - but rather of realizing that we’ve decided to, and have been brought up to, pay attention to certain aspects of phenomena and to ignore others. (Heldke, 1989, p. 113)

Harding (1986, 1991), Fox Keller (1985), Rosser (1989) and others have focused on the conceptual dichotomizing characteristic of scientific ideology and practice. Sue Rosser argues this kind of dichotomizing is a masculine way of relating to the world, and one that excludes women. Indeed, the construction of science and its cultural stereotype are closely intertwined around issues of gender. Science embraces the same kind of dichotomies found in a conventional construction of gender. As Fox Keller and Harding point out, maleness is equated with rationality, objectivity, activity and the self. To be female, on the other hand, is to encompass emotionality, subjectivity, passivity and selflessness. The metaphors associated with science highlight these sexual differences. We dub scientific facts as “hard” data and feelings as “soft,” the former being a masculine quality and the latter, feminine. Even within the purview of science, certain branches, i.e., physics, are perceived as “harder,” more intellectually demanding, and more masculine than others. Ruth Hubbard (1989) argues that the use of dualisms has served to maintain the sexist, racist and classist regimes of many science projects. The information derived from these projects is used to justify exclusionary practices - in themselves, value-laden - and support elitist positions of particular groups (Rosser, 1989). Despite their insularity, however, these kinds of dichotomies have become embedded in our intellectual structures and social representations of science. Through language power structures are maintained.

Is there an alternative? Some suggest that a feminist method requires the rejection of dualisms which currently permeate science (Fox Keller, 1985; Harding 1986, 1991; Rosser,

1989). Metaphors that stress context and interaction, rather than isolated moments or linear relations, need to be brought to the fore. Harding does not advocate a single approach, however, but states that an important component of feminist critique is the inclusion of many types of knowledge and experience. She also emphasizes the need to address social, cultural and personal processes. Mainstream science fails to consider important questions about social influences on scientific knowledge. Harding argues the contrary. "Scientists must acknowledge that their values and beliefs influence their scientific practice and learn to identify their effects." (Harding 1991, p. 299). She proposes an approach to science where scientists are clear about their assumptions, as well as open, critical and reflexive in their interpretations. Science would be pursued with the recognition there is no single truth, but it is complex, often incomplete and culturally bound. This would help dispel science's hierarchical ordering of objectivity over culture. As Shulman (1994) argues, if one perceives nature and culture as interacting together, there would be "no one unique set of laws toward which scientific knowledge converges" (p. 4).

Belenky, Clinchy, Goldberger and Tarule (1986) explore similar ideas with respect to the dominant epistemic premise of academia. They argue that in learning women exhibit more concern for context and relationship than what typically commands classroom pedagogy. They emphasize the incompatibility between "women's ways of knowing" and current educational and technological practices. By stressing competition over relationship, and making technical advance the hallmark of science, Belenky *et al.* believe that both academia and technology neglect women's connected approaches to knowing.

We believe that connected knowing comes more easily to many women than separate knowing. We have argued...that educators help women develop their own authentic voices if they emphasize connection over separation, understanding and acceptance over assessment, and collaboration over debate; if they accord and respect to and allow time for the knowledge that emerges from firsthand experience. (Belenky *et al.*, 1986, pp. 5, 229)

Bryson and de Castell (1995) have some difficulties with this approach. They argue it suffers from essentialism in its assumptions about women as a category. Applications to

technology or education imply a particular style or “way” or learning that characterizes women as all the same. Further, they argue that “women’s ways of knowing” ignore “the intersecting differences of ethnicity, class, and material conditions” (p. 39) among women. The discordance between “thinking style” and school culture minimizes the complexity of disenfranchisement. Neither does it take into account how the identities of women (and men) shift within multiple positions.

Dunne and Johnston (1992) make a similar kind of argument with respect to constructivism. As a pedagogy, constructivism places the experiences and understandings of the student at the heart of the teaching-learning endeavor. Knowledge is not seen to be separate from the learner but inherently situated in the context where she/he works. In discussing teacher education, MacKinnon and Grunau (1993) write: “We prefer to think that knowledge of teaching is actively constructed by practitioners themselves, inextricably linked to their experiences and inquiries in actual situations of practice.” Learning to teach science is viewed as a “social process of making sense of experience in terms of extant knowledge” (Tobin 1993, p. 242). It is social, interactive and constructive. The literature attests to the broad acceptance of this view.

But while constructivism has been widely embraced by university educators, it does not question the underlying policies that sustain current science culture (Haggerty, 1995). It is a fact that females continue to be under-represented in science. Teachers still give male students more extensive feedback than girls in science classes, women are less likely than men to study physical science and research still shows science and technology as fields filled with obstacles for women (Acker & Oatley, 1993; Haggerty, 1995; Morrell, 1991). Thus while social constructivism emphasizes social construction of knowledge, it does little to challenge deeply entrenched beliefs, many of which support gender divisions in science. Dunne and Johnston’s (1992) article is very important in this regard.

There is an apparent contradiction within this position which overtly proclaims the social construction of knowledge, but leaves unquestioned the power relations that circumscribe the way it is organized....Schools, and science and

mathematics classrooms in particular, are the sites of production and reproduction, where inequities which describe this broader social structure are manifested through the construction of difference. (pp. 519, 524)

Others challenge constructivism on the grounds that it is unclear whether participation in a constructivist environment helps teachers change their orientation with respect to scientific knowledge or whether they just adapt features of a constructivist environment to their own framework. Johnston (1988) makes the argument that teachers can interpret a constructivist view of learning in a number of different ways to justify a number of different teaching strategies.

In advocating an alternative view of science, Fox Keller (1985) refers to the work of Barbara McClintock. In studying plant genetics, McClintock abandoned the predominant theory of the time which looked upon DNA as the single, "Master-Molecule" that controlled gene action. Her studies focused instead on the interaction between the organism and its environment as an important locus of control. Fox Keller writes that McClintock's scientific passion rested on an appreciation of nature's complexity and "respect for individual difference" (p. 163). She rejected all-encompassing theories that tried to make "everything fit." Fox Keller suggests that McClintock's respect for difference and complexity, as well as interest in function and organization, reflects an approach that is more pluralistic than traditional ideologies. It impresses upon us the need to look at difference and complexity not as elements of a hierarchy, but as pieces within an interlocking web. Fox Keller believes this kind of approach has the power to expand the way we conceptualize science.

Although examining a different realm, Britzman (1991) also discusses the need to recognize complexity in teacher education. Rather than accepting curriculum as linear or neutrally received, she writes "knowledge must be approached as problematic in its social construction" (p. 43). Knowledge is not dispensed in a social vacuum, but located within the tensions of teachers' lived experiences. It is being continually reworked and reinvented. Learning to teach occurs within an array of contesting, contradictory and temporal discourses.

To speak and act as if there is one monolithic culture of teachers, students or schools, is to take up a discourse that is at once authoritative and impossible. Within any given culture, there exists a multiplicity of realities-both given and possible-that form competing ideologies, discourses, and the discursive practices that are made available because of them. It is within our subjectivities that we can make sense of these competing conditions as these competing conditions “condition” our subjectivity in contradictory ways. (p. 57)

It is only within the contradictory world of experience that knowledge is acquired or realized. Gone is the glass wall between objectivity and subjectivity, or as Heldke (1989) observes between knowing and knowledge. Hubbard (1989) emphasizes this point when she cites Freire as referring to “the indispensable unity between subjectivity and objectivity in the act of knowing” (Freire 1985, p. 51).

Although feminist theory has made a unique contribution to the understanding of science, to date, very little has been written about using this theoretical framework to guide teacher development and science education. Yet the need for educational reform appears to be most urgent for elementary teachers who are often apprehensive or uncomfortable about teaching science (Berrill & De’Bell, 1995; Roychoudhury *et al.* 1995). For both female and male teachers, understanding the power structures that maintain science highlights the need to examine and approach science from a feminist perspective.

In her book, *Female Friendly Science*, Rosser (1990) offers a number of recommendations aimed at making science teaching more gender inclusive. These include expanding the kinds of observations traditionally used in science research; situating science in the interests and personal experiences of students; providing a cooperative, less competitive environment; and increasing project time to foster a connection between students and the subject of their study. Indeed, Berrill and De’ Bell (1995) identified relational learning through human connectedness and familiarity (with equipment as well as concepts) as two important strategies in inviting student teachers to participate in a university physics course. Likewise, Roychoudhury *et al.* (1995) found that making connections between everyday experience and physics greatly enhanced a group of preservice teachers’ interest in physics. These findings

were particularly striking given the apprehension and anxiety many of the students had initially expressed about science.

Conclusion

This review explores how beliefs, views or concepts about science influence a teacher's relationship to science and science teaching. It also chronicles how everyday experiences form a significant part of people's beliefs about science. Teachers bring to their classroom their individual histories, "educational biography" (Britzman, 1991) as well as understandings of science that are part of and dominated by cultural world views. Similarly, culture is encoded in science, and transmitted through its language. Central to the legitimization of our beliefs, as well as knowledge construction, is social interaction.

Many feminists who have examined science conclude that the formation of a different kind of science classroom requires an critical examination of scientific tradition as well as the reconceptualization of gender roles. I have tried to indicate how feminist critiques of science can inform our understanding of science and lead to a more inclusive approach to science education. This begins by encouraging students and teachers to look for hidden assumptions in science and make them explicit. It requires recognition that science is not absolute and value free, but a human endeavor shaped by concrete, social interests. It necessitates appreciation of complexity, respect for difference and valuing of context. Further, as feminist theory moves toward greater consideration of the ways in which women (and men) are influenced by multiple, complex identities (Alcoff, 1988; Bryson & de Castell, 1995), it begs that intervention projects become aware of such issues.

Chapter 3

Methodology

Beginnings

For the past 12 months, this research has possessed my life. It's always there, in silence and in words. Thoughts about what I have written and where it will go dominated my waking hours. I ponder, rework, go back to the literature, reread passages and articles as well as seek out new interpretations in trying to understand the significance of this work. Deep in my thoughts, I often do not hear my children or others close to me. I ask them to repeat their words or forget what they tell me. I put off meeting friends who call. Yet for all the intensity this research has acquired, its beginnings are largely unremarkable.

This thesis has its origins in my attempts to find grounding in my magisterial work. Coming to a field with no experience in the discipline proved far more difficult than I expected. As part of my course work in education, I read theory, partook in discussions, listened to teachers' examinations of their practice. But as someone who is not a teacher, these realities were far from my own. I struggled to make sense of it all, to find meaning and a place within this particular culture. Yet, the direction and clarity I needed were not forthcoming. Community was not to be had.

After a year into the program, I had reached a crossroads. I decided that I would take one more course required for my degree. If I did not find the direction I sought, I would drop out of the Master's program and return to medical journalism. A number of people had recommended that I take Celia Haig-Brown's course in qualitative methodology. I was told the course pushed the boundaries of educational analysis. As someone who has engaged in "positivist" work for the past 15 years, I was also intrigued to learn what this methodology was all about.

Although I expected to learn something new, I was not prepared for the issues that would confront me. I was forced to examine my own biography -that of a biologist and medical journalist -in the context of feminist, modern and post-structural discourses. The assumptions underlying my knowledge, and work, were challenged. Also disrupted were the universalizing principles central to my beliefs in science and journalism. No longer could I consider knowledge as objective and value-free. Gone was the wall between the journalist and the observed. Never before had I considered the roles played by culture, society and gender in forming scientific tradition. My ideas about the nature and aims of inquiry were reeling. But within this ideological maelstrom, I found focus. My excitement about academia returned.

I came to this degree with an interest in issues relating to science and teacher development. The dearth of science education at my daughter's school, in particular, had led me to question how do teachers come to know science. Why are elementary teachers seemingly so fearful of science? How does science exclude? Given that the vast majority of elementary school teachers are women, are there issues related to gender equity in science and science teaching? By the time I had finished Celia's course, I had a strong desire to learn more about individual teachers' life stories with science. I wondered what science meant to them and how their personal experiences shaped their scientific beliefs. I wondered how an individual's views interacted with her visions of science teaching. I also wondered whether teachers I talked with would describe certain approaches or strategies more appealing to them in learning science. How might this relate to science method courses offered at university? Can particular strategies help offset the alienation that may have occurred?

Celia drew my attention to the fact there are, and always have been, some very successful female scientists. What makes their experiences different? I was forced to question my assumptions that all women teachers may feel uncomfortable with science. It was compartmentalizing their experiences. Through interviews, I thus hoped to document those experiences that enhanced participation in science as well as those that excluded. Further, I

was challenged to explore my biographically determined self. Why do I have positive feelings towards science? Why do I consider science important? Why do I ask these questions?

The participants and interview

Although not an ethnography, the principles of ethnographic research served to guide the work. Hammersley and Atkinson (1983) describe ethnography as a detailed investigation of the ways “in which people make sense of the world in every day life” (p. 2). It serves to study people in particular contexts and in interaction with one another. It admits the experiences of both the interviewer and participants into the research frame; its approach to knowledge is relational. In inviting negotiation between the researcher and participant, LeCompte and Goetz (1982) write: “ethnographers must demonstrate that the categories are meaningful to the participants, reflect the way participants experience reality, and actually are supported by the data” (p. 47). Ethnographic writing attempts to provide an interpretation of how people view events in their lives, but it is hardly a description or translation of experience. It is a re-construction of the self as well as others, a process that is “complicated by the action of multiple subjectivities” (Clifford, 1988, p.25).

Similar to ethnography and other types of qualitative studies, the data for this study are derived from person-to-person interviews. As Anderson and Jack (1991) observed, interviewing provides a valuable means of uncovering people’s perspectives. It allows the participant “to tell her own story in her own terms” (p. 11). In talking with teachers, I hope to gain insight into an individual teacher’s concerns and perspectives about science. I also wished to explore with each teacher the potential links between three areas: her life history with respect to science, her concepts of science, and her view of science teaching. In seeking participants for the study, I wished to interview both practicing and student teachers to see whether perspectives differed as a result of teaching experience.

Participants were selected by providing the option to students enrolled in a module of the Professional Development Program to participate in my study. Eleven students

volunteered. After university ethical review clearance, I approached the students initially by phone. I briefed them about the purpose of the study, as well as the types of questions I would be asking. I informed them verbally, as well as in written form, that they had the right to withdraw from the study at any time. I made arrangements to interview five student teachers from the original group. Availability and scheduling determined which students I selected. They gave me their consent by return of a signed consent form.

I also presented my research plans to a group of teachers taking a science methods course [Designs for Learning Science] at the university. Three experienced teachers agreed to participate in my study. I also approached a teacher whom I had met at my daughter's school. I explained to her the nature of my study, and she agreed to be interviewed. Thus four practicing teachers, and five student teachers, comprised the study participants.

The teachers I interviewed ranged in age from 24 to 50 years. The PDP students had little or no science background. Only two had taken a post-secondary science course beyond the one-term science course required for acceptance into PDP. Neither did any of the four experienced teachers hold science degrees, yet three cited science as important component of their classroom teaching. Provincial residents made up the study population. Their ethnic background was predominantly Caucasian. English was the first language for all but one.

Data collection and analyses

I collected the data over a six month period from November 1985 to April 1986. The data consisted primarily of tape-recorded interviews and observations captured in field notes. I transcribed all tape-recorded interviews to written record myself.

I thought of the interview as semi-structured, guided by certain questions. However, I did not follow the questions in any given order. Conversations shifted according to who was interviewed and as I tried to attend to what mattered most to them. The interviews ranged from one to two hours in length. Analysis of the interviews employed Goetz and LeCompte's (1984) method of analytic inductions in which continued readings of the interviews revealed

common patterns. Out of my notes and ponderings, three categories emerged: beliefs, gender and connections. An analysis of the teacher education literature on beliefs and science education, feminist critiques of science and social representation theory formed the theoretical framework for interpreting the data.

I returned both the original transcripts and critical portions of the analyses to the participants for their approval. I asked for feedback in an effort to ensure that my interpretations most accurately represented what their experiences meant to them. Two people asked for minor changes in wording in order to clarify their positions. Another participant did more extensive editing on her quotes because she felt uncomfortable with her speech and grammar in the original text. The remaining participants made no changes to either the transcript or the analysis. I can only hope that they did not feel embarrassed or uncomfortable with me in voicing changes to the document. In an effort to assure anonymity, all participants are given pseudonyms. Further, the names of towns, schools or specific locations that may identify the participants are deleted from the documentation.

Specific techniques of validity are tied to qualitative research just as they are with quantitative. Recent discussions by Lather (1986) call for an approach to validity premised on reconceptualizations of construct validity, face validity, catalytic validity and triangulation. She argues that construct validity must entail a systematized reflexivity, which gives some indication of “how a prior theory has been changed by the logic of the data” (p. 67). It requires a critical evaluation of how one’s beliefs, conceptions, views are modified by an encounter with the participants. Face validity is integral to establishing data credibility and involves member checks. Catalytic validity is reformulated to include the participant in examination of self-understanding and thinking through the research process. Triangulation goes “beyond the psychometric definition of multiple measures to include multiple data sources, methods and theoretical schemes” (p. 67).

In this study, construct validity entailed an ongoing evaluation of my assumptions and beliefs and how these were challenged, explored or made evident by discussions with the

participants. The keeping of a research journal assisted in this process. This was not a linear experience, however. Although I recorded observations and thoughts following each interview, often insights came to me at totally unexpected moments. On numerous occasions, I found myself grabbing for a pen and paper to jot down ideas that came to me outside the research situation.

Face validity was established by giving the transcripts and thesis analysis to the participants for their approval and feedback. My ability to foster catalytic validity was moderate, although four participants told me they enjoyed partaking in the interview process. They said it helped them reflect upon and clarify their thoughts about teaching and science. Two other participants also said they valued having the opportunity to tell their story. Triangulation of data included taped semi-structured interviews, respondent validation, and personal reflections. The inclusion of different theoretical positions required examination of the data for contradiction.

Biases, assumptions and the evolving interview

My first two interviews occurred with teachers who were enrolled in the science methods course. I began each interview by asking the participant about her reasons for taking this course. In doing so, I held certain assumptions. I assumed the teachers came to the course with an established view of science, and their views of science, as well as feelings about their own ability to do science, were shaped by their own school experiences with science. I came with the assumption that content knowledge would be a critical factor in determining one's comfort level in science. I thought many of the teachers may be taking this course to fill a void in their own knowledge about science or science teaching. Given the considerable literature on gender inequity in science and technology, I also suspected this void may be a result of a negative past experience which, in part, was related to gender. These assumptions guided my questions, and became the focus of my initial interviews.

But the interview process helped me to redefine my ideas. I found my interests evolved as I tried to better understand what science meant to the individual participants. Rather than looking at issues around the science methods course, it was the individual's relationship to science knowledge that became the focus of my questions. Through the interview, I sought to establish context. (What is your background in science? Do any events stand out for you with respect to your science education in elementary school, high school or university? Did anything happen that made you doubt your ability to do science?) I was also interested in understanding the impact of these events on the participant's life and her relationship to scientific knowledge. (What does science mean to you? Do you see scientific knowledge as different from ordinary knowledge? What do you feel most influences what and how you teach science?) We also explored these issues with respect to learning science. (Do certain teaching strategies make you more comfortable with science than others?)

The changing nature of the interview led me to reflect upon my past and present notions of what constitutes credible research. As a journalist and a graduate student in zoology, I had retained the belief that if I did my job/research properly, I could be neutral and describe my findings objectively. My method required that I adopt an analytical, macro-structural approach. This work led me to question the tenets of research to which I previously subscribed. It also led me to the realization that the researcher, regardless of what methodology she selects, inevitably imposes her will on the work. Research is never agenda-free.

Sandra Harding says that a research method is "a technique for gathering evidence." As I do my interviews, the method stays the same (semi-structured conversation) but the questions change. This runs contrary to all my notions of "objective research." How could my study be statistically sound if I alter question to match/suit/take advantage of every new situation? In the past, I would have said that I was unprepared; that my questions should have been better thought out. Inclusive enough to cover every situation. I now realize that is not possible. One must respond to the subtleties of the situation. Sometimes these question are adequate. Other times they sorely miss the point. But as my questions shift with respect to the interview, I am also looking ahead, thinking about how will this material be used in my research. Even if I let the theories "emerge from the data," there is this built in bias of me selecting what goes in and what stays out. I have a nagging concern about the impact of the

researcher's views and beliefs on the research, that such work is never agenda-free, that theories never emerge value-free. Unless I analyze what I have removed from the central arguments (thereby making a new chapter in itself), I fall prey to the original problems in any sort of research inquiry. (Fieldnotes: February, 1996)

This notion of editorial control is one that plagued me throughout the research process.

I reflected on it further after rewriting a particular narrative.

Who gets to tell the story? What is the imperative that drives it? The experience of re-writing Anna's narrative illustrates for me the power of the editing process. What remains, what is ignored, what is discarded, results in another story. In this re-telling, I have created a very different narrative from the first. I think, however, both versions bear a reality. They both share a truth, although obviously I think the second version is closer to the 'real' story and Anna's intent than the first.

More than ever, this process has made me realize the impact the researcher has on the research. Ultimately, the choice of words are mine. The emphasis given, the positioning of quotes, reveals as much about me (my interests, my choices) as it does Anna's. Although I have tried to tell her story, in fact, the narrative is a re-creation. Representing another's voice is hardly pure. It is shaped by multiple interests/meanings/positions that are not often articulated (Fieldnotes: June, 1996).

Britzman's (1991) writings, in particular, caught this dynamic for me. She wrote:

"The retelling of another's story is always a partial telling, bound not only by one's perspectives but also by the exigencies of what can and cannot be told. The narratives of lived experience-the story, or what is told, and the discourse, or what it is that structures how a story is told-are always selective, partial and in tension" (p. 13). Indeed, I came to consider the narrative as just a beginning. Although its textual form implied a permanency, it was only one of numerous stories that could be told. This is not to abdicate or minimize my responsibility to be true to the participant's words or to her intent. It is just a recognition that an individual's story is ongoing and that it can involve many different tellings.

There were instances when I felt more comfortable with the interview process than others. Most interviews led to easy conversation and became quite intimate. Participants often surprised me with the intensity of their emotions.

I am just amazed at the passion and the intensity of feeling that has come up through the interviews. I would not have thought the questions that I asked would evoke these kinds of reactions. It shows how much I misunderstood this whole thing of education (Fieldnote: November, 1995).

Other interviews were more stilted. One, in particular, required that I change my approach so that I could hear what the participant had to say. My awareness of how personal agendas can disrupt the listening process grew in my interview with Kate (pseudonym).

My interview with Kate has been the most difficult so far. After talking to her for a while, I realized I couldn't follow the structure that I have used with everyone else. The questions I had asked seemed pertinent to the other participants. They could talk about them for quite some time whereas Kate could not. It isn't that she is not articulate, or bright. It is just that what is important to her is really quite different. She does not necessarily talk about science in the way that I am used to talking about science. It means a totally different thing to her, probably in part because of our different backgrounds. (Fieldnote: February, 1996)

As I progressed with the interviews, I began to realize that I should never take anything for granted, or assume that I understood what the participant meant. It was a mistake to draw my own conclusions without asking the participant first. I must give the participants the opportunity to interpret their experiences, and to state their viewpoints, in their own way. When I interviewed Andrew, he talked in general terms about the difficulty he had with the subject and his perception that it was something he could not do. At one point in our conversation, I asked: "Am I right in saying that your fear of science results from an overall sense that it is something that you cannot do, versus a specific experience?" He responded that it was really both, and went on to describe an incident in Grade 8 that contributed to his alienation from science. If that question had not been asked, I would have misinterpreted his experiences as well as missed an important detail of his life story. Once again, this caused me to reflect upon the interview process with respect to various research methodologies.

My interview with Andrew really illustrated for me that I cannot generalize from these people's words. Or if I do, I have to have them verify that my generalization is indeed the correct one. This is where I am finding a real difference between positivist versus qualitative research. As a journalist, I never felt that I had to ask that question. If anything, having my information verified from the source discredited my skill as a professional. (What if the interviewees changed their minds???) This shift in focus, from information gathering to process, is liberating. If what I want to do is reflect what the people's experiences mean to them, I have to ask them all the way along is my interpretation the correct one. It makes for a lengthier process but I think it does make it more accurate, more true to the participant's thoughts and intent. Ironically, in a way it also makes for more "objective" research. (Fieldnote: March, 1996)

The interviews also revealed for me how contradiction is woven throughout our experience, understandings, and interpretations. Indeed, we often live our lives within the tensions of those contradictions. The friction may perplex, but it also makes way for change. Claire, for one, expressed that tension to me when describing her views of science. Although she recognized that science is always changing, she maintained that scientific methodology renders a more exact way of acquiring knowledge. She described scientific knowledge as neutral and less arbitrary than other forms of knowledge. Yet her approach to science teaching did not require her students to absorb predetermined facts, but rather to draw upon their own creativity in cultivating science interests. It was an enlightening experience for me to include these dissonant aspects in the research. Prior to this work, conventional methodology had required that I choose. Contradictions were absorbed, negated or neglected, in a demand for simplicity. Early on in my fieldnotes I explored this notion.

Simplicity is so valued in western culture. Our language indicates that society does not approve of more complex analyses. Terms like "wishy-washy" or "straddling the fence" etc. are used to describe someone who does not have a clear/singular/monolithic opinion. We are taught to be judgmental and unequivocal in our beliefs, otherwise our thinking is considered weak. Why have contradiction or complexity become equated with irrationality? Why are they considered less than true? (Fieldnote: January, 1996)

My experience with this research led me to redefine the interview in terms of process rather than the recording/reproduction of data. I shared my views and life experiences with the participants, as well as asking them about theirs. Despite my intent to shift the interview from information gathering to interaction, however, I could never escape the feeling that it was still a disruption. Even within the guidelines of a feminist interview, I saw mutuality as only temporary. Respect for the participant did not or could not engender equality. The intrusive nature of my participation became an area of contradiction for me, and one that I continue to struggle with.

Although we would like to think of them as such, I do not believe interviews are true conversations. In an attempt to get away from positivist research, we frame/discuss an approach to interviews using words such as conversation. Although this is far preferable to the Q & A drill to which I am accustomed, I think we fool ourselves if we think of the interview as a conversation. We as

the researcher, the interviewer, are still asking the questions. The interview may go off in other directions, but we initiated the conversation with some kind of purpose in my mind. Is it just happenstance that interview is so close to intervene in the dictionary? In both instances, we are disrupting another person's life. Judith Stacey's words come to mind when she states there can never be a feminist ethnography, only research enhanced by feminist perspectives. (Fieldnote: May, 1996)

Indeed, involvement with one participant in particular made me ponder the ethics involved in doing this kind of research. Not only did our conversation bring up many painful memories for her, but our continued interaction caused her further self-doubt.

I just talked to H. on the phone, letting her know that the transcript is on the way. I was really dismayed to see how she viewed our initial interview. She said she couldn't see how her stories/opinions/thoughts would have any value to me and apologized for using up two sides of the audio tape. I tried to reassure her that everything she said had value. That her story, as well as others, were the focus of my research and that each story had incredible importance. I can only hope that she believed me. Her self-confidence appears to be greatly shattered, but she is an incredibly articulate and sensitive woman. The last thing I wanted to do was cause her more pain. In many ways, quantitative research is far more safe. (Fieldnote: November, 1995)

I talked with H. on a number of occasions after this. She was pleased with how her experiences were portrayed in the narrative. In our last conversation, she said that she appreciated having the opportunity to tell her story, saying that it gave it purpose. Still, the process troubled me. What if the research continued to cause H. pain? Was it ethical to include that interview in my data? Should I be partaking in a type of research that could possibly hurt? I found no easy answers to these questions. While qualitative research opened the doors to new understandings (and dilemmas) for me, I also realized that I was not ready to dismiss quantitative research. Numbers can be extremely powerful. They often make a statement, prove a point, that cannot be done in any other way. This work made me aware, however, that quantitative methodology is only one way of looking at things. It is just a tool as is qualitative methodology. All these tools are available to us and should be examined carefully in planning our research.

Science connections

As well as exploring ideas around methodology, this research brought me to different understandings of science. When I first began the work, I was well imbued with traditional notions of science. I had accepted without question that science represents an authority, a way of knowing that is objective, value-free and true. I assumed that if I was to partake in the world of science, I must accept that truth, work with it, and then apply it to my field of interest. Similarly, I thought science was accessible to everybody. It comprised a discipline, a body of knowledge, in which everybody should partake. Why then was the status of elementary school science so poor? What created this aura of fear?

Until I read Fox Keller's (1985) book, *Reflections on Gender and Science*, it had never occurred to me that scientific "truth" represents one view of the world. Upsetting my entire intellectual grounding was the realization that the methodology we so revere is not value free, but has been determined by a narrow segment of society. I began to reflect on my experiences in zoology and medical journalism and could readily see how mainstream science has polarized what we do. I knew of numerous examples where science failed to consider information valid because it did not conform to a methodology singularly prescribed. In a pluralistic society, we acknowledge the desirability of variety, but the amount of variety we are willing to promote is limited. Our fixation with statistical validity, in particular, has excluded many valuable interpretations. In their reverence for proof, scientists may have forgotten what science is all about.

Fox Keller wrote that the naming of difference is not problematic, but the power positions that become attached to them. Rather than respecting diversity, we have a tendency to place value and organize these differences within a hierarchy. Indeed, my own experience as a graduate student had taught me that science seeks out the positive. We relish that which is certain, knowable, predictable and uniform. But this desire for uniformity rapidly becomes

exclusionary and oppositional. It becomes elitist, imposing a hierarchical ordering upon various experiences, ideas and people.

My readings also made me think about the scientific methodology and its claims of absolute legitimacy. If being “dispassionate” and objective is the ethos of the scientific enterprise, it makes sense then we must have a technique, a set of rules to guide what we do. Scientific methodology gives us that. But we have made it more than what it is. It has become “truth,” the only way of investigating the unknown. Anything less is not good science, is not good truth. It is imbued with judgmental knowing. We continually replace one “gold standard” with another, advancing and perpetuating the notion of hierarchy. No longer, for example, are simple mathematic relationships considered adequate. We must describe scientific findings using new words, a statistical “significance” that is yet further removed, more abstract, from the event itself. In our pursuit of the rational, we have disengaged ourselves from everyday science. I began to wonder if more female voices were heard in the making of the scientific enterprise whether these trends would have occurred.

In addition to the readings, interviews with participants made me re-examine my relationship with science. In particular, this process revealed to me how my biography enabled me to think about science in certain ways. I realized how the concepts and the categories I used for reflecting upon and evaluating scientific knowledge came from *my* cultural context. Science was part of my heritage. From grade school well into university my parents told me science was something I had to do. But for many of these participants, their exposure to science was limited to one or two classes in high school. Their knowledge of science was thus very different from my own. Indeed, for some science had become something that they did not think about or care to know about. In comparison, it had dominated my life.

Yet despite its place in my upbringing, science meant something more to me. My interview with Susan prompted me to explore this connection.

Like Susan, I took many science courses and did not understand a thing. This continued through university where I took organic and inorganic chemistry, physics and calculus all in preparation for pre-med. Although I had to work

hard, I managed to do well in these courses. Yet, I did not understand the subject material and for all my years of learning, remember very little.

But for whatever reason, whether it be growing up in the mountains of New Hampshire, or going to school in rural Maine, nature held a strong attraction for me. And this I equated with science. It held the same magic or sense of wonderment that I would find in certain stories. But more so, nature connected me with something spiritual (dare I say god?), that kind of life force that is both the self and outside the self, that includes me but transcends me, that is part of my finite world at the same time as running through every molecule. With my high school curriculum tied into an Outward Bound program, the opportunities to experience the outdoors were vast. It was the sense of spirituality, that I find so difficult to articulate, that promoted a connection to science. (Fieldnote: May, 1996)

My interviews with Susan also helped me clarify the meanings I gave to science. In response to the question, does science have value to you, she said: *“Oh yes, I would say definitely it has value. Look at the society we live in, it is so scientific...If it wasn't for science, we wouldn't have lights, we wouldn't have cars, we wouldn't have microwaves or TVs or all that stuff that is so integral to the way that we live our lives.”*

What she talked about as having scientific value is something that I would have ascribed to technology, not science. Even though scientific principles shape/drive/force the development of technology, I viewed science as more theoretical. Indeed, until I transcribed the interview tape, I did not really think about science as permeating the details of our everyday lives.

Until listening to the tape of our conversation, I never really stopped to think about science as technology and being part and parcel of who we are, how we live and what we do. Although I recognized that we confer greater authority on scientific knowledge, I thought of science as dealing mainly with what we do not know. Technology, on the other hand, is something applied.

It is curious that this distinction stands out for me. Medicine is definitely something applied. Scientific rules/knowledge/findings/observations put into practice whether it be a new drug, new imaging technique or new way of performing a surgery. But I guess medicine still has that sense of mystery for me - something that is always changing, whereas I see technology as much more fixed. It is an illusion, a strange distinction to have made because there are certain things in medicine that have remained the same for the past 100 years. And technology likewise constantly evolves. (Fieldnote: February 1996)

Interviews with the participants also caused me to change my views of what constitutes scientific success. As a member of the science community I had conformed to its

rules and readily accepted its practice. I did not think to question its knowledge, and thus was puzzled by the difficulty so many elementary teachers seemed to face. Yet through the interview process I came to realize my parameters of success were extremely narrow. My naive notions of what made for good science were disrupted. The participants showed me that an inability to do science or lack of desire to participate in science did not mean someone was not accomplished. Rather, many of the participants who failed in traditional academic terms were far more creative and articulate than I could ever be. They had retained a critical voice, looking at science not as what was expected of them, but how it interacted in their lives. Their exclusion from science rested not on personal failure but a denial of voice.

Conclusion

This chapter gives an overview of the methodology used for this research project. It also provides a brief discussion of the reconceptualization that occurred due to the interactive nature of the research. In summary, interviews were held with nine teachers. These serve as the basis for the results presented in the next chapter and are concerned with the way teachers make sense of science within their life experiences.

Although this chapter presents this work as a linear progression, it was far from that. The process was dominated by uncertainty, disruption and change. In the written form, the narratives seem framed, final in their completion. This masks, however, the disorder that plagued the work. In particular, I struggled with the analysis - allowing themes to "emerge" from the interviews. To the extent that the analysis appears distant and rational, I worried it would suppress the individual's voice. By favoring certain meanings over others, I thought the analysis might devalue certain perspectives. It did not permit the multiplicity of experiences to be expressed.

Yet the analysis allowed me to explore new ways of thinking about the participant's experiences. It allowed for discovery, and in the written form, communication of new meanings. Thus, this is an issue that I cannot resolve in practice. The analysis denotes a

struggle been the detailing of experience, interpretation of that experience and recognition of difference. Just as scientific models tend to simplify the real world so does the written text. Experience is more complex, more multi-faceted, than anything we can write. Yet, within this space on the written page we make our meanings.

Chapter 4

Findings

Introduction

This chapter offers a narrative account of the life stories of nine teachers with respect to science. Each profile is based on the interview I held with the individual teacher. Presented first are the stories of the student teachers (Susan, Eric, Nancy, Kate and Andrew). These are followed by the stories of the four experienced teachers (Haley, Pat, Anna and Claire). Out of the profiles emerge certain themes which are further explored in Chapter 6.

Although this chapter details the data I collected, it is not a conventional “results” chapter. In addition to the profiles of the various teachers, included here are methodological insights which arose from doing the work. The chapter also provides some initial analysis that I considered necessary to leave in context of the original data. I approached the chapter this way in recognition that research is rarely a linear process that can be divided into discrete sections. Rather, it is an integrated, multi-faceted process that is affected by both what precedes and follows it. Indeed, the research I conducted was shaped by my reading of the literature, interaction with the participants as well as ongoing thoughts about the analysis. These various elements worked in concert as I collected the data. This section is an attempt to represent that aspect of research.

Although I organized the profiles into two sections - those of the five student teachers followed by the four experienced teachers- I did not present profiles in the order I interviewed the teachers. Rather, my understanding of the material, ongoing analysis and emerging sense of categories determined how the profiles were organized. As Merriam states, “devising categories is largely an intuitive process” (1988, p. 133), as well as one that is methodical and informed by the study’s purpose. Ultimately, however, this process is concerned with making sense of the data and I did not think the chronology of the interviews affected their meaning.

Profiles - The Student Teachers

Learning to teach is not a mere matter of applying decontextualized skills or of mirroring predetermined images; it is a time when one's past, present, and future are set in dynamic tension. Learning to teach-like teaching itself-is always the process of becoming; a time of formation and transformation, of scrutiny into what one is doing, and who one can become. (Britzman, 1991, p. 8).

Susan

Susan volunteered to participate in this study early in January at the beginning of her PDP module. After an initial phone call, in which I explained to her the nature of the interview, we met at the university. We found an empty classroom and sat together at one of the tables, with the tape-recorder in between. At 3:00 p.m., the room was filled with the remnants of a school day. Tables were askew, papers littered the floor, empty coffee cups and a few half-eaten sandwiches lay on a tray in the corner of the room. The room provided an unobtrusive backdrop to our conversation except that the overhead lights -which must have been on a sensory timer- kept turning off and on their own.

Before we started the interview, I told Susan that I was interested in understanding how she saw her own experiences with science and how these influenced her current views about science. I emphasized there were no right or wrong answers, but individual interpretations. In re-creating Susan's life history, however, I recognize this narrative is in part my construction, my interpretation of Susan's experience. It is also important to recognize this narrative captures Susan's story at one day in time. Her views, feelings and thoughts about herself as a learner and teacher of science may change as she completes her teacher education.

Susan lived her childhood and adolescence in Alberta, graduating from high school in 1989. She remembers little about doing science in elementary school, short of watching a video on childbirth in Grade 5. She recalls being quite frightened by this video, as well as by

her teacher. *"I remember that I was sort of scared of him, just his whole person and the way he acted toward students."* The video seemed to reinforce this impression.

Susan says her memories of science really begin in high school, however. With her parent's encouragement, she took all three sciences (biology, chemistry and physics) through Grades 10, 11 and 12. Her personal feelings towards her teachers had a great influence on her perception of the subject matter. She discussed enjoying Physics 11 and Biology 11 in tandem with liking her teachers. Chemistry 11 was another story, however. She found her teacher cold and aloof. Moreover, the teacher's approach to the subject matter - reading out loud from the textbook - tapped into one of Susan's greatest fears. Her recollection was painfully narrated.

In grade 11, I hated chemistry so much, mostly because I was terrible at reading aout loud. I just got really nervous about it. I could read out loud but I just had no confidence. And my voice would start to shake and it would sound like I was going to start to cry. I just hated it. But all my chemistry teacher did...was sit at the front of the room and have us read through the textbook and read through the little workbook. She would just randomly call on people to read a long paragraph. I was fine if it was just a few sentences, but if I had to read a paragraph to the whole class, I would be just so nervous that she was going to call on me, that I would think of nothing else. Sometimes I skipped the class, and I wasn't the type of person to skip a class, I never skipped classes, but I would skip that class because I was so worried she was going to ask me to read. That was a really bad experience. I didn't like that teacher at all...Sometimes I thought, this is ridiculous, I should just go and talk to her about it, and [say] please don't ask me to read because it petrifies me, but she was the type of person I think that would not care.

Susan's high school science classes comprised a mix of hands-on activities, experimentation, lectures, workbooks and memorization. The study of motion was a major theme in Grade 10 physics; there were experiments with fulcrums and pendulums. In Grade 11 physics, Susan recalls doing a project on solar energy. Chemistry involved laboratory work, experiments with partners as well as lecture. Her Biology 11 class consisted of little more than copying down information from overheads and memorizing it for exams. She found Grade 12 Biology far more interesting with its emphasis on human anatomy. There was also the opportunity for dissections and *"more hands-on stuff like heart monitoring."* But once again, she referred to her teacher as having a negative impact.

He [Grade 12 biology teacher] was kind of mean in the way he acted towards students - especially some students, he seemed to pick on them. So I didn't really like him as a person and I thought he was a terrible teacher because it was obvious that he did not enjoy teaching. I think he liked the science part of it, but he didn't enjoy teaching at all. So I didn't like really going to his class.

Although Susan did well academically in all her science classes, she says she lacked a real understanding of physics and chemistry. She learned all the formulae and algorithms, and even how to apply these things, but did not understand how the answer came about. This made her feel uneasy and set the tone for much of her science career. She repeatedly voiced concern about her poor comprehension.

Physics was something for me that I never really understood. I was good at memorizing and learning things, so I could memorize what I had to do and I did fine. I ended up with an 80 or 85 in the class as my final mark, but I didn't really understand it. I just memorized it and I could do it that way...It was the same way for me in chemistry. I never really understood what was happening. But I could do the experiments.

Susan saw the irony in this situation, especially when she compared herself to a peer who did not do as well academically as she did.

I used to sit by one of my friends and he was the opposite from me. Sometimes, he couldn't get the right answer but he always understood what was going on a lot more than I did. It was kind of weird. He knew what was happening and I could get the right answer, but I couldn't understand what was going on. It was kind of interesting that way. But I was good at math. Math was one of my favourite subjects and I think that was why I could do the work in physics without understanding it.

Susan equates science with work. When she started high school, she had no clear idea about the type of career she would pursue. Her parents encouraged her to take all three sciences believing this would provide her more options for the future. Science thus became something that had to be done. Susan says she never enjoyed taking science in high school. She did not “look forward” to a physics or chemistry class. At the same time, she does not recall having specific negative experiences in science, with the exception of Chemistry 11. Neither does she feel she was discriminated against as a female doing science. Rather, Susan never gained a sense of comfort doing science or a love for the subject matter. In her words, “I guess maybe science just wasn't my thing.” She never achieved a personal connection with science learning.

For Susan, the perception of science as work is embedded in its very language. PDP has been influential in helping Susan re-examine her beliefs, however. Susan's first practicum in a Grade 2 classroom afforded her the opportunity to explore science with children. She described an experiment she did with her class demonstrating that oil and water do not mix. She first dyed the water blue, and then poured yellow oil on top. When the children shook the jar, yellow oil globules would mix in with the blue, and then separate out again. The effect was quite dramatic, and Susan said the children really enjoyed it. *"So now, I am starting to see science more of a fun thing. Like fun little experiments you can do and learn about things around you and stuff, whereas before I used to see science as the big confusion out there that I would never really understand."* A trip to Science World through PDP, as well as participation in a school-based inservice science workshop, also added to Susan's view of science. A model of science education which stresses fun and personal meaning makes sense to her understanding of teaching and learning.

The discovery that science can be "fun" has caused Susan to reflect on her own experiences. She ascribes her difficulty with science to both her schooling and herself, a mismatch between teaching approaches and her particular learning style. At the same time, however, Susan holds some resentment towards her educational experiences.

Now in this module when I see some of the things that we are doing and some of the things you can do in classrooms that are related to science that are fun and that kids can understand, it makes me sort of sad that I missed out on that. I didn't really understand that science can be fun, that it doesn't have to be like just total memorization and that kind of thing.

Teacher education has made science more approachable for Susan. Rather than a body of knowledge divorced from personal experience, she is beginning to view science as a process and a way of making sense of the world. The notion that one can work things out, "discover things for yourself," has added another dimension to Susan's definition of science. She articulates this emerging perspective in response to my question: "What does science mean to you?"

I used to think of it [science] more as a body of knowledge that was out there, and if you were really smart or really intelligent you could add to that body of

knowledge. Like you could discover something or take it further. But now, I am starting to see it more as like things that you do with the environment, just to manipulate it and see how things grow, and how things work, and discover things for yourself, and not so much as a fixed body of knowledge that needs to be memorized and learned. I am starting to realize the importance of discovering things for yourself because that is when you understand, when you do something and then you realize, oh, that's how come it works that way...Actual hands-on. I guess I am seeing it more now as a process of learning and working things out for yourself. Obviously there are things that you can learn from what has happened. And there is a body of knowledge out there that you can glean things from.

Susan's new understandings are overshadowed by contradictory images, though. For example, she continues to struggle with the word "science," It is a "label" that begets feelings of incomprehensibility, silencing and even fear. To name science "science," divorces it from what it truly is. She believes this holds true for young students as well.

Kids, especially in the elementary grades...really enjoy the science experiments especially if they are not labeled as science. The label kind of turns them off sometimes, whereas if you study living objects and study plant growth or something and don't label it as being science, the kids find it interesting and really enjoy it and learning about that kind of thing. For me too, sometimes the science label kind of scares me. It is like way out there and I don't understand. I think how can this work and it kind of scares me. I am starting to realize that it shouldn't be a scary thing for me but if it is something that you work at and get your head around it, it can be simple, it can be broken down into simple steps. It is not this big, complex thing that can't be understood.

The transformation of Susan's position to science has been neither easy nor complete. As she negotiates new understandings echoes of her past ring through. Her PDP experience is marked by an uneasy exchange between old and new ideas.

Eric

For Eric, high school science classes provided the flexibility and freedom that his other classes did not. Rather than seeing science as facts to be memorized, or formulae to be applied in fixed, specific situations, Eric saw science as open and fun. It gave him the chance to explore, test and to manipulate. He could pursue questions and investigate problems on his own. Indeed, science proved to be the antithesis of his regular academic routine.

To me, it [science] was a chance to do things in class; get away from pencil and paper and do something a little different. Most of school was a lot of

writing and reading, just in different subjects. In science class, sometimes you had a chance to get away from that.

I interviewed Eric at a school in Surrey. Because of our conflicting schedules, we could not find a convenient time to meet at the university. Instead, I drove out to the school where he was doing his first practicum and met him for the first time (*Lori: "I am short, with brown hair and glasses." Eric: "I will meet you in the entrance way and will be wearing a brown, leather jacket*). At Eric's suggestion, we had our interview sitting on a couch in the corner of a busy hall. With doors clanging, children shouting, carts rolling by, and overhead speakers booming, it was difficult at times to hear each others' words. Yet, this seemed like such a natural place to speak. It situated our words in the context, business and noise of everyday school life.

Eric grew up in a small town in B.C., where he attended both elementary and high school. After taking a year off from school, he pursued a degree in psychology at SFU. From there he went to law school. Disliking it intensely, he quit after a few months. He then worked for a year, and took some preparatory courses for PDP. He began teacher education at 26 years of age.

Eric was the sixth PDP student I interviewed. Unlike previous participants, I gave him a copy of the interview questions prior to turning on the tape-recorder. Before that, I just discussed with each participant the nature of my study and stated verbally the questions I would be asking. My previous interview with Andrew, however, made me aware that the researcher is in a position of control. Despite my attempts at conversation, and desire to let the participants construct the interview in their own terms, ultimately my questions directed the talk. Unwittingly, I had become party to the act of "othering." I hoped giving the participants the questions beforehand would help share that control.

As a research process, the interview entails a hierarchy. Although it seems so obvious in retrospect, this comes to me as a surprise given my experience as a medical journalist. When I interviewed physicians or medical scientists, I never felt that I held a power-laden position. Rather, I felt the doctors were in control. They were the makers and dispensers of information. They had the opportunity to restrict, shape or dominate over what was told. I felt very much dependent on the information they gave me, and at times, their responses made

me feel that I was troublesome, or wasting their time. Because of this, I did not give much thought to providing my participants with a list of questions before the interview took place. I never imagined I would be viewed as anything but an equal.

After conducting a number of interviews with students, I realize this situation is different. The researcher is indeed the power holder. Although I prefer to think of the interview as a conversation, in which I also disclose aspects of my life and experiences, ultimately I am the one who is asking the questions, seeking opinions and directing the talk. Some of the PDP students, in particular Andrew, have been quite concerned about answering my "questions." (I saw him peering at my paper, and because he was sitting opposite me, trying to read the questions up side down). Kate asked me whether she answered my questions completely, or provided *me* with what I wanted to know. Having a piece of paper with a list of questions in front of me, must generate or add to the asymmetry that is inherent in this interview situation. I should, and have not done this up until this point, give a copy of my questions to the participants beforehand, so they have a clearer understanding of what direction our conversation might take. Issues of control are complex (Fieldnote, March 1996).

Eric says he has been "*a big science fan*" ever since he can remember. As a child, he lived on a farm. Much of his time was spent outdoors poking about, digging in creeks, finding and collecting small animals. Nonetheless, he has very few memories of doing science in elementary school. Most of it involved book learning - reading and writing - or "*filling in the blanks type stuff*." He does have vivid recollections, however, of participating in a Grade 5 science fair.

I had my own exhibit. I put a lot of effort into it. I went to the library and did some research, and I built a shocking machine. It was like a make-and- break circuit like they have in an electric fence. It worked really well....I was really proud of it.

In high school, Eric took biology up to Grade 12, and Grade 11 chemistry and physics. He also took an advanced science class in Grade 12 that was offered to students who did well in their regular courses and were keen about science. It delved into a bit of everything - biology, chemistry, physics and math. Science, in particular biology, always ranked as Eric's favourite subject in high school. He spoke of these classes as being different from his others. He relished the opportunity these courses gave him for individual exploration.

The memories I have of science is that the teacher made it enjoyable. We had a lot of individual investigation. You could work on your own, there was a lot of autonomy there. Kids could investigate and find things out for themselves, rather than being dictated to or having things just shoved down your throat. I

liked that about science, it could be more fun that way....And the subject matter, a lot of it is interesting. Biology - I just couldn't get enough of it.

Eric credits his teachers, as much as the subject matter, for fostering his love of science. He describes his physics and chemistry teachers as being very good, despite a minor personality conflict with the latter. His biology 12 teacher, in particular, made a big impression on him. The teacher was knowledgeable, entertaining and “*didn't condescend.*” He also encouraged students to develop their own ideas and take risks. Eric recalls one assignment in which the students were asked to investigate the effect of different drugs on the body. He and a friend did a research project on alcohol.

We actually put a lot of effort into it and did a video tape. We used a Cam-recorder and filmed it, spliced it and edited it and he played it in front of the class. It was sort of a sensitive subject, especially in the school, and I wasn't sure how well it would go over...It was a tape on the effects of alcohol, and we did it from a teenager's perspective, partying and stuff like that...Some teachers may have found some of it offensive. But he didn't at all. He thought it was appropriate...That made me feel good about going out of your way to try something different. He wasn't the type to just say no.

In addition to giving his students freedom to experiment, Eric said this teacher put a lot of effort into designing an interesting curriculum. There were a number of dissections to do, including the rabbit and pig. The course was demanding, but, more than difficult, Eric said it was challenging. It pushed him to think. “*The subject matter was just incredible. I actually loved the textbook so much that I tried to buy a copy of it from the school.*” Because of this course, and his overall success in science, Eric considered pursuing sciences at the university level. Over the next year, however, his interests turned to psychology. “*I don't know why I changed my mind. I don't think there was any real turning point. I just decided to go one way. It was a gradual process more than anything.*”

In extending his personal experiences to theoretical perspectives, Eric characterizes science as both information and process. He says science consists of a “*huge body of knowledge*” that has been accumulated about “*all kinds of things.*” It is an orderly body of knowledge with facts and laws. This type of factual knowledge is reflected by the volume of

subject content students are expected to learn. He marvels at the growth in scientific knowledge occurring over history.

One of things that I find interesting is looking at the history of science - the way [scientists] discovered things, and how actually little they knew back then about human anatomy, the body, the way trees worked, anything....I always thought how did people come up with these things? Who discovered them? How did them find out about them? And here we are, and I would think I am just a kid, and we know way more than people 100 years ago in their lifetime.

Equally important to Eric as facts, however, is the “process” of science, the way scientists go about discovering and accumulating their knowledge. “I would say it [science] is almost a balance of knowledge and process because the knowledge came through following certain processes, trial and error, discovering new things by being meticulous.” Indeed, for Eric it is the process more than anything that seems to define science. He describes the scientific process as: “being exacting and consistent in the way something was being investigated.” It is rigorous, careful and precise. He believes this process to be the true and ultimate way of describing nature and its problems.

Despite his obvious respect for science, Eric does not place greater value on scientific accomplishments than other kinds of endeavors. Nor does he think knowledge derived from scientific process is more worthy. Rather, science has led to considerable technological advancement, which in turn helps mankind. But Eric also views the “arts” as playing a critical role in understanding, interpreting and experiencing the world. The arts may be less exact, or more subject to individual opinion, but are nonetheless significant. Eric articulates his view with these words:

I don't think one is more important than the other. I mean it is important to have the arts, and science is important to the way we live obviously. We couldn't have almost any of the things we have in terms of medicine and advancements. The human race is pretty much dependent on a lot of scientific advances we have, even if you want to look at it in terms of evolution, how many people live today because of science. We almost control our environment, we are not even evolving anymore it seems because of the extent to which we control our environment. So it is a pretty powerful influence and I guess it is important to maintain it in that sense but I wouldn't say to the exclusion of writing, or reading or the arts. That is important, too. It is part of being human, too.

Like others, Eric's image of science is contradictory and complex. On the one hand, he said science is a human construction, a set of ideas that account for physical phenomena. But at the same time, he believes "*there are certain bigger truths, a sort of hierarchy, certain laws dictate certain things and all other things following in the group of that particular law are affected by it.*" Although he does not employ the terminology, Eric envisions science as deductive: a set of laws or principles which can be used to explain particular events.

You know Einstein's theories, such as the theory of relativity in space - those are pretty vague powerful concepts. They dictate the way the entire universe works, which is a pretty awesome thing to think about....I don't have much of an education in science but that is always what I thought science would be like - you had to understand these basic laws of whatever you are studying, chemistry or physics, and if you didn't you couldn't get into the finer things or start researching in a relatively unknown area unless you understood certain basic fundamentals.

Although it is still early in the PDP program, Eric suspects science will comprise an important component of his teaching. Drawing on his own experience, as well as his observations as a student teacher in the classroom, he said "*hands-on*" learning will form the nucleus of his approach to science. I asked Eric what hands-on learning meant to him. His definition emphasized interaction and relevance.

By hands-on, I mean physically manipulating things: Using a microscope, or doing a dissection, or building something, or taking something apart, or experimenting with simple machines, things like that. Actually getting to use something instead of just taking notes, or writing something down and expecting to know how something works because you have written about it, or read that it does that. Actually finding something out for yourself. Seeing principles of science in action....I think that is important. Kids need to see how things work, or discover for themselves, or else they just say what is the point. I don't see the point in learning this. Why are you telling me this? It is not important to me, or doesn't interest me, or else they just don't understand it. A lot of times just reading something, or having something told to them or even if it was shown to them, they would be better off doing it themselves.

Nancy

Nancy is one of the few participants I interviewed who has distinct memories of doing science in elementary school. She moved from the Philippines to _____ Bay in northern B.C. at the age of six. There she attended a small elementary school from Grade 1 to Grade 4. The

classroom architecture reflected an open environment with the main area divided into various activity centers. Nancy describes the science center as being her favourite.

We had a big science center, and the one thing I really enjoyed about it was that we had a lot of animals. We had guinea pigs, fish, salamanders, newts and turtles, we had birds, we had chickens, we had rabbits....I remember sitting in front of the salamander tank just watching them. I could just sit there and observe. I was able to feed the animals and pet them, collect the eggs from chickens. It may have seemed that we were running a farm, but it did hone up to science.

The school also had a small garden. Nancy's speaks enthusiastically about her experiences here as well.

The other thing we had was a garden. And we went from actually planting a seedling in a little cup, to going through a growth spurt until it was big enough to go outside and plant it in the garden and watching it grow, and actually harvesting what we planted...We grew snow peas and got to eat them afterwards.

Nancy's view of science is the consequence of active "hands-on" participation. She credits this as being an instrumental force in making a connection to science. "It was the hands-on, that was when I enjoyed science the most, when I actually got to do the planting, the digging,...pet the animals, and feed them." Roberts and Silva (1968) describe this "messing about" (p. 22) as the savoring phase of students' learning. Nancy says she has to feel, touch and see to really understand. The theme of "hands-on" science emerges and re-emerges throughout her academic career. It allowed her to make a personal connection with science.

Nancy's belief in her ability to do science began to wane through the upper grades, however. She has no memories of science in middle school, suspecting that it comprised mostly book work and memorization. Because of a strong aversion to blood, she stayed away from biology in high school. Instead, she opted to take Grade 11 chemistry and physics. With the exception of a few experiments, the courses consisted mainly of reading, memorization and tests. Science took on a much narrower perspective. She also began to have difficulty in mathematics, and equated these problems with an inability to do science. Indeed, the

mathematical aspect of physics and chemistry became quite frightening to Nancy. She comments:

In high school, there tends to be a lot more math involved in the sciences. So not being a strong math minded person, I thought if I can't do math, I can't do science.

Nancy had difficulty grasping concepts, especially in physics. Her course work portrayed a single image of science. True knowledge was disseminated by the teacher and textbook. Concepts were to be memorized and had little to do with everyday experience. Consistent with her view about science in relation to mathematics, she began to feel that science was only for “*smart*” people.

I saw people who generally did well in school did well in science, and maybe people who didn't do well in school, didn't do well in science. A lot of that may have been where I grew up to go to school. It just seems like there was a really big separation where you were either did really well in school, or really were on the poor side...If you are dumb in one thing you are dumb in all things. I think that had some influence on me why I felt that science was for the smart person.

Although there was no specific harassment, gender bias was prevalent in her high school. Teachers and students alike shared the expectation that “*girls did history or language arts*” and “*boys did science.*” Stereotyped ideas that girls are less able to do science than boys fueled Nancy’s self-doubt. She was made to feel that she did not belong in science. Racism complicated the situation. With other students from _____ Bay, Nancy went by ferry to _____ for high school. One science teacher, in particular, belittled the students from _____ Bay. Nancy attributed this to the fact that a large proportion of students from _____ Bay were of First Nations ancestry.

Nancy: *One teacher there had such a negative attitude about people from _____ Bay. He said if you get an A or B in _____ Bay, here at _____ that means C or a D. So right away, he shot you down, and he was a science teacher. So it was like, hey, I don't want to be in his class if he is going to feel that way towards me. That kind of negative attitude, this time from a teacher, can really affect how you see the subject he is teaching.*

Lori: *I wonder why he held a bias towards students from your town?*

Nancy: *A lot of that was because the town I lived in, half of it was a First Nations reserve. And there weren't a lot [of First Nations students]*

who actually made it through Grade 12. I think he was just thinking, oh they are going to drop out right away, they shouldn't even be coming to school if they are going to drop out. That type of mentality was really something you had fight against.

Although not a First Nations person, Nancy felt implicated by what she perceived as the teacher's racism toward the others. She felt marginalized, somehow less than many of her peers. She blamed herself for not doing well in science, and felt responsible for educational situation. This added to her discomfort with science. By the time she got to university, Nancy perceived science as something “*way up there,*” something she could not do. Her undergraduate program required that she complete one science course, however. She enrolled in a first year chemistry class. Here, she rediscovered that “*doing*” was critical for her learning. In this case, “*doing*” meant applying formula to specific examples, working out chemical equations with pencil and paper.

Through Chemistry 100, I learned that you can't learn science from reading, just reading. And sometimes I am a person who tends to do that a lot. I just want to read and I don't want to work out questions and stuff, I will just look at how they do it as a formula. Then, I found this wasn't working so I started doing all the old exams and tests and finally it became better. So from that perspective, I learned that science is something that you just can't read. It is something that you really have to experience.

Nancy's success in chemistry was a turning point. She completed a Bachelor's degree in Arts and Economics and worked for two years in financial services. She then returned to university to fulfill course prerequisites for PDP. She enrolled in her next science course with a lot less fear. Her experience here confirmed previous thoughts about what she liked about science.

I took an earth science and that was actually quite a good course. We went on a field trip and looked at different rocks, we went to rivers and things like that, the actual seeing and doing, not just getting information from a book. So that was pretty good. We actually handled different types of rock, different types of minerals, looking at them through a microscope, doing different tests on them. It's more real. They have that saying, seeing is believing. But I think in science, maybe doing is also believing. Instead of just reading, doing is also believing.

Nancy's perspective about science is multi-faceted. She sees it as a body of facts, derived from observation and experimentation. It is real; a true representation of the external

world. She also views it as a process, a means of exploring and generating information about particular events. Nancy observed that scientific knowledge does not exist in isolation, however. It is sought by people. Further, current scientific norms have the power to shape the way we view our world as well as determine subsequent action. She describes this notion in relation to renewable resources.

To me, now a days, science means growth, basically in all areas. Growth literally as in trees growing, plants growing, growth as in our mental abilities, the more we learn broadens our horizons. That kind of thing. Science is also understanding our world, how it physically works, and how the physical part of how the world works can affect how we think mentally. For example, renewable resources. We think it is renewable so we can just keep mining, or keep chopping down trees, never thinking about whether it may be renewable. But if you take too much there will be nothing to renew.

Nancy has begun to look at science as something other than an academic subject to be mastered. She sees its presence everywhere, both in the knowledge we have about the ourselves and world, as well as in technological advances resulting from that knowledge. Although far less threatening than it once was, science still holds considerable power for Nancy. She is awed by its magnitude.

I think everything reverts back to science. Learning to read would go under language arts but then, how you learn to read goes back to your brain, your eyes, it all boils down to science. It is the building block of learning. Observation is science. Even as babies we observe.

Kate

Kate's struggles with science began from the outset. She has few memories of doing science in elementary school, but recalls high school science as being "a nightmare." She took Chemistry 11, worked hard and passed the course without a real understanding of the material. She failed Grade 11 Physics, however. Her teacher gave her no support, and seemed to undermine her efforts to succeed. Her story is painfully narrated.

I would go after school for help, ...but he just didn't have the time to help me, didn't want to help me. He told me to go home and work on my homework and that would help - get your dad to help you, get your mom to help you, whatever. I worked so hard at it, and I just couldn't get it. Just couldn't get it. Not only that, he wasn't really there to help me through it, and when you go home, your parents don't really understand, or know what is expected of you.

The stuff is difficult for them, this is grade 11 physics, you know. But my Dad was trying to help me a lot with it because he has a degree in science. But still he was getting frustrated and I would end up in tears. This was an ongoing battle with math and science. Ongoing. All the way from junior high.

The reluctance of Kate's teacher to help her was in part an issue relating to gender. She recalls on more than one occasion, the teacher stating that girls were less capable in science than boys. He expressed the belief that if girls did succeed, their success was due to hard work and not intelligence or ability.

Kate: The physics teacher I had was really difficult and he didn't really feel girls were able to learn science, so when I needed help he wasn't really there for me.

Lori: How did he get that across?

Kate: He used to say it in class...There were little things like "now the girls are going to have a more difficult time grasping this concept." There were only two of us in the class.

The teacher's attitude, coupled with her own struggles in grasping the material, severely undermined Kate's self-confidence. This was made worse by the fact that mathematics played such a large role in physics. It presented an obstacle in her effort to understand, and Kate came to believe that physics was something she could not do. In seeking help, she was rebuffed by both her physics teacher and a parent. Kate: *"I remember my Dad would get so frustrated...He would try and help me with the problem solving. Don't you see, even understand this is what they mean? The car drives so fast. I just couldn't see it. The light didn't go on. I couldn't make the connection."* She was made to feel like a failure. After graduating from high school in 1985, Kate went on to a community college. By now, she felt thoroughly intimidated by science, but her program requirements mandated that she take another science course. She selected chemistry. Once again she experienced difficulty, but this time her professor gave her the encouragement she needed.

My prof was really helpful. I saw him everyday and he gave me help. And when I did poorly on the midterm, we went over it, and over it and over it and decided that it was an amalgamation of things. Settling down, and being more prepared, and having certain aspects of your environment that aided you. For me, it was having all the pencils ready and sharpening them and having enough there. Even having enough sleep. Just being prepared really helped me do better, just little things like that. And he was always there for me. Knock on

the door, always there. He would get off the phone, he had the endless amount of time to help me out, so I got through it.

Kate completed two years at college and then went onto to university. She began in the kinesiology program and after a year transferred into psychology. Statistics was one of the program requisites. As with her high school mathematics, Kate could not make the link between the conceptual aspects of statistics and formulae. Nor could she see a relationship between statistics and psychology. Numbers held no meaning for her and she failed the course. Kate enrolled in statistics for a second time. Within two weeks, however, she knew she was *“totally lost and there was no way I was going to get through unless I got some help.”* Her experience in physics came back to haunt her. Once again, she encountered inflexibility and a professor who showed no concern for her situation.

I made an appointment to see him...told him...I need to get through this course to pass, to graduate with my degree [in psych]. I am willing to come in everyday. I have done it before. I am willing to work with a TA on this. Is this a doable situation? He said if you are already lost and this is week two, I suggest you drop out of the course. I don't think you'll make it through...So I said, you are not willing to help? He said: “No. I am afraid not. “He said: “In my experience you probably won't make it through this course.”

Given this response, Kate dropped out of university. *“I was feeling this huge sense of failure. I had already been in university five years, and was wanting to feel like I was getting ahead. But I was feeling like I was hitting this wall.”* She worked for a year and then returned to complete her degree. Once again, Kate enrolled in statistics. Based on the advice of an academic counselor, however, she took the course from a psychology professor instead. The professor, a woman, was willing to give Kate the extra help she needed. She also taught the course from a totally different perspective. *“She taught concepts so that it was easier to grasp...She spent a good week with us saying, this is why we need to learn stats. This is how it applies to psychology. This is why it is important. With that, you were able to put connections together...Now, I understand why we had to have it.”*

Reflection: In conducting an interview, Anderson and Jack (1991) emphasize the researcher must listen and discover how individuals define their experiences in their own terms. “Realizing the possibilities of the oral history interview demands a shift in methodology from information gathering, where the focus is on the right questions, to interaction, where the focus is on

process, on the dynamic unfolding of the subject's viewpoint" (Anderson & Jack, 1991; p.23). Although Kate's experience with statistics is not science, this was an important part of her story. Her previous experience with physics set the tone for failure here. But more importantly, Kate really wanted to tell this part of her life history. After our interview, she told me the interview had been very cathartic for her. This part of her history had been muted -there was no one really to tell - and she desperately wanted to voice her account. For this reason, Kate enthusiastically volunteered when Allan asked the PDP students whether anyone was interested in participating in my study. Although comprised of a different subject matter, I think I can put statistics under the same umbrella as science. Statistics, like science or any curriculum, still constructs visions of authority and power. Britzman captures this dynamic when she writes: "Every curriculum authorizes relations of power, whether it be those of the textbook industry, and demographics, established scholars, business and industry, specific traditions of knowledge, or theories of human development" (1991, p. 18).

Indeed, "*making connections*" is critical to Kate's understanding of science and scientific concepts. The relationship between learning physics, for example, and everyday experience was missing for her. If that relationship is not clear, she has great difficulty in working with concepts. Unlike Susan, or myself, memorization alone did not enable her to succeed. She found it impossible to memorize and apply what she did not understand.

I remember having problems...and I think it is because the underlying concepts aren't built in an individual way you can relate it to. All these numbers and symbols don't mean a whole lot....Although we did experiments and saw what was happening, I had a really hard time making the connection. Problem solving was my real enigma....And in every exam we took, there were always word problems. And so what I would do is try and get through the numbers part and then I would get to the problem solving, and I would just freeze. I couldn't get beyond the words. What do they really want? I don't see it.

Indeed, Kate's personal experiences have led her to question whether her science ability is in part related to gender. She questions whether boys have an innate ability to understand mathematical/scientific concepts, whereas girls learn in a different way. She described a recent activity in which she and her peers from PDP took a group of children to Science World. One of the exhibits involved using shapes [triangles, squares, rectangles, hexagons] to make a picture. On the wall were pictures of animals and forms based on the shapes. The children were asked to manipulate shapes to make similar pictures. Kate did this activity with two children, a boy and girl of similar ages. She said the boy had no difficulty

with the activity. He completed four pictures in less than five minutes while the little girl was still stuck on one.

She just couldn't understand how that fit to make that, she couldn't make the connection from there to there. But if she had been give more time, and had done it week after week in her center time whatever. I think she just needed more time and more practice....I think they say that women have a more difficult time with spatial concepts than men because the way the brain is set up. Our brains are a little different. If that is a proven fact, that is OK but maybe we have to teach girls in a little different way so that they do get the concepts a little more clearly.

Kate says she is no longer frightened by science, but recognizes this shift has occurred because she is not a student. As a teacher, she gathers the resources, selects the activity, and decides which scientific concepts will be explored. Her orientation towards knowledge and identity has changed now that she is control. She recognizes the authority this brings. She felt powerless as a learner, but not as a teacher. She is no longer solely a “receiver” of knowledge, but has an active role in determining the conditions for learning.

I am not afraid of it [science] now. I am teaching a K-1 class, so the science stuff we are doing is really basic. We have a tub of oil and put an ice cube in it...We watch, we observe, we make predictions and then make our observations. So in a way I am getting to learn with the kids. And I know the answer, so that is nice. I can use resources. So that is kind of the way I feel about science now. I am in the teacher position, and I am teaching it, and I have to know it really well before I teach it. I can find all the information out and then teach it. I am not limited that way.

Kate also believes that science can be fun. She said that the children in her K/Grade 1 class are very enthusiastic about science time. They love “doing” science: seeing, feeling, touching and manipulating. The unit materials contain numerous activities which are meant to engage students. Kate insists activity and participation are key to cultivating children’s interest in science. On the other hand, Kate does question the relevance of what she is teaching. Although she has gained authority as a teacher, she is powerless to determine the curriculum. She questions whether what she teaches may seem trivial because it has no relevance to the majority of her students’ lives. “Here lies the tension” (Britzman, 1991, p. 31). Once again, she refers to the experiment with oil and water.

We were talking about density and water melting. So OK if there is water at the bottom, the oil is on top, why is that? The water is heavier, so why is the

water heavier than the oil. They think about it....But I don't know how it really relates to the world, though. Even now as an adult, I am not sure that would relate to our environment knowing that water is heavier than oil. So that I find a little difficult sometimes.

Memories of her own experiences with science echo through Kate's words. Kate sees her encounters with academic science as largely irrelevant. Often reduced to a textbook account, devoid of context, Kate found no meaning in what was taught. "Do you remember the periodic table? We had to memorize that. That was a nightmare for me. It didn't mean anything. It didn't MEAN anything." Similarly, laboratory work provided little value for Kate.

I didn't really enjoy science experiments that much. Didn't really care about that chemical reacting with that chemical. So big deal, it makes a big brown spot or big poofy thing...It doesn't tie into anything.

In accordance with her previous experiences, Kate views science as a structured body of knowledge. It can also be reduced to a methodology that is applied to the world in a precise way. Objectivity is also central to Kate's view of science. No other subject epitomizes this notion. It is the claim to objectivity that gives science power and authority.

Science is not necessarily a right or wrong, but definitely more objective. I guess I am thinking of - you can use science in different ways - but if you are doing an experiment, there is a certain outcome that is going to happen or not happen....With science there is always a hard and fast rule.

Although her experience in the classroom is limited, Kate recognizes the need to accommodate different learning styles. With the emphasis on discovery in science lessons, teachers have placed more faith in group activity as means of exploring and learning. Kate observed that this approach may not succeed for everyone, however. Students may require different opportunities to allow this to develop. Again, Kate cites her own experience.

I am not so good at learning with others, so maybe not all kids are. Maybe some kids will need to do the experiment on their own instead of in groups. I get really anxious when I am forced to work in a group and I am not ready to. I can work in a group but I need to do my own bit first. Let me explore it, and feel it, and touch it, and think it and analyze it first. Then OK, I can get together with another person and share my ideas and work on a group project. But I always got really apprehensive in school when we were given the idea, given the lesson and then thrown into a group....So individual differences are really important.

Although Kate previously said that science no longer frightened her, she later painted a more problematic picture. Teaching has helped Kate re-gain her self-confidence, but doubts still plague her about her ability to learn science. During our interview, I told her about a proposed science specialization program that may soon be offered to PDP students at SFU. She referred to this program when I asked: "What question should I have asked that I didn't?" The difficulty of her relation with science is captured in the following comment:

It was funny, when you were telling me they were going to do courses for designs for teaching science I got apprehensive. I was flinching. I know I would probably choose an art or a music, even through I knew it [science] was my weakness. Actually, because I knew it was my weakness would be the only reason I would take it. Not out of interest and not out desire, but because I knew this was a weakness for me...But my sense was maybe if I wanted to keep my GPA up it probably would not be a good one to take. It would be better if I took something more creative.

Andrew

Andrew began PDP at 36 years of age. Prior to this program, he worked as a recreation therapist. Believing that he was "not smart enough" for academics, he opted against going to university after high school. Instead, he obtained a diploma in therapeutic recreation following two years at a community college. Andrew's first exposure to elementary teaching came when his children began school. Volunteering as an assistant in his children's classroom, Andrew discovered a fascination for education. Teachers there also recognized his ability, and encouraged him to pursue the teaching profession himself. He returned to university as a part-time student in 1991. He pursued a Bachelor of Arts in history and then enrolled in PDP.

I met Andrew at the university following a day of PDP. He gave the immediate impression of being a soft-spoken, friendly man. Prior to our meeting, I was nervous about the interview. I held the assumption that Andrew, like any other male, would have a much easier time in science. I took for granted that science in the minds of students, as well as their teachers, is a masculine endeavor; thus the challenges he faced would pale in comparison to many of female participants in my study. This supposition concerned me regarding the bias I

would bring to the interview. Andrew was the first male teacher with whom I'd talk. Would I be able to hear his story? Would his words be a magnet for my preconceptions? Would my assumptions preclude critical reflection? Andrew's story made me much more aware of the problems that come with essentialism.

Andrew's first memories reveal an image of science as something he could not touch. His experiences with science in elementary school were disjointed, episodic events. He recalls looking at pictures, and memorizing information from charts and textbooks from time to time. But there were no activities that called for interaction between students and material.

All I remember about science in those earlier years was that a textbook would come up, and we would learn about a volcano and see a picture. Occasionally there would be a filmstrip or a slide show and that would be the science up to that point. So I always thought it was being quite boring. Later on in junior high, it gets into a period of remembering the theories and chemical charts and basically that was what we had to do for our tests so that is what we thought you had to do and that is how you got your good marks - you remembered, but you never knew how to use it.

In Grade 8, he recalls doing a few experiments. But these were conducted in a structured way with no room for variation or individual thought. Andrew described the work as mindless assembly. *"I think a monkey probably could have been trained to do this same experiment."* In one case, he remembers being admonished for not conducting the steps of an experiment in a particular order. He was told his results were not valid.

It was one of those experiments...where you add a drop from bottle A...you would look at it and see what colour it was and write down the colour. Add another drop and write down the colour and then at the end you would write down the colour, and if there was any difference [in the solution]....For some reason, I reversed procedures because it was step 8 do something and then step 9 do something. Well, I did step 9 and step 8 reversed. I had to start all over again. I was told not to even worry about what I saw because that was not important and I had to go back to step one.

With this experience, science was reduced to single, linear methodology. Andrew began to doubt his ability to succeed in science. *"Obviously I did it wrong. It is not something you do. You have to follow the rules. And you have to go down, step by step. And if you don't remember the rules, you shouldn't really be doing it."* At the same time, students at Andrew's school were being streamed according to perceived ability. Those considered

advanced were given support and encouraged to focus on their academic skills. Those labeled average were left on their own. Andrew felt this separation keenly, particularly with respect to science.

There were some students who really excelled. They seemed to be taken under the wing of the teachers so they got to go to the front of the room, and do the experiments. There were usually one or two per class, and that was it. They got a lot of attention and a lot of time, whereas the rest of the class watched. I remember science rooms were always in rows of tables. And so if you were at the back, which usually was the students who had the most problems, you didn't even get the chance to see the experiment very closely. It is amazing that after all these years I can still see in my mind the desks that were used, and the tables, and how far back I was and never really feeling like I could touch the experiment.

Once into high school, Andrew took Grade 10 chemistry and biology plus two years of physics. Chemistry and biology proved to be an enigma for Andrew. He learned names and formulae, performed the experiments, but the subject material held little meaning for him. Biology and chemistry comprised facts to be memorized and regurgitated. He had little understanding of what he was doing or why he was doing it. Andrew was unable to take ownership of this knowledge. It was something out there, waiting to be acquired. It did not belong to him.

I got to the point that I was really feeling scared. My marks were OK, but it didn't seem like I really remembered what I was supposed to remember. And I felt like I barely got through, although I got Bs and B+s on tests. But at the same time it wasn't knowledge that I felt I could carry through to the next year.

Andrew was further frustrated by the fact he could not express what he did know. Even when he learned something, he felt that knowledge could not be used.

It didn't really seem like I was using other skills. It didn't matter what I saw and how I should describe it. It was usually a blank and I had to fill the blank with the right word. That was what our tests would be. It could either be a chemical formula or some physics formula or some biology name. It was just fill in the blanks...It didn't make any sense to me.

Andrew dropped biology and chemistry after one year, but continued on with physics. In contrast with the former subjects, Andrew saw physics as something he could use. The knowledge was practical and could be applied to everyday life. His teacher stressed relevancy, teaching theories and concepts through familiar events. *"If we were playing pool,*

for example, we could think of how this ball would react if you hit it on certain angles.”

Physics, in contrast to many things he had to learn at school, was validated by personal experience. It provided knowledge that connected various parts of his life.

Despite doing well in physics, however, Andrew gave little value to his achievement. His positive experience was overshadowed by past failure. *“With the physics it seemed something so easy to me and .. it seemed so little because I did so well. I went all the way through high school with it, but at the same time, I felt like it wasn’t something I could use in university.”* This was further complicated by the fact that Andrew perceived so few people as understanding physics. *“Physics seemed too scary because of other people’s visions of what physics was.”* He viewed his success as almost accidental.

By the time he left high school, Andrew felt poorly equipped to do science in an academic setting. Yet, science intrigued him and he continued to seek out scientific information. He read science magazines, and became an avid fan of science programs on television. Here he began to learn that science did not mean just one thing, but encompassed a variety of perspectives. *“After watching some show on plate tectonics and hearing three or four versions of it, [I would think] wow, these people are arguing about this and there is no right answer.”* Science did not necessarily entail a single, authoritative voice.

His fear of academic science remained strong, however. After he returned to university, Andrew was required to take a science elective for his degree. He chose an earth science course. The unit materials contained numerous activities which were meant to engage and involve students. The activities called for interaction between students and the material, students and student, and students and professor. Field trips enabled students to gain first hand knowledge about rocks and geomorphology. They learned about climatology by predicting weather patterns. Because he understood the material, however, Andrew thought the course could not have much value. It didn’t fall into his notion of science.

I didn’t feel it was real because we were having fun and it couldn’t have the same worth. Here we were drawing pictures of rock in Lynn Canyon. I could do this, I could do this. It didn’t take any knowledge from 10 years ago. It

took knowledge that I had learned a couple of weeks ago and we got to look at and actually touch it and see it. So it seemed easier. It didn't seem like science.

At the same time, however, Andrew realized this was knowledge that he could use. “*It seemed like something I could show someone, could explain and tell them what that is.*” He shared his discoveries with his children. Science was something he could talk about it. It acquired meaning through dialogue with others.

Andrew's experience with this course reflects a complex relationship with science. On one hand, he feels like an outsider; that he does not have access to science. On the other hand, he sees science as integral to seeing and understanding his world. He wavers between fearing academic science and having a desire to learn more. Andrew credits his children, however, as being instrumental in changing his attitude toward science. In bringing science home, they have provided a new link to science learning. They have helped break down the barrier he perceives as science, and made him realize that science is something he can do.

I watch my children who are at 8 and 10, and they get to bring stuff home. Or I go in the classroom student teaching and see things happening. It is like I get to learn at the same time. Things that I know, now I can put them in context. Or something that I always wondered about, I had a theory in my mind, but I was always afraid to say it, it is like I can do an experiment now too. I get to become part of the learning process. I am a learner as well. So even when my children bring things home, they teach me and then we actually try it.

Through his children, Andrew feels that he has experienced a “*rebirth*” in his knowledge. Not only does he get the opportunity to do science again, but this time have fun. Rather than being one-dimensional, science has taken on a much broader perspective for him. There is a personal component to learning. He emphasized his children are equally proud of their scientific knowledge and role as experts.

They really feel that their knowledge basis is going to be useful. They are really proud of their work and they want to show everybody. I just get really amazed. But now I can see that science is to me like playing, but playing with exploration in mind. Before it was something to remember, something to look at in the distance, but now it is something you can actually look up close, look at it and try it and there is no real wrong answers. Whereas before it seemed like there was all wrong answers and there were only one or two students who always got it right.

Reflection: Scientists among themselves recognize the ever changing nature of science. Open to questions/challenge/criticisms within the scientific forum.

Why is it then to the public that science appears as static, rule bound, and god-like? Andrew's insights have made me realize that I have also fallen prey to the notion of science as something infallible. Although as a graduate student in zoology I found scientific methodology restrictive, nonetheless I envisioned science as something real, impermeable and out there. I still recognize there is something concrete about science - otherwise various medicines or technologies would not work, nor physical laws prove predictable and repeatable. However, now I give much greater import to the views/perspectives the individual researcher brings to the study. Science just like any other human endeavor bears multiple "truths," multiple ways of knowing. It has been our downfall to emphasize just one. The inclusion of multiple perspectives would make for a far richer science, and one that might make science more accessible to many more people.

For Andrew, hands-on activities and experience- touching, feeling, manipulating - form a vital part of science. "*Science to me is the chance to explore your world or any aspect of it.*" But equally important to science is language. Talking, communicating, sharing, and testing ideas is what makes science come alive for him. Discussions of interpretations play a central part in his learning. It requires creativity and imaginative thought.

Interestingly, Andrew's perspectives on academia have changed greatly since he first started university. Initially, he was drawn to history as his major because he saw it as open and inviting different interpretations. Science, on the other hand, was linear and constrained. It entailed memorization and restrictive methodologies. Now, his perspective about the two subjects has undergone a reversal. He comments on the irony.

I really enjoyed history before because there seemed to be this chance of looking at the world and there were different theories. Well, as you went along it seemed to get narrower and narrower and now when I get into science, the little dabbling that [I've had] the chance to do, it seems the world is expanding. That there's even more variations of what I can imagine because I communicate with other people... When you get into a fourth year course it is pretty certain to say no, no that theory is a little too wild, whereas in science it seems to be no, no you can expand that a bit more and see where you can go with it... There is nothing wrong with history but I am really amazed because I can see there is far more potential with science now. I don't know if it is true or not, but that is how I see it now in this perspective.

Although Andrew feels far more comfortable with science than he once did, he admits it still holds an element of fear for him. His shift in attitude has not been instantaneous nor complete. He continues to struggle with past, negative images of science at the same time as trying to negotiate new ones.

Andrew: It is interesting. I think I still perceive that I could get it wrong and there may be a wrong answer. I think that is because I have to overcome my own feeling that I am not a boy in grade 8 in physics class or chemistry, that I will get it wrong. So I feel like if I don't push myself I will fall back into that trap. If we are talking about something in class and it is science related...I feel that there is a wrong answer so I will be quiet and not say anything. Or I won't want to play with it in front of the class, whereas that is really not the right thing to do and it is something I have to catch myself on.

Lori: Because that fear is still there?

Andrew: Yes.

Profiles - The Experienced Teachers

Haley

I met Haley when doing a field observation of a science methods class for my qualitative research course. After a brief introduction to Bruner's model of discovery learning, the professor invited us to engage in a hands-on activity ourselves. He placed three shallow, plastic dishes containing mealworms in front of us, adding that the object of the exercise was to find out everything we could about mealworms. He then left us to explore on our own. I shared a plastic dish with Haley and together we completed the exercise. I followed up this initial contact with a phone call, and asked whether I could interview her for my study. I hoped talking with Haley would give me insight into the perspectives of a teacher involved in this class; to use Merriam's (1988) words: "to consider the meanings that happenings had for the people involved in them." She agreed.

Because of conflicting schedules, I met Haley at her home.

Haley lives in a fairly new suburb of Abbotsford. We go upstairs to her kitchen to have our interview. She is nervous and says so. She sets about making muffins while we talk. She says it will make her less nervous. Should I be doing this interview? (Fieldnote, November, 1996).

Haley lived her childhood and adolescent years in Surrey. She finished high school in 1972 and from there went to SFU. She married at 20 years of age, and together, she and her husband took turns working and putting each other through school. They both became

teachers. After university, they traveled for one year and then in 1980 moved to a small community near Terrace. Haley taught elementary school there for six years. Her classes comprised special needs children the first year, and Grades 1 to 4 the following years. Haley stopped teaching in 1986 after the birth of her first child. She had two more children, and moved back to the lower Mainland with her family. Haley would now like to return to teaching after a 10 year absence from the profession. This requires she take university courses to upgrade her skills

Haley remembers being fascinated with science ever since she was a small child. *“I love science, always have...starting from the mud pie level and building up. I used to work in my dad’s garage with him, building things, creating things. A lot of people would say that was not necessarily science. It has more to do with mechanics and electricity. But my interest was multi-faceted.”*

By the time she reached junior high school, Haley decided she wanted to pursue a career in biomedical electronics. In preparation for this career path, she had to take courses in electricity and electronics. These subjects were not traditionally offered to girls at her school, however, and Haley had to apply for special permission. The guidance counselor belittled her request, calling it *“ridiculous,”* and sent her off to speak to the principal instead. Here she obtained the support she needed. *“The principal was an absolutely wonderful man - for some reason in that huge school he had taken me under wing. He gave me permission.”* But Haley had to jump a few hurdles yet.

In order to get permission, I first had to state verbally why I wanted to attend electricity, and then I had to write an essay to present to my science teacher and the electricity teacher to give a good solid reason why. Then when they decided OK I would be allowed to take the courses, I had to maintain an A average. If there were any disturbances or behavior problems with the boys because there was a girl in the class, then I would lose my right to attend. Of course, all these boys were attending and it didn’t matter whether they got Cs, Ds, or whatever. They had the right to attend. The only way I could maintain my right was to keep an A average, and act invisible, so as not to distract anyone.

Haley persisted. She gained entry into the electricity class and worked very hard. Some of the boys harassed her, making negative comments about her ability as a girl to do

science. However, her efforts impressed her teacher. He came to her defense and urged the boys to follow her example. Although his statements created another set of expectations, and did nothing to minimize the gender stereotyping, Haley appreciated his support.

He just turned to the boys and said this girl has really got her act together. Let's see if you can keep up with her. And that kind of turned the tables. When I first went into the class I was getting a lot of snide remarks and laughter and the typical kind of thing you would expect when a female goes into an all male situation. It was very hard at first. But when the teacher came right out and said that to the class, and I remember the day he said that, the attitude changed. I became a challenge for the boys to keep up with and no longer did I get the snide remarks and the teasing. It was ooh, this girl is good and we have to prove our manhood now. It was reversed, which was so silly in itself, but it was there.

Haley finished Grade 9 and 10 electricity without much incident. In senior high school she took biology and was the only girl in chemistry class. But as soon as she expressed interest in electronics, she encountered resistance. Once again, she had to apply for special permission from the principal to take the course. This was granted under the condition that she maintain an A average and did not disrupt the classroom. But this time, she was not allowed to use the laboratory. The laboratory period took place during the lunch hour. The supervising teacher would open the lab and leave, returning only periodically to check on the students. Haley's presence meant a teacher would have to remain and no one was willing to accommodate her. Haley expressed her frustration clearly.

If I was there it meant the teacher had to be there all day, everyday at lunch time and after school. So I wasn't allowed to use the labs...but I still had to keep an A average. Now if I look back at my records I am pretty sure that I did, but it was tough...It is like biology, if you don't use the labs you don't learn. I managed to pass the tests and keep high marks, but I didn't get the most valuable hands-on experience that builds and reinforces confidence in one's learning.

Despite the hostility of her environment, Haley persevered. She was determined to take courses in both electricity and electronics. She never lost sight of her goal - a career in biomedical electronics. Moreover, the subject material interested her greatly. Haley applied to BCIT in mid-Grade 12 and was thrilled when she was called in for an interview. The program accepted only 20 new students each year, far fewer than the numbers who applied. She thought she had succeeded. The years of fighting for the right to take the courses she needed

had been worth it. But although Haley had encountered many obstacles throughout her academic career, she was not prepared for the discrimination she would face at BCIT. Her memories are painfully narrated.

I remember getting there and being just so proud walking into that office for this interview. I was being considered for one of those 20 seats. The professor, I assume he was a professor, maybe he was an administrator, I remember exactly what he looked like. He was mid-forties, dark-hair, really nice looking, really with-it kind of guy. I walked into the office which was half glass. Floor to waist height was solid wood and from waist height to the ceiling was glass. So I saw him before I entered the room. And when I entered that room he didn't even invite me to sit down. He sat looking-up at me. He had this look of shock-surprise on his face which I can still see clearly in my mind 25 years later, and he said I am sorry I didn't realize that you were a girl. We don't accept females in this discipline. He stood up and closed my file to indicate the finality of his statement. As I left the room, I turned back to see him push my application off the desk and into the garbage can below.

Haley felt absolutely defeated. She returned to high school the next day believing that she had no recourse left. As it was only three weeks into the spring semester, she dropped electronics and chemistry 12. She enrolled in child care and cooking instead.

I gave up. I thought science, no matter what area it was in, was not for me. I knew I could get in to be a biology lab technician, or something like that, but I wasn't interested in that. I wanted biomedical electronics. That was my area of interest since the age of 13. And suddenly the door was shut in my face. I was devastated by that, absolutely devastated. I gave up any hope of ever taking part in anything to do with science...I stepped right into the mold they wanted me in because it was easier and because I couldn't see any point in fighting the system anymore. Even when I played by all their rules it made no difference. I felt completely powerless.

Haley completed high school and for the next year struggled with what she was going to do. Eventually, she turned to teaching. Her interview at BCIT had dealt a deep blow to her self-esteem, however, and belief in her ability to succeed. “If you are in a program that takes many years to get through, the loneliness can destroy you after a while. It reaches a point where it is not worth it. You can't fight like that anymore.” Haley felt that her dreams were not hers to pursue. Ultimately, gender defined what she could or could not do.

If I was going to have a career in science there were certain places where I was welcome and certain places only...If you don't want to be in any of those traditional niches, then don't enter science because there is nothing beyond that for you. That is the attitude I grew up with. The whole area of science had a door with a sign on it that said “No Women Allowed.” So unless you were very strong, very strong-willed and very strong in your focus and your

direction, and you had a very good support system behind you, you didn't enter certain fields. Rather than providing a mentoring and encouraging environment, the schools and especially the post-secondary school, were playing a power-game controlling "who's in" and "who's out."

Similar to school, Haley's academic endeavors were not supported at home. But here things were far more complex. On the one hand, her parents believed that women were meant for "breeding and house cleaning." They actively discouraged Haley's interest in post-secondary education, saying it was an "absolute waste of time and money." But on the other hand, Haley credits her father for cultivating her interest in science. "I was always out in the garage with him, working on things, building things, making things, designing stuff. I spend half my teen years out in the garage with my dad." Indeed, Haley was not allowed to drive a car until she re-built its engine first. The conflicting messages confused her.

He encouraged that break from the mold, and at the same time he was telling me, "Don't go to school because all you are going to do is get married and have babies." So it was a real struggle there. I never knew what my role was and what it should be.

Haley's conceptions of science reflect her own struggles in the field. In continuation with her lived experiences, the image of science as powerful and exclusionary comes through. At the same time, she sees science as part of everyday life, a way that children set about exploring and defining their world. She also views it as part of what she does at home out of personal interest.

When I think of science, I think of people like astronauts, people working for pharmaceutical companies in big labs, people working in hospitals, designing equipment and things for hospital use. I think of laboratories that are all closed in and are very secretive where people are doing experiments and research on specifics for the enhancement of technology and quality of life, that sort of thing. But I think of it as a field or profession that is over "there" with a big blank wall separating it from the rest of humanity. Then I think of the next level of science, which is the study of science at university. When I think of science at the university level, and again it is from my own personal experience, I think of it as a filtering system where a whole bunch of people are wanting to get into the world of science behind that big wall over there, where they filter who is going to make it and who is not. This has a lot to do with how smart you are, what sex you are, how strong you are and on your determination to run the gauntlet that is required to jump the hoops that are required in order to be allowed to get behind that wall and be a real professional scientist. And the level down from that is what I would say is real science, the science that goes on in the schools; where kids learn to work with things, fiddle with things, discover things, make discoveries, solve problems.

That is what I think of as real science, the basic science-like activities that real ordinary people do in their everyday lives as a means to learn something new.

Despite the obstacles she encountered, Haley's interest in science remains strong. Science has always played an integral role in her classroom; she "*made a point of teaching it all year long.*" Even before integration became the norm, Haley integrated science with other units in the primary curriculum. She taught reading through science and writing through science research. She advanced the belief that children learn best when teaching occurs around subjects that interest them. "*My philosophy was that children are motivated through interest in topics which generally fit within the realm of science. So I always had science in my classroom. Even if I couldn't fit an integrated unit around it, I always had centers where they were fiddling with things.*"

As a teacher, however, Haley also realized how difficult it is to break from the past. She taught the way she had learned, and unwittingly had incorporated sexist teaching strategies into her own practice.

During my first year of teaching, I remember catching myself doing to girls exactly what had been done to me. It was as though there are certain ways of doing things, there are certain ways of teaching and girls aren't part of this process. Even though I knew what it felt like to be under the thumb, to be on the losing end, even though I knew the girls had as much right as well as ability to participate, I remember in my first couple of months of teaching, catching myself, and saying "Hey, what are you doing?" The boys shouldn't participate in all the hands-on activities while the girls watch. The girls should be in there just as much as the boys.

After this realization, Haley made a conscious effort to include the girls as much as possible. Initially, she insisted that the girls have greater participation in science activities to compensate for past exclusion. She eventually found an acceptable balance in her practice.

Although she always placed an emphasis on science in her classroom, Haley gives little credit to what she does as "*science.*" Her feelings reflect the tensions arising from her personal history. Professional science is divorced from her world; it remains secluded behind an opaque wall. On the other hand, "*real science*" is part of everyday life. The former carries greater authority, however; it is what is recognized as science. This has led Haley to question the value of her teaching and expertise. Her sense of accomplishment is hard to find.

Because of my experiences, I had a tendency to think of myself more of as an arts teacher. Even though at the primary level I always put a strong focus on science, I didn't think of myself at all as a science teacher. That's not my area. I am not allowed to be that. I am just fiddling with little kids. That is why I call it little kids' science, which is completely unaccepted and completely unrespected by everyone in the field of science. I'm just a little primary teacher who is playing with little kids. But in my mind it is real science. Now it is not respected in the field of science maybe, and it is not accepted as real science in the field of science, but that is what I do. And "it" is the providing of situations where children can use a hands-on inquiry approach to learn new and interesting stuff they really want to know about.

Haley took the science methods course in hopes of gaining a more confident view of both elementary science and herself as a science teacher. The course has been influential in this respect. As a result of the course, Haley feels she is better able to articulate her views of what science in the elementary school classroom should be. She is developing confidence in her knowledge about science, as well as the value of her science teaching. Haley sees her professor as a mentor who is sensitive to the problems teachers face. His approach has helped her examine and elucidate her beliefs.

I could not really confidently verbalize what I thought science is in an elementary classroom. I am getting better at it now that I have been in this course. [The professor] is wonderful for that. He is wonderful for helping you clarify and develop confidence to say what science can be in a primary classroom. I think I am getting closer to the ability to do that now: to stand up and say "You might not think what I do is science, but I think what I do is science and you are not going to knock me down anymore." That's why I took this course. I needed to be able to turn to other teachers, other high school teachers, other parents, anyone from the ministry who is telling me what I am supposed to be doing, or what I am not doing. I needed to develop the confidence to be able to say that what I am doing is valuable. And this is science.

In taking this course, Haley's concerns were not in having too little content background in science, but rather in learning new strategies which she can bring to the classroom. She recognizes the importance of content knowledge, adding that if she did not know something she would not teach it. She feels that her content knowledge is sufficient to cover most subjects taught in the primary grades, however. Her interest lies instead in constructing new strategies that might help children learn. Haley speculated on how she might mediate hands-on experience with conceptual learning in the classroom. Developing an approach that makes science "safe" for students was a major focus of her reflections.

I think if I was to teach a science lesson tomorrow, it would definitely use hands-on discovery. I would probably put a whole bunch of stuff down, set up centers with a bunch of stuff, for example the mealworms or the electronic batteries and wires and lights, etc. Let the students have a bit of fiddling time to make them feel comfortable with the material and the general topic, and then bring them back to a large group situation. Have them talk about what they did, what they saw, what they learned, what they discovered, and then send them back with a specific problem. Do not let them go back to just helter-skelter fiddle through stuff, so that maybe they will learn something, maybe they won't, but give them a choice of specific problems they are to work through in small group situations. In a small group, they are not left in isolation to deal with a problem that is overwhelming for them. By sharing ideas and problem-solving strategies, by sharing their failures, their problems and their difficulties, the students realize that nobody is smarter than anybody else right now, we are altogether, it is safe. It is safe so we can take some chances here, try something and if it doesn't work so what...It's OK. It is a psychologically safe situation to experiment with materials, with ideas and strategies, and with one's power to learn.

Indeed, Haley views safety as critical to learning. Students - both children and adults - need a safe environment in order to explore and to take risks; to share success as well as failure. Safety furthers our capacity to participate in the shaping of our experience. With it, knowledge becomes more accessible. In some ways, however, this notion of safety contradicts current practices of both classroom and professional science. By emphasizing laws and universality, science carries an authoritative tone. It appears definitive and complete. Traditionally, science education has not provided the safety or context where mistakes could be made without penalty. As Andrew put it: *"It seemed like there were all these wrong answers, and there were only one or two students who always got it right."*

For Haley, it is important that this safety extend to everyone. Despite her negative experiences, she would not like to see girls favoured over boys in science classes. The idea of reverse discrimination is abhorrent to her. Instead, she sees cooperation as the hallmark towards achieving equality in the classroom. Haley stressed this point in response to my question: Is there anything you would like to talk about that we haven't?

One thing I feel very, very strongly about, and maybe it is because I have three sons, is that I would hate to see the pendulum swing in the opposite extreme. Just like we were saying earlier, in my teaching I caught myself focusing mostly on the girls in order to compensate for the benefit the boys had all these years. I would hate to see that happen; that we start focusing purely on women, that we get women into science to the detriment of the males. There has to be balance and equality from both sides of the argument. You can't have

two extremes fighting each other, hoping that somewhere in the middle there will be a balance. You have to have both sides working together cooperatively to find a happy balance...both men and women have to contribute towards creating equality. It can't be a fight.

At the beginning of this interview, I was concerned with the ethics of the situation.

The interview obviously made Haley nervous and I was unsure whether I should continue. I should not be putting her in a position where she felt uncomfortable. Our one hour interview turned into a four hour conversation, however. Tea became lunch; we shared histories and talked about our personal experiences for hours. Before I left, Haley said that she appreciated the opportunity to tell her story. Although she believes that gender is no longer the problem in science it once was, she thinks it is important stories like hers are heard. The right for females to participate in science was hard fought. It came after struggles like Haley's and many people were hurt in the process. In returning to university, Haley feels that her younger colleagues often lack this understanding. They do not realize her position or why she may struggle with self-confidence. *"They look at women my age as though to say, oh, what is your problem? They don't realize the fight that went on before their time to give them the right to be where they are."* In this sense, the discrimination goes on. Haley has not found safety yet.

Pat

While Haley took the science methods course in hopes of learning new teaching strategies, Pat sought something more specific. She hoped the course would provide her with knowledge that she could use in extending her students' understandings of certain scientific concepts. In this way, she was disappointed; but the course proved something else to her. As a music and drama teacher for 23 years, she had virtually nothing to do with science. Indeed, she taught French in a colleague's class in exchange for him teaching her science. Her experience in the science methods course made her realize, however, that science was not completely off limits to her. In fact, it was something that she could do.

Pat: I got out of the class that I can teach science, even though I do not have a lot of background in it. But I also disagreed with him [the professor]

totally that you don't need knowledge to teach...The course made me realize I would have to go one step further.

Lori: In terms of getting content?

Pat: Yes, that knowledge. I would have to go out and get myself some knowledge before I could do it. The way he presented the course you didn't need knowledge. Because I said, "Where do I start?" And he said "Start anywhere." But I don't have any background knowledge. [He said] "It doesn't matter." Well, it does to me. So that is where our philosophies differ. I can't fake my way through something, and not that I would.

Content knowledge is integral to Pat's comfort level in teaching. She said she could not teach anything without having some background knowledge of the subject. *"After taking this course I know that I can do it. But I also, for my own safety comfort zone, I need to get some more content. Just so that I can help lead the kids."* Content knowledge provides Pat with safety. It allows her to better direct students in their exploration. It informs her of various possibilities. It also means empowerment. Pat does not seek absolute authority as a teacher; nor does she wish to control her student's investigations. But if she is going to teach science, Pat feels it is her responsibility to understand a phenomenon. In this context, safety means to Pat knowing enough about a particular event so that she could answer her students' questions or guide them in their inquiry.

Pat is one of a number of teachers whom I met when conducting an observation of the science methods class for my qualitative research course. After the class, I told her about my study and she agreed to be interviewed. We met at a later date at her home. Pat teaches Grade 7. She obtained her education degree in 1969, and was hired as a music specialist by the _____ School Board soon after. Her expertise lies in the fine arts and humanities. She is currently working towards a fifth year in Education.

Pat lived her childhood and adolescent years in East Vancouver. She recalls doing almost no science in the primary grades. The little that was taught was integrated with other subjects, for example, seasons in combination with social studies. One image stands out vividly in her mind, however. In grade 5, her teacher performed an experiment using a heated pop bottle and a balloon. Pat muses about the demonstration.

The balloon was flopped and it started to rise. And I remember being absolutely amazed. But that was the only thing I ever remember out of all of my elementary school science. Being east end kids, I guess we had a reputation of being a tough school and we had some really mean teachers... We weren't encouraged to inquiry about anything.

Once in high school, Pat did not find the culture of academic science particularly appealing. She took a year of chemistry, but did not do well. Concepts were hard to grasp and the subject material held little meaning for her. A girl friend more predisposed to science than Pat had to drop out of Physics 11. This added to her fear of science. *"I considered her intellectually superior to me, so I thought if she couldn't handle it there is no way I could."* Pat did well in biology, and *"loved it."* At one point she was even considering a career in forestry. The latter required she take mathematics, however, an area in which Pat had considerable difficulty. Ultimately, it was the mathematical aspect of forestry that defined her options. Her difficulties in math persisted and she dismissed the notion of pursuing forestry.

Pat does not believe that she was openly discouraged about doing science, however, students and teachers alike shared the expectation that science was a male domain. *"I think perhaps there has been an attitude right from the beginning that girls can't do it. I knew I couldn't. I didn't even really try past biology."* Boys were considered to have a natural aptitude towards science. They were *"smart"* and showed true understanding, whereas girls had to work extra hard. Even within the realm of science, certain subjects were differentiated along gender lines. Biology, which tended to attract more girls, acquired the reputation of being *"soft."* Physics and chemistry were considered *"hard."* Pat remembers thinking her accomplishments in biology had little value as science.

In high school and university, the boys were the ones who were always taking these courses. They were the smart ones because they took these really hard science courses. I don't know, I always felt that if you did biological sciences, that was easy, that's not real science, soft science. That's not real science. Real science is physics and chemistry. That is the real stuff.

Pat recognizes her perceptions about science were strongly shaped by the prevailing attitudes of the time; and her statements confirm much of the literature in existence. But even now with equity gaining greater attention, Pat believes gender differences still exist. *"My gut*

instinct, looking at the girls that graduate now, is that there is also a submissive quality about them to stay away. They are OK in biological sciences but they seem to stay away from the physical sciences." Her observations make her believe that girls generally have less confidence about their science capabilities than boys.

Pat believes curriculum and teaching approaches to science have not take into consideration how females learn best. Science examples are either likely to be embedded in situations more familiar to boys (machinery, cars, etc.) or have no context at all. Teaching strategies still rely heavily on competition. Neither aspect seems to be conducive to girls' ways of learning, nor do they incorporate their interests. In this way, Pat thinks that girls may be still under-served. She speculates on how science education could be different.

I am wondering whether the instruction should have been changed because girls do learn in a different manner. I think girls learn by helping each other whereas boys do not. It is a very authoritarian way they [boys] learn. They learn by lockstep methods, whereas girls learn in a totally different way. They learn by helping each other, by saying "Look I think my way is better, what do you think?" A give and take, whereas boys don't have that.

Pat's words are in agreement with some of the current literature, which suggests that women have different "ways of knowing" than men. Belenky, Clinchy, Goldberger & Tarule (1986) described many women as being "connected knowers," meaning they learn through relationship with others. Pat feels that she learns best in collaborative situations, but did not reap the benefits of this approach particularly with respect to science. *"I don't think we were given enough opportunity to work together. It was such a competitive thing. Like you had to pass this exam...So I lost out on that whole aspect of my education because I don't think high schools cater to the female mind or a girl's way of learning."* Indeed, interactions with her peers are central to her learning even now.

I work really well in a two [person] situation, where you bounce your ideas off of each other. I am doing a course now where there are four of us in a discussion group. And one says one thing, and that sets off a chain of thought, and you say something else. And I really like the idea of bouncing off someone, so to learn content in order to teach it, I think it would be really beneficial to work in pairs, or three's to start with, and then develop lessons from there.

Despite feeling uncomfortable with the subject matter, Pat cares deeply about teaching science effectively in her classroom. This was brought on by her students' obvious dislike of the subject. Her colleague teaches science out of the textbook, emphasizing lecture and rote memorization. Pat was dismayed by the “*collective groans*” coming from her students each time the science lesson was announced. “*Their attitude made me sign up for this Natural Science...to get some kind of background in teaching my own science.*”

The science methods class emphasized inquiry and hands-on approaches to learning science. Although Pat enjoyed the opportunity to partake in these activities, she found the experiences rather disjointed. She felt she had no background knowledge in which to anchor these activities. The professor also encouraged his students to look at their practice and teaching of science as problematic. But for Pat, everything was problematic. She didn't know where to begin. Rather than looking at her own practice, she had hoped the course would provide her with a better understanding of children's conceptions of scientific events. She was looking for ideas and resources on how to extend children's thinking with respect to specific scientific events.

Because I have such a small background knowledge in science, I assumed that what I would get from him would have been not necessarily this is how electricity works, but ideas on how to get the concept across to children...things to do with children that would assist them in doing a discovery approach of how electricity works...I was hoping for him to give me ideas on where to take the kids, how to extend their thinking...Not my knowledge, that is my responsibility to extend my knowledge, but to extend the knowledge and the learning of the kids.

For Pat, content knowledge is critical to guiding her students and giving them better direction. She needs to have basic knowledge about the study or experiment, as well as what course it will take and why. Lack of knowledge causes her anxiety; she would not feel confident in teaching the subject. Pat also believes that it is the responsibility of the teacher to be the expert in guiding the student to complete the task on her or his own.

You need to have the content to know why the hands-on stuff works. If you are going to make a simple circuit, you have to know about electricity a little bit. Doing parallel circuits and multiple circuits is fine, but you have to know something about electricity. Just jumping in and experimenting, to me, is a waste of time. You have these kids for five hours a day, and have to teach

them...Yes, I believe they should do hands-on. And yet, I believe they should experiment, but they need to be directed.

Pat does not like the notion of telling the student to go to a textbook for an answer because she [the teacher] cannot better advise them. *“To me, saying “I don’t know” is a cop-out. That is not what the teacher is there for...you are there to direct them to find the answer...to another experiment or another process that would solve that problem.”* Pat also believes by giving the response *“I don’t know; you go find out,”* the teacher shows no respect for student’s dilemma. *“They can’t find out the answer because they wouldn’t have asked you the question to start with.”*

Based on her experience, Pat believes children learn best if their investigation is directed. *“For me, to take a whole day to fool around with two bulbs and a battery is a total waste of time....I really think you need to focus in onto something. You have to have a question that starts it. How many different ways can you light this bulb? I find my best lessons start with a question and then the kids work to that question.”* She also feels that inquiry is not the be-all and end-all to science and that teachers must be prepared to incorporate different teaching strategies. She said it is important to recognize that children learn in different ways, adding that not all students will benefit from inquiry based learning.

You have to realize that you are dealing with a child’s mind and every single mind is different and learns differently. Inquiry method may work wonders for certain kids but the kid who can’t stay seated in his seat for less than two seconds without making noises and being totally disruptive, inquiry learning is not going to do it either. Because they have so much happening in their lives, and in their heads, that they can’t focus in.

In extending her experiences to theoretical perspectives, Pat views science as a *“process with an end-product in mind.”* She sees science as the exploration of the unknown, a set of skills that allows us to find out more about the world around us. But as with science teaching, she does not view scientific investigation as open-ended. Her conceptions reinforce her belief that any academic endeavor must be directed. There is a purpose to the discovery, a reason to the questions that have been posed.

[Science is] whatever interests you - finding out how it works, or why it works, or why it is like that, how it can change and why does it change. If you

see something, what it is made up of, why does that happen, if you see something that it is an unusual chemical reaction, why does that happen. I know one time when I was a teenager I coloured my hair and it turned out green, why did that happen? Curiosity and knowledge about your surroundings...a process with an end-product in mind. Not a process that will take you through this maze and at the end, you still don't know where you have come and why you have gone there. I think there has to be a wrap-up, a point to everything.

For Pat, science must be connected to our life experiences to have meaning. Although she recognizes that certain branches of science tend towards the abstract, Pat believes that scientific knowledge has the most value when it is incorporated into everyday knowledge. Science is not a disembodied piece of knowledge that cannot be questioned. It does not exist in a vacuum. Scientific knowledge, like all knowledge, is subjective, and dictated by the norms, experiences and interests of society. To suggest otherwise places science at the top of an intellectual hierarchy. Pat argues against perpetuating this kind of myth.

I think science knowledge is something you need to be able to use...Not some very finite pieces of knowledge that are so removed from everyday life that it is almost like I am waving a flag and saying look how smart I am because I know this and you don't. I don't think that is education. It is almost like a stratification of society.

Although she says the specialized sciences still “scare” her, Pat places great value on scientific enterprise. She sees modern science as making numerous contributions to our lives. From technological advances to medical breakthroughs, its benefits are vast. In this regard, Pat says is it surprising that science is not more respected. She draws parallels between the way society values science and the way it values education.

Pat: I don't think we value it [science] enough, actually.

Lori: Why is that?

Pat: A person that is trying to find a cure for a disease is not paid anywhere near what a football player is paid. So what does that tell you? That life does not mean anywhere near what throwing a football means? Or hitting a baseball? I don't think learning is valued at all in our society. I think it is what you can do with physical prowess or business prowess. Mental prowess is not valued.

In fact, Pat would like to see science being made more accessible to children and beginning teachers alike. She said young teachers are often overwhelmed by the amount they

have to learn. They would benefit greatly from a science course that is more specialized. Rather than focusing just on teaching strategies, Pat believes new teachers need practical information and examples of lessons they can directly bring to the classroom. They need to know how children conceptualize and learn about science through specific activities. This means teaching content as well as the “*messing about.*”

I really think I would have been a lot more comfortable teaching if I had something kind of specialized for me, as the classroom teacher of grades 5 to 7, this is the specialized post-holing method for you guys. So you get the content, the opportunity to mess about so you can know what it is going to look like when you get into your classroom, and you go from there.

Anna

As a primary teacher, Anna has always placed a strong emphasis on science in her classrooms. She feels that children have a natural curiosity, a desire to explore and learn more about the world around them. They are eager to investigate about everything, and full of ideas of how to go about it. In fiddling with things, using their senses and making discoveries, Anna says children partake in science everyday. Classroom science can take this process one step further. Indeed, she hopes that the skills learned in the school setting will serve children all their lives.

It [science] is a lifeskill, I think, too. I mean science is all around us...I don't think we ever stop wondering. We may get discouraged because we don't know how to pursue what we are wondering about, but I think if you've given the kids that skill that they can keep going, they can figure it out.

It is the ability to question and pursue a problem that is most important to Anna when teaching science. Although she does not view it as separate from content or factual knowledge, ultimately the “*process*” is what defines her approach. “*Process is the observations skills, the classifying skills, communicating, the testing, the hypothesizing and making predictions, all of that.*” Process is key to investigating new problems. Content, which she defines as the “*topic*,” determines the realm in which a scientific discovery is made. Anna commented on the tension between content and process when describing her philosophy about teaching science.

In teaching science, I don't necessarily see it as the content. I see it more as teaching the process of finding out. I think there is content that is important but it is not the number one concern. Once they have figured out how can they test things, how can they come up with their theories and ideas and check them, they can use that in any other content area. But I do think we need to teach some basic content too. I don't think we should just say oh, content is irrelevant. Because it is not irrelevant. they should have some background in all different areas.

This focus on process is also integral to Anna's definition of science. She does not view science as a body of knowledge, manufactured by scientists and waiting to be acquired. Rather, she thinks of it as the way by which we examine phenomena and come to an understanding of the world. *"I think science is the questioning. As I just tried to say there about the kids being curious and things they wonder about, those are the things I think that drive science...It is how to figure how to get the answer to what you are wondering about, or how to find out more about what you are wondering about."* Science is a way of knowing. It is an attempt to explain how and why things happen. It provides a lens through which we interpret the natural world.

Anna currently teaches science in a Grade 4 class one day a week. She graduated from university with a Bachelor of Arts and a teaching certificate from PDP in 1977. She taught full-time for 10 years, and then scaled back to part-time after her children were born. Anna says her focus on science fits in well with the job sharing she does. She observed that science often takes a back seat to language arts and math in the elementary curricula. Plagued with competing demands, teachers frequently find it difficult to integrate science into their regular routine. *"Science I think is the easiest one to drop because it takes so much to organize to teach your science class. You have to gather materials where you don't if you are teaching a social studies lesson."* By concentrating on science, Anna's skills are complementary to her partner's.

Anna remembers liking science ever since she was a small child. She has even kept over the years a science notebook from when she was in Grade 5. In the elementary grades, however, much of her learning was text-book orientated. Her memories of her regular teachers are vague. Those who made an impression on her were two student teachers. They

took the children out of the classroom to explore science outdoors. She describes two incidents in particular.

One student teacher taught in the class when I was in grade 5 or 6. And I remember going out with him doing tree identification...I remember that as significant, and I still remember the trees from those lessons. Then we had a biology student teacher who took us to the beach and we did some seashore ecology. That was excellent and has stood with me for a long time. I use what I learned from that student teacher with my own kids when we are down at the beach. So I think those kinds of events are really important. You know when you get out of the classroom and do hands-on.

Anna went on to specialize in science in high school. She took Chemistry 11 and 12, as well as Biology 11. She particularly liked the lab work associated with chemistry. “*I really enjoyed watching the reactions and figuring out how the molecules fit together.*” She enjoyed the problem-solving, did well in the exams and obtained top marks in her class. Despite her success, however, Anna said she lacked a true understanding of the subject matter. When the class engaged in theoretical discussions, Anna did not participate. She did not feel that she had the understanding to contribute to the discussions. As a result, she did not continue with chemistry after high school. She recalls running into one of her high school peers at university who was surprised at her decision.

He asked me what I was doing...are you doing anything in science? He said because you were so good in science, you would always get the top marks. I said I could study and memorize everything that was being done, but if you fellows in the class, there were only two girls in the grade 12 chemistry class, if you guys got talking I had no idea what you were talking about. So it was the understanding I think. I just didn't have the understanding. But I had what I needed to pass.

Although Anna says did not feel discriminated against because of gender, she was not part of the inner circle. Her chemistry teacher observed her lack of participation in class discussions, but made no attempt to help her. She does not remember him inviting or encouraging her to partake in the discourse. Instead, he penalized her for her apparent lack of attention.

In Chemistry 12, I got the top marks on every exam because I was very good at memorizing and spitting it back out...But for the mid-term mark, he [the teacher] gave me a B. I went to him and said how can I have a B when I've had the top marks in the class? He said because you look out the window too much. You should be listening more to what I am saying. And it was probably

when the boys were discussing things and I was just saying, OK, I'll look out the window. But for the final grade he gave me an A; I had stopped looking out the window. So it had the effect that he wanted it to have. It made me focus a little bit more. But I wonder what I was doing during that time, whether it was not really relevant to where I was, or maybe he was focusing on the boys with their discussions. And I really do recall that feeling of I have no idea what they are talking about.

Anna's reasons for taking a science methods course at university are complex. On the one hand, she continues to be fascinated by science. The subject matter interests her greatly, she enjoys teaching it and wishes to teach it better. However, the driving force behind her decision to take this course has been intensely personal. Her brother recently died in a car accident, and she found the grief overwhelming. She looked to the university course as a step towards working through her grief and moving forward with her life.

I had a brother who was in education and he was killed in a car accident a year ago. And that was a really tough year for me least year. I thought I don't know if I can manage it. Every time I mentioned him I would start to cry. Tears would come. It was a really, really tough time. And I thought he was well known in his community for the things he did in education. That gave me some inspiration. I thought O.K. instead of grieving for him this hard forever, do something about it. And the one thing I missed was the talking amongst teachers that I had been able to do...when I was working full-time...I had been thinking about this for a few years, of either doing a Master's or my sixth year, just doing something more at the university level. So then I decided because of the personal situation, get on with it...and because of my interest in teaching science that was the course I chose to do right away.

Anna added the part-time nature of her work precludes the opportunity for much discussion or sharing with other teachers. She has always been interested in professional development and missed the opportunities for this that came with full-time work. She thus looked to the university course as a chance to interact more with other teachers, discuss and be critical, as well as further her own knowledge about science teaching. She also saw going back to university as a way "to change things" and help resolve the grief of her brother's death.

In this way, Anna says the science methods course has met her expectations. Her experience there helped her to articulate her beliefs, as well as explore more deeply aspects of her own thinking about teaching. She sees the professor's emphasis on practice as problematic extending into other areas of her life. "He tries to encourage us to be critical of what we are

seeing from the ministry, and in all areas, not just to accept things. And I think that is important in your life too. Not to just accept everything as it is and say you can't change it."

The tension between content and process re-emerged in our interview when Anna elaborated on her needs as student and teacher. In the science methods course, she emphasized the importance of having a balance of theory and content. She said she would be dissatisfied with content alone. She didn't want just more "*lessons to teach*," but to think about why and what teachers were doing when they taught science. The attention to theory was crucial to her professional development. However, she also discussed how content knowledge affected her self-confidence with respect to teaching science in the classroom.

I do have those concerns that I need to know a little bit more. I don't need to have all the answers, but I need to have some understanding of the content so that when kids are developing their own theories of how things works - I don't need to lead them - but I need to be able to feel comfortable in responding some ways to where they are going. If you have no idea of the content, I don't think you would; personally I wouldn't feel comfortable.

Reminiscent of her childhood experiences, Anna identified hands-on participation as a valuable component of her own learning, as well as her students. She referred to a particular class activity, in which she and her colleagues experimented with light bulbs, wire and batteries in order to learn about electrical circuits. The hands-on activity provided content, the factual information around which she worked. It furthered her understanding of electricity and electrical principles.

I thought it was really important they have this balance of theory and thinking about how we are teaching, plus the hands-on activities. We need some content to do that with. And that particular lesson - electricity - is something that I would never touch.. By doing that [unit on electricity], I went and bought the equipment I need to start and I am going to do it [in my classroom] after Christmas. So I think that is important too...that he [the professor] has the time in his course for us to do hands-on.

The hands-on activity provided something new that she could bring back to her classroom. But more importantly, it provided a domain in which she could examine her teaching as well as understandings of science. "*I really like the balance that we are getting of some actual lesson that we could do in our classroom and the thinking about why we are teaching science and what we are doing when we are teaching science.*" She also feels the

sharing of questions and ideas with her colleagues helps prepare her for the theorizing her own students will do in the classroom.

Anna's definition of "hands-on" is multi-faceted. Although the hands-on activity provides, the content, a specific substrate for learning, she believes "hands-on" is not simply manipulation or physical interaction with objects. Anna stressed the importance of intellectual engagement in hands-on activities: the selecting, building, constructing and testing of ideas. Drawing on constructivist theory, Wideen *et al.* (1992) suggest that learning does not occur by merely handling materials, but through conceptual change. Anna refers to this aspect of learning in response to my question: What does hands-on science mean to you?

I want the kids doing things actively as much as possible rather than sitting observing what I am doing. In an experiment, I want them to be able to try their own ideas. To prove or disprove their own theories. It can start from me demonstrating but then I want them to also fool around with the stuff too. Now what can you find out from that? Why did it happen that way? So hands-on can go in many different directions...If they just copy what I do, I don't consider that to be hands-on. That is a portion of it, but they have to be thinking about what they are doing and why they are doing it and what they could do next if this is what happened. The process has to be continuous and on-going.

Anna said that she does not question or doubt her ability to teach science. She feels there are enough resources and people around to whom she could turn if she had difficulty. Her subject matter knowledge, as well as science-related experiences, allow her to feel comfortable in not being the expert. She doesn't think she has to know all the answers, but rather how to guide her students with their questions and pursuits. What makes her doubt her effectiveness and ability as a teacher, however, is the nature of part-time work.

In job sharing, one of the things I sometimes feel, is that what I am doing is not significant. That I am only in there one day a week. Do they really get anything from what I am teaching? Does it have any carry over to the rest of their week or lives?.. It is the part-time work that has made me doubt rather than the full-time work...I am almost like a substitute coming in once a week. You know, it is quite a long time and it is always separate from the other things they are doing.

As I wrote this narrative based on my interview with Anna, I came to realize that conversation reflects an individual's feelings/thoughts/perspectives at one moment in time. Our relationship to knowledge, and meanings born from that, shift with our daily lives.

Things can and do change. I had the opportunity to speak with Anna for a second-time, almost nine months after our first interview. It was near the end of the school year, and she felt quite differently about her effectiveness as a part-time teacher.

You realize you have been significant. It is like the beginning of the year. September/October you think are things going all right? And for me, being a part-time teacher, that takes a little longer. That period of floundering is just extended. So now at this time, I think it has been good, and they [the children] have learned a lot, and I can see the growth. It comes together. It takes a little bit longer. (June, 1996).

Claire

Claire began teaching in 1980 with an initial focus on learning assistance. She taught special education at the intermediate level for four years, and another four years in the primary setting. Here she served as vice-principal as well. Claire left administration after the birth of her first child. Since 1991, she has taught part-time in a regular classroom.

Claire has always valued science. As a team-teacher in a Grade 2/3 classroom, science and mathematics comprise the nucleus of her teaching. She integrates science into many themes including reading, writing and social studies. Science also played a large role in her classroom when she taught special needs children. Here she recalls it having particular value. It provided a special link to learning that much of regular schooling did not do.

I worked a lot with problem kids and they were very different in the outdoors, their opening up to learning. Just taking them outside made such a difference. They would "oh, look at this." There were things all around, and you didn't have to have a lot of materials....I remember for a while I thought with my Special Ed class that I should have them outside the whole year. Because you took them back in the classroom, they would be shoving each other into walls and having to take drugs. I think they would have survived much better if they could have been outdoors. They seemed calmer and more open, so to me it was a solution to behavior problems and everything.

Claire was born and raised in Vancouver. She remembers always liking science, being strongly influenced by her three older brothers in this respect. As children, they had numerous pets ranging from fish, gerbils, lizards and dogs to frogs and snakes her brothers brought home. At one point, Claire recalls having over 100 animals in their basement. All three of her

brothers pursued university degrees in science. Their discussions held a great fascination for Claire.

My oldest brother took genetics from David Suzuki...He was 17 years old, so I was only in grade 7, and I remember just being fascinated with this talk about fruit flies and cross breeding and things like that....My middle brother always wanted to be a zoologist. He just loved animals..Because they were interested, that influenced me too, what they were doing...So it [science] was all around me.

Once in high school, Claire took Grade 10 physics and chemistry as well as Biology 10, 11 and 12. She remembers her physics and chemistry teachers as being aloof and unapproachable. “*The science teachers were kind of a separate breed....They seemed so clinical, sort of cut and dry.*” Physics held little meaning for her. She found the concepts hard to grasp; the experiments bore no relation to her everyday experiences. “*With physics, all I remember is the little cars, and ramming them against the wall and measuring distance. That is all that really stayed in my mind and yet I took a year of physics.*” Chemistry seemed equally foreign. It also held an additional element of fear for her. She did not feel comfortable experimenting with chemicals, nor using the required equipment.

Something that scared me a bit in chemistry was fear of the chemicals and what I could do wrong. You always hear of blowing up the chem labs and things like that. I didn't have the same fear with the biology labs, but I remember the sight of test tubes and things bubbling, and all that stuff, not impressing me and scaring me. I didn't like to burned. I think that had an effect.

Claire dropped chemistry and physics after one year, but continued on with biology. Her experiences here were far more positive. In addition to regular lab work, the teacher taught biology around situations and landscapes that were familiar to students. The Vancouver Aquarium served as the focal point for a study of marine biology. He used Queen's Park as the laboratory for teaching plant science. There were trips to the planetarium and medical laboratories. In doing so, the teacher made science relevant to the life experiences of his students. Indeed, Claire says her experiences here have carried over into her teaching life. She recalls two field trips in particular.

One [field trip] was done in the Aquarium. The instructor had set out all the questions where you had to go through the Aquarium and had to spend at least four hours doing it...I have loved the Aquarium since then because he made

you look up and find out things and ask people things, and learn a lot that normally you walk through and wouldn't do. We also did one at the McMillan Bloedel conservatory at Queen Elizabeth Park. We studied plants and did plant identification. We had to find different habitats and things...Those ones I still use with the kids, so I think they were the most valuable.

Claire retained an interest in biology throughout high school. At the same time as instigating her interest in science, however, her brothers undermined her achievements. They told her that teachers gave her good grades because of their previous success. “*My brothers would say things like the only reason you are getting As is because we got As - stuff that is typically brothers.*” Although Claire looked at their ridiculing as nothing more than sibling harassment, she decided to pursue history instead. This was an area in which she could prove herself without being overshadowed. It was an area in which she could claim success as her own.

Claire began her post-secondary education with the intent of becoming a teacher. Her first two years were spent at a local community college. Although history was her declared major, she also took one more year of biology. Here she encountered discrimination of a different sort. Entrenched within the biology department was a disdain for the teaching profession. She was told by her peers to not inform her professor that she was in the education program. If she was to do well, she had to hide who and what she was. As a future teacher, she must play mute.

When you were in teaching programs, as opposed to being in a science program, that they would put you down because you were going through in education rather than as a science major. And when I was in college taking my first year biology, I didn't put that I was going into education because I had been told if they know that they will give you a lower mark because they just think that you are not really interested in sciences.

Claire later transferred to university to complete her education degree. Of all her education courses, she remembers her science education class as being particularly disappointing. Highly theoretical, it afforded her no insight into her own ideas about science or role in teaching it. Rather, it reinforced negative impressions that education course work was more of an intellectual exercise than an understanding of practice. In direct contrast to this course, however, outdoor education provided her with the hands-on experience she craved.

The students teachers were paired with children in schools, and together they explored natural sites.

We took classes of kids on camping trips. We took them to the bird sanctuary and on day field trips... We did all these trips and it brought back what I had done in university. It gave me the chance to get into the community and learn and be a part of things rather than locked away.

Having personal involvement is integral to Claire's understanding of science. She needs to touch, feel, explore, manipulate. Real science is embedded in personal activities. Using Belenky *et al.*'s (1986) terms, Claire is not a received knower. She does not accept knowledge readily from an outside authority. Being part of a community, being involved in the learning, are at the heart of her learning; otherwise she feels that knowledge does not belong to her. She explains this concept in relation to hands-on learning.

By hands-on, I mean actually being able to manipulate the things that you are working with. See them, touch them, smell them, whatever. Not just have a teacher write it up on the board and the teacher just do it. The teacher demonstrates the experiment and the kids sit and watch it. If I don't actually do things myself, I don't remember them. If somebody just shows me and I have to write it down, it doesn't stay with me. Unless I actually take it and have to try it out myself I don't find I learn as well, so I try and do that for the kids too. Because you just know that it will be gone the next day if it is not done.

Indeed, Claire tries to bring these concepts to her own classroom by making experience the touchstone of her science teaching. She would like to foster the natural curiosity of her students and believes that hands-on activities, and making sense of one's experiences, constitute the core of learning. What seems most important to Claire, however, is that her students develop ideas on their own. She urges her students to select science projects that interest them rather executing something their parents or others deem important. Her description of one student's project in particular embodies this notion.

We have been doing science fair things, and I was really encouraging them. I said if you get stuck go to a book and find an experiment and do it, but try and think of something in your life that you are interested in and you would like to find out why and explore that. Even look in your bedroom, look around your house, see something that you have always been interested in and you like and try and learn more about it. So one girl had a collection of crystals. She loved the light and stuff going through, so she did an experiment on how to make the rainbows and stuff with her crystals. And I was really pleased because it was something she was interested in and carried out.

Contrary to her own experiences with the physical sciences, Claire also tries to teach her students that science does not necessitate one “*right answer*” or one way of doing things. She uses a failure to achieve an anticipated result as a starting point for further exploration. She encourages her students to view experiments that do not work as variations within science. *“I have been trying to stress that they could discover something that no one else has, and that the idea is to try things. And if it doesn’t work, that it doesn’t mean that it doesn’t work. Letting them feel comfortable about trying things and not covering up the results.”* Despite the supportive environment, Claire observed that many students still tend to seek the “*right answer.*” Even at the age of 7 or 8, her students get worried when their findings are contrary to what might be expected.

I had two girls doing an experiment: do plants need light? So one put their plant in the dark and the other one put it in a window. And the one in the dark grew. And they were so upset, but I said great, we might have discovered the one plant that will grow in the dark. This could be great, I said, but also, what else could it be? And we talked about that the seeds might have not been that good. So we left it, and it turned out that the one eventually did grow and it was a more solid stock and the other one, a big long spindly one, so [we discussed] which plant is better. Well, the one girl was convinced because this one is bigger it was a better plant. But the other one started saying, no I have grown those and beans don’t come out. So it generated a lot of ideas and things, whereas they were worried that it wasn’t working because they said, it is supposed to need light. But I was really pleased that it didn’t work because it got a lot of ideas going.

Although Claire tells her students that science is not absolute, she has only come to this realization as an adult. Even as a beginning teacher, she did not view traditional science as a realm in which one could take risks. Experiments had to turn out right. She said it has only been over time that her perspectives have shifted and she began to see science as a field inviting exploration.

While teaching has expanded her view of science, Claire’s relationship to scientific knowledge is contradictory. She says science means exploration and “*finding things out,*” but it also involves an element of “*truth.*” Claire likes the certainty of science. There is an exactness to it that she does not feel exists with the humanities or social sciences. Claire elaborated on these views when we were discussing what science meant to her.

I always thought of science as the nonfiction part of the world, and the other was the fiction. Anything that was more fact related, more into discovery. I think I liked it because there were answers to things that you could find out, whereas the arts were so much more open-ended and people could mark you depending on how they liked you, whereas in science they had to mark you on the answers. As a teacher, I like marking them because it is easier that way too. It is very hard to mark somebody's ideas and give them a grade.

Science allows for exploration, but an exploration within certain boundaries. Science provides Claire with a way of knowing, a precise methodology, that she does not find with other disciplines. She associates creativity with the arts. The latter is far less controlled, subject to the whims of individual interpretation. Kate also associated creativity with the arts and not with science. But while creativity implied freedom to Kate--the chance to express herself-- it is something quite “scary” for Claire.

Science is a whole bunch of things, but things that are more based on discovery and finding and solutions and things whereas the other side is more of the opening up and expressing and just the creative side. There is a lot of stability feeling for me with the science part. There is a grounding and a process and a way to do things, whereas the arts can sometimes be too scary because it is so open-ended and not really a process to go through. I think I liked studying and I liked that feeling that you had accomplished it and done something, and I could finish off a science project and feel that it was completed and done, whereas I agonized over my arts type - especially English papers - so much more. It was much more of a challenge in that way, and you wanted to do well and you just weren't sure how to do well. What does this person really want?

Although she sees the two as closely intertwined, Claire feels process more than content is what gives science its authority. “*I think it [science] is a groundwork to find ways to look at what we do, and what we see. Things may be true only for a certain amount of time because they are always evolving and changing. So I think of science as a process, and the stability comes with the math and the...way of doing an experiment and trying to keep things consistent in how you experiment and test for things.*”

Conclusion

This chapter details the science understandings of nine elementary teachers. The individual profiles portray how personal experiences influence the perspectives teachers hold

about science, as well as shape their visions of science teaching. In the next chapter, I identify categories which emerge out of the profiles. These serve as the framework for the analysis.

In concluding this chapter, I would like to address why I did not present the profiles in chronological order. I did not interview the first participant, write her profile, and then move onto the next interview. Rather, I wrote the profiles in order of how I came to understand the stories. I began with participants whose experiences spoke to my own, and with whom I shared a ready understanding. (Like Susan, I did well in science but much of it confused me. At the same time, I shared Eric's excitement about science). I then proceeded to the profiles that required more searching, more work on my part, as I tried to give an account that most accurately represented the participant's experiences. (How could I communicate the discrimination Nancy, Kate and Haley faced?) Each person I spoke with deepened my understanding, and thus linearity or a chronological ordering of the profiles seemed inconsequential. Rather, I let my growing understanding guide how the profiles were organized.

Chapter 5

Analysis

Introduction

Chapter four has laced together a series of stories told from the vantages of both beginning and experienced teachers. For many people, school is the first and only exposure to science. It can also be the most powerful. Schooling fashions the meaning, experiences and discourses around science from which students draw their understanding. It is here ideological representations are created, reflecting lived experiences as well as the viewpoints of teachers, administrators and policy makers working within and without the practice of public education. The words and views portrayed by these teachers cast light (as well as darkness and shadow) on the difficulties faced by many in the classroom. We learn much about what participants perceive as contributing to success and failure; the inclusions, alienations, and the dynamics of learning science. Their stories depict the struggles in which individuals are engaged, as they construct knowledge about science. More than anything, these stories emphasize the diversity and complexity in lived histories. They also emphasize the dialogic in coming to know or find meaning. Learning, like any relationship, is rarely static. It involves an exploration of authority and a constant shifting and negotiation between what is lived, perceived, and valued. It cannot be reduced simply to the subjective informed by the objective. Britzman explores this dialogic with respect to learning to teach.

Enacted in every pedagogy are the tensions between knowing and being, thought and action, theory and practice, knowledge and experience, the technical and existential, the objective and the subjective. Traditionally expressed as dichotomies, these relationships are not so nearly neat and binary. Rather, such relationships are better expressed as dialogic in that they are shaped as they shape each other in the process of coming to know. (Britzman, 1991, p. 2)

As I read and re-read these stories, I feel overwhelmed by the diversity of the participants' experiences. Each individual's story is so unique; so many things shaped,

influenced or could affect what was said. To look for themes or theoretical categorizations seems almost incompatible with the stories told. Further, to do so imposes my interpretation on events even more so than I have already done. Yet, as a researcher I recognize that I am part of these stories. My analysis began with the first question I voiced. It continued as I documented certain aspects of the participants' experiences and ignored others. It is manifest here. Thus to imply that I do not theorize as I come to an understanding of this research is misleading. But as I consider certain themes, it is important to recognize the analysis reflects a partial understanding. I tried to negotiate this understanding by giving the transcripts and narratives to the participants to critique, but the construction is still largely mine. Others may come to different interpretations from the narratives. For this reason, I feel that it is important to let the narratives stand alone in their entirety as a separate chapter. My analysis may thus seem repetitious at times as I draw on some of the same material. Yet as science has been rightly criticized for decontextualizing experience, I do not want to participate in further fracturing. When words are taken out of individual stories, we retreat into categorization and labels.

With this struggle setting the terms for the discussion then, I begin my analysis with a brief description of some background patterns. Most of the teachers I interviewed had little or no experience with science in elementary school. With the exception of isolated incidents, only two of the nine participants recalled partaking in science in their early years. High school appeared to be the time during which relationships to science were forged; that either interest in the subject, or feelings of incomprehensibility and alienation from it occurred. Participants cited their own teachers and school experience as being instrumental in shaping their attitude toward scientific knowledge and future science practice. Fear characterized many of the participants' experiences and feelings about science. Images of science as "scary" recurred in six of the stories told. These images are tenacious. For some participants in the study, science still evokes fear.

Beyond this level, three themes emerged and will comprise the focus of the ensuing chapter. They revolve around notions of belief, faith and science; gender, language and

science; and connections and science. But while initially I discuss these themes as separate entities, they converge within and across the text to render another theme, that of scientific representation. Science comes to resemble certain things or take on certain identities as meanings are socially constructed. Through a dialogic, subjective meanings become objective entities, which are then internalized as subjective realities (Berger & Luckmann, 1966). Constructed from partial, multiple and local positionings, subjective and objective elements inform, shape and are shaped by each other to yield representations of experience. Ultimately, our representations are reflected in everyday knowledge and practice about science (Flick, 1995).

On belief, faith and science

As members of a particular community, scientists usually display shared commitment to particular sets of beliefs (Kuhn, 1970). Physicists look to relativity, chemists to kinetic theory and biologists to Darwinian evolution to explain certain events. Although guided by observation, scientific beliefs are inextricably bound up with the particular culture that helps give them shape. They suggest a way of thinking that relies not only on formally expressed concepts, but tacit, and personal understanding (Kuhn, 1970). One can argue about facts; beliefs, characterized by opinion, values as well as observations, are far more difficult to dispute.

Kuhn writes scientific knowledge is “embedded in theory and rules” (1970, p. 187). Although theory can impart different understandings, I take it to mean a “structure of ideas” (Lerner & Bennetta, 1988, p. 37) through which we attempt to interpret or explain certain observations and events. Theories reflect not only our understanding of the world, but the values we impose on them. They are part of who we are - localized in our culture, society, history and lived experience. We thus bring ourselves, as well as our beliefs, to theory. In turn, theory becomes our belief. Once again, I am drawn to Britzman’s emphasis on the

dialogic. These kinds of relationships “are shaped as they shape each other in the process of coming to know” (1991, p. 2).

It is not surprising then that new theories or those which challenge one’s beliefs, are not readily accepted. As Kuhn rightly argues, the adoption of a new belief or theory to explain events often requires faith.

The man (sic) who embraces a new paradigm at an early stage must often do so in defiance of the evidence provided by problem-solving. He must, that is, have faith that the new paradigm will succeed with the many larger problems that confront it, knowing only that the older paradigm has failed with a few. A decision of that kind can only be made on faith. (Kuhn, 1970, p. 158)

The criteria for such choices are complex. Often the question is not which theory offers the fullest explanation or makes the best prediction, but which theory fulfills a multitude of inexplicit criteria. As Kuhn states: “Something must make at least a few scientists feel that the new proposal is on the right track, and sometimes it is only personal and inarticulate aesthetic considerations that can do that” (1970, p. 158).

While philosophers of science, sociologists as well as scientists recognize that theory is influenced by beliefs, this notion is rarely acknowledged in the classroom. School science, it seems, continues to misrepresent the nature of science. Students are taught to trust implicitly in scientific processes, concepts and theories they do not understand; to treat theoretical concepts as real, rather than conceptual tools or models for assisting us in understanding the world. Theories become directives for interpreting events unencumbered by disputation or subjectivity. To be academically successful, students are required to share these beliefs. Yet much of this knowledge is not empirical. We cannot see, touch or smell neutrinos. Atoms are beyond manipulation in our daily lives. Scientific understanding thus becomes acceptance, belief in someone else’s words, or similar to the scientist embracing a new paradigm, even a matter of faith. Although usually seen as ideological polarities, science and religion impose similar dogma on students. Both ways of understanding require either a belief, or faith in a belief, which attempts to describe/explain/interpret happenings that cannot be observed. Thus

in this analysis, I see belief as being used in two ways: theory as equivalent to scientific belief and students' belief/faith in science and scientific principles.

The importance of belief, with respect to scientific understanding, recurred in many of the participants' stories. For Nancy, hands-on activity was the key to her achieving belief.

I took an earth science course...We went on a field trip and looked at different rocks, we went to rivers and things like that, the actual seeing and doing, not just getting information from a book. So that was pretty good. We actually handled different types of rock, different types of minerals, looking at them through a microscope, doing different tests on them. It's more real. They have that saying, seeing is believing. But I think in science, maybe doing is also believing. Instead of just reading, doing is also believing.

In reflecting on her experiences, Nancy said that seeing, feeling, touching and doing are integral to her understanding of science and scientific concepts. She likes to try out new things, to manipulate, to explore with her hands and senses objects and concepts related to the subject matter. The knowledge she constructs from these lived experiences is more meaningful to her and necessary for her belief in science. As she emphasized, "*doing is believing*" in science. Nancy's words corroborate Polanyi (1966) and Kuhn's emphasis on tacit knowledge in learning science. This sort of learning is not acquired by verbal means alone, but rather "it comes as one is given words together with examples of how they function...by doing science rather than by acquiring rules for doing it" (Kuhn, 1970, p. 191).

Others struggled to achieve both a belief and an understanding in science. For Kate, the connection was never made. She saw her encounters with academic science as largely irrelevant. Often reduced to a textbook account, devoid of context, Kate found no meaning in what was taught. She could not readily believe in scientific concepts. Facts, theories and scientific laws were unconnected and trivial. They did not foster belief.

Do you remember the periodic table? We had to memorize that. That was a nightmare for me. It didn't mean anything. It didn't MEAN anything.

Kate's experience in academic science was marked by failure. Others managed to do well even though they did not understand the material. Susan took biology, chemistry and physics throughout high school. Although she achieved academic success, she was unable to

translate scientific language into her own. She accepted scientific authority, and believed/had faith in what was taught, but she felt like an outsider to scientific thought. Science, for Susan, remains something “*way out there.*” It is foreign to her experience and ways of understanding. Scientific knowledge is not hers to use.

Physics was something for me that I never really understood. I was good at memorizing and learning things, so I could memorize what I had to do and I did fine. I ended up with an 80 or 85 in the class as my final mark, but I didn't really understand it. I just memorized it and I could do it that way...It was the same way for me in chemistry. I never really understood what was happening. But I could do the experiments...I would have to start right from scratch again if I was to try to do it over again. I don't remember anything. And I knew even at the time, I knew that I didn't understand it but I could do enough of it to get the right answers. But I didn't really understand how that answer came about.

Both Anna and Andrew voiced similar views. They did well in science. Anna even managed to have fun in chemistry class, but neither felt she nor he had a true understanding of the material. Over time, Andrew came to feel like a fraud with respect to his science knowledge. He recalls being fearful of getting caught.

I got to the point that I was really feeling scared. My marks were OK, but it didn't seem like I really remembered what I was suppose to remember. And I felt like I barely got through, although I got Bs and B+s on tests. But at the same time it wasn't knowledge that I felt I could carry through to the next year.

For Andrew, science was characterized by linearity. It reflected one viewpoint, one methodology, one way of doing things. Prescribed experiments required prescribed results. To veer from this set course was wrong. “*You have to follow the rules. And you have to go down, step by step. If you don't remember the rules, you shouldn't really be doing it.*” Initially, Andrew believed in science and its authority, and did not question this approach. Yet he was unable to partake in this knowledge.

There was a lot of distance between me and science. Science was on one range of the spectrum and I was on the other. And the few times I got to cross over and actually touch it were the times I felt that I understood it. But because all the other parts of it were so distant still I felt like what I learned must not be valued.

Andrew was able to change his orientation to science once he discerned that scientific theories represented explanations and beliefs, rather than distinct facts. Through television

programs, he began to learn that science did not mean just one thing. Rather, it encompassed a variety of perspectives. He became aware that alternate meanings could be derived from the same observation. *“After watching some show on plate tectonics and hearing 3 or 4 versions of it, [I would think] wow, these people are arguing about this and there is no right answer.”* Science did not necessarily entail a single, authoritative voice. Scientific knowledge embodied people and their opinions. This realization gave Andrew access to scientific knowledge.

Of the people I interviewed, those who did well in science voiced less criticism than the participants who encountered difficulty. For both Claire and Eric, science made sense. They readily believed in scientific concepts, principles or laws that were presented. They enjoyed its concrete aspects. They enjoyed the laboratory experiments and the feelings involved in discovering how things worked. Science came to represent a clear understanding of the world; its premises did not require negotiation. In this way, their experiences are similar to mine. Although I did not always understand the concepts around physics or chemistry, I never thought to question them. This knowledge came from a greater authority.

Claire in particular, enjoys the certainty of science. It provides a methodology, an exact way of doing things, that she does not find with other disciplines. Science has an order to it. Its development is marked by an accumulation of individual discoveries and inventions. Claire takes comfort in the notion that scientific knowledge is less arbitrary than other forms of knowledge. Further, because it is grounded in a precise methodology, she views scientific knowledge as having *“more value.”* She feels that it is not influenced by opinion as are other kinds of knowledge.

Science is a whole bunch of things, but things that are more based on discovery and finding and solutions and things whereas the other side is more of the opening up and expressing and just the creative side. There is a lot of stability feeling for me with the science part. There is a grounding and a process and a way to do things, whereas the arts can sometimes be too scary because it is so open-ended and not really a process to go through.

This view conveys an image of science as objective. What counts as knowledge is generated through observation and can be verified by experimentation. Scientific methodology

gives our observations greater validity. As Claire says, “*there is a grounding and a process.*” She has developed a representation of science as a body of knowledge that is neutral, beyond opinion and human values.

No monolithic statement can be made about teachers who were successful in science versus those who were not. However, as someone “successful” in science I feel that I can speak to my own experience. After listening to these stories, I recognize that I was less questioning, less challenging and more conformist than the participants who encountered difficulty or failure. I readily believed; I had faith in what I was told.

Claire’s words bring to mind the similarity between religion and science. For many, science exhibits the same sort of inflexibility that we associate with the most dogmatic religions. Both hold claims to objectivity, and omnipotence. Both require, at times, faith in particular beliefs. If we expect to portray a more accurate picture of science in our classroom, students need to know that theory is only an ideological tool to help us interpret our observations. It is important to bring human authorship to our fact finding. As Goldstein and Goldstein (1978) state: “Science does not begin with facts; it begins with perceptions of a problem and the belief in the possibility of an answer” (p. 19). Perhaps if we were more honest with students, more explicit in defining theory as an explanation developed by certain people at a certain time in a certain place, science may become more accessible. We need to worry about students who are being alienated from science. As a culture, we also need to worry about what constitutes “academic success” in science and how this shapes, empowers, humiliates or anesthetizes us as learners.

On gender, language and science

Much of the research documenting gender differences in science education has focused on participation and achievement, with statistics continuing to show disparity between males and females (Guzzetti & Williams, 1996; Haggerty, 1996). Others have looked at how the culture of academic science discourages and disadvantages women (Acker & Oatley, 1993;

Kahle, 1990). Although I did not frame this research specifically around gender, it is an issue in which I am interested, and one that surfaced time and again. It was clear from the participants' stories that gender inequalities exist in a myriad of ways. It is not a simple issue, however. Gender intersects with race, class, ethnicity, sexual orientation (and in Claire's case, profession) to create a science culture that is oppressive and exclusionary for many people (Bryson & deCastell, 1995; Hubbard, 1989). I believe that it is important to document situations where gender prescribes the parameters of an individual's experience with respect to science education. But at the same time, I recognize this kind of analysis does little to address the complexity embedded in social control.

Pat went to high school in the 1960's, at a time when cultural stereotyping of science as "masculine" was very strong. She does not recall being openly discouraged from taking science. However, students and teachers alike shared the expectation that science was a male domain. *"I think perhaps there has been an attitude right from the beginning that girls can't do it. I knew I couldn't. I didn't even really try past biology."* Boys were considered to have a natural aptitude towards science. They were "smart" and showed true understanding, whereas girls had to work extra hard. Further, Pat felt her schooling did little to accommodate different approaches or "women's ways of knowing" (Belenky *et al.*, 1986) in science. *"I don't think we were given enough opportunity to work together. It was such a competitive thing...I lost out on that whole aspect of my education because I don't think high schools cater to the female mind or a girl's way of learning."*

Claire initially felt that it was her brothers who discouraged her from pursuing science by casting doubt on her achievements in school. In a later discussion, however, she speculated about gender. She suggested that her brothers' attitudes towards her science ability, their harassment and belittling of her success, were shaped by cultural expectations. Boys did science; girls, arts and social studies. Thus they could not expect her to do well in science. Although she dismissed their harassment as "brother stuff," she did not challenge their claims. Rather she switched to history as her academic focus. Her decision not to pursue biology in

university is one she has later regretted. *“I think if I was going through now I would have stayed in sciences.”*

Anna did not feel that gender bias was part of her high school science experience. She took chemistry in Grades 11 and 12, and was top of her class both years. Nonetheless, as one of two girls in chemistry class, she was not included in the group of “knowers.” She recalls not partaking in many discussions, nor really understanding the nature of the discourse in which the teacher and boys engaged.

For Haley, gender defined what she could and could not do. She fought a system that was geared toward discrimination. It proved extremely powerful and she ultimately lost. Because of her gender, she was shut out of a career that she had long sought.

If I was going to have a career in science there were certain places where I was welcome and certain places only...If you don't want to be in any of those traditional niches, then don't enter science because there is nothing beyond that for you. That is the attitude I grew up with. The whole area of science had a door with a sign on it that said “No Women Allowed.” So unless you were very strong, very strong-willed and very strong in your focus and your direction, and you had a very good support system behind you, you didn't enter certain fields. Rather than providing a mentoring and encouraging environment, the schools and especially the post-secondary school, were playing a power-game controlling “who's in” and “who's out.”

It is now 20 years later, but Haley still sees science as a field characterized by elitism, power and authority. Not only has this defined her career choice, but has led her to question the value of her teaching and expertise. She sees professional science as divorced from her world; it remains secluded behind “a wall.” But at the same time, Haley believes “real science” is part of everyday life. Because the former carries greater authority, however, this is what is recognized as science. Haley's words reflect the tensions arising from her personal history. Scientific accomplishment is something from which she is excluded.

Because of my experiences, I had a tendency to think of myself more of as an arts teacher. Even though at the primary level I always put a strong focus on science, I didn't think of myself at all as a science teacher. That's not my area. I am not allowed to be that. I am just fiddling with little kids.

Despite greater attention being paid to issues of inequity, gender still makes a difference in science classrooms. Susan, Nancy and Kate graduated from high school in the

mid to late 1980's. Of the three, only Susan said she was not discriminated against in school. She did not connect her struggle in science with anything other than personal difficulty. For Nancy, issues of gender interacted with racism. Teachers and students shared the expectation that “*girls did history or language arts*” and “*boys did science.*” But ethnicity posed another obstacle. Her high school science teacher belittled students from Nancy's town because a large proportion were of First Nations ancestry.

One teacher there had such a negative attitude about people from _____ Bay. He said if you get an A or B in _____ Bay, here at _____ that means C or a D. So right away, he shot you down, and he was a science teacher. So it was like, hey, I don't want to be in his class if he is going to feel that way towards me.

Kate, who graduated from high school in 1986, experienced overt gender bias in her physics class. She recalls on more than one occasion, the teacher stating that girls were less capable in science than boys. He expressed the belief that if girls did succeed, their success was due to hard work and not intelligence or ability.

Kate: The physics teacher I had was really difficult and he didn't really feel girls were able to learn science, so when I needed help he wasn't really there for me.

Lori: How did he get that across?

Kate: He used to say it in class...There were little things like “now the girls are going to have a more difficult time grasping this concept.” There were only two of us in the class.

Feminist scholarship has challenged the positivistic theory and language that underlies traditional science. Harding (1991, 1986), Fox Keller (1985), Rosser (1989) and others have argued the conceptual dichotomizing characteristic of scientific ideology is a masculine way of relating to the world. Science, as conventionally known, has been developed from the perspectives of a single group, namely, the male Eurocentric one. It tends to exclude different understandings, different viewpoints, privileging male experience over female. Indeed, much of science rests on many of the same kinds definitions and dualisms found in the construction of gender: subjective/objective; intuition/reason; nature/mind; dependent/value free (Fox Keller, 1985; Harding, 1986). These kinds of dualisms have become embedded in the

structure of science, as well our individual and social representations of science. They shape the way we think about science; they are part of our language.

Indeed, in many of the participants' stories, language and language use set the terms for understanding their science experiences. As Berger and Luckmann (1966) state we employ language to interpret our experiences in a finite province of meaning. In some cases, language served to mystify science; in others, to intimidate and make the learner feel powerless; in others, still, to define experience according to gender. Language has a role in creating and maintaining power structures. Pat, for one, "loved" biology in high school. She even considered pursuing a career in forestry. However, she remembers thinking her accomplishments in biology had little value as science.

In high school and university, the boys were the ones who were always taking these courses. They were the smart ones because they took these really hard science courses. I don't know, I always felt that if you did biological sciences, that was easy, that's not real science, soft science. That's not real science. Real science is physics and chemistry. That is the real stuff.

Pat's experience supports much of what has been reported in the literature. Even within the realm of science, certain branches are differentiated along gender lines. Biology, which tends to attract more girls, has acquired the reputation of being "soft". Physics and chemistry are considered "hard." This quality of being "hard" renders a subject higher status. It is perceived as more intellectually demanding, more exact, more "truthful" and more masculine than others (Fox Keller, 1985). For Pat, it also made science more real. "Biological sciences...that's not real science, soft science." Her words affirm a value system that puts women backstage to "real" action.

Similar to Pat, Andrew equates "hard" science with "real" science. At university, he took a course in earth science to fulfill his degree requirements. Field trips enabled students to gain first hand knowledge about rocks and geomorphology. They learned about climatology and predicting weather patterns. Because he understood the material, however, Andrew thought the course could not have much value. It didn't fall into his notion of science:

Andrew: I didn't feel it was real because we were having fun, [so] it couldn't have the same worth...I don't think my marks were much different from than they were in high school, but it felt like I would go home and explain it to my children and they would understand it. It felt like I wanted to show somebody this knowledge, whereas before I really couldn't tell the chemical makeup of iron. I mean what is it? On the chart, I couldn't tell you...Because I now know how weather systems work, and how Lynn Canyon was developed, it seemed like something I could show someone, could explain and tell them what that is. So yah, university was good but at the same time I felt like I was bailing out because I would really have loved to learn more about biology and anatomy and what have you. I felt that was just way too far.

Lori: It is curious that there is a sense if you do understand it, that there is something wrong with it. It is not quite science.

Andrew: It can't be hard enough then.

Andrew's words highlight the disjunction between the way science is represented and the way it is often experienced in the classroom. Science is purported to be a study of the world; a search for understanding, "for a sense of having found a satisfying explanation of some aspect of reality" (Goldstein & Goldstein, 1978, p. 6). Yet for Andrew, "real" science does not provide an understanding of the world. It is the contrary. His earlier experiences led him to think that if he can understand science, share his science knowledge with others, there is something wrong. Although not his sole representation, he has cultivated an image of science as "hard," decontextualized and beyond reach. It denies a mode of understanding which acknowledges connection. His language suggests that he has internalized a Eurocentric world view that science is something apart from human experience.

Britzman writes that teaching is "a dialogic relationship characterized by mutual dependency, social interaction and engagement and attention to the multiple exigencies of the unknown and the unknowable." (1991, p. 237) The same kinds of relationships are evidenced in learning science. Gender is one of many elements embedded in our experience which shapes our understanding of scientific knowledge. Gender may operate as an explicit force, or have an indirect impact in the formation and selection of preferred goals, methods and explanations (Fox Keller, 1985). The construction does not take place solely inside the individual, but within the terms for understanding set by pre-existing social relations and

cultural values. As individuals, we negotiate multiple exigencies to develop our own representations of knowledge.

Indeed, Haley's conceptions of science and scientific knowledge reflect her own struggles in the field. In continuation with her lived experiences, the image of science as powerful and exclusionary comes through. At the same time, she sees science as part of everyday life, a way that children set about exploring and defining their world. These different levels reflect a hierarchy within science, however. They are distinct, with one level holding greater power than the other. University lies in the middle, representing the doorway from one level to the other. Like the upper level, however, it is not value-free. Haley's words paint a vivid picture.

When I think of science, I think of people like astronauts, people working for pharmaceutical companies in big labs, people working in hospitals, designing equipment and things for hospital use. I think of laboratories that are all closed in and are very secretive where people are doing experiments and research on specifics for the enhancement of technology and quality of life, that sort of thing. But I think of it as a field or profession that is over "there" with a big blank wall separating it from the rest of humanity. Then I think of the next level of science, which is the study of science at university. When I think of science at the university level, and again it is from my own personal experience, I think of it as a filtering system where a whole bunch of people are wanting to get into the world of science behind that big wall over there, where they filter who is going to make it and who is not. This has a lot to do with how smart you are, what sex you are, how strong you are and on your determination to run the gauntlet that is required to jump the hoops that are required in order to be allowed to get behind that wall and be a real professional scientist. And the level down from that is what I would say is real science, the science that goes on in the schools; where kids learn to work with things, fiddle with things, discover things, make discoveries, solve problems. That is what I think of as real science, the basic science-like activities that real ordinary people do in their everyday lives as a means to learn something new.

As a result of her experience with gender, Haley has developed a representation of professional science as "secretive" and exclusionary. It is imbued with power. Students must be prepared to "run a gauntlet" if they are to gain access to this domain. But even then, they may be excluded on the basis of gender or other factors beyond their control. On the other hand, Haley believes "real" science exists in everyday events. She says children's approaches to learning are really a simple and basic form of scientific inquiry. They begin with a problem

theorize about what is happening, and then test it to see if their theory works. Haley's relationship with science is contradictory and complex. It excludes at the same time as providing access. It operates within a hierarchy.

Although representation certainly does not prescribe action, it does suggest a certain orientation to knowledge. Flick (1995, p. 75) quotes Moscovici in stating the goal of representation "is to make something unfamiliar, or unfamiliarity itself, familiar" (1984, p. 24). It is part of the social process of constructing reality, enabling people to make sense of their experiences. Representation also implies a relationship between knowledge and the producers of that knowledge. Open to the shifting nature of individual experience, it renders people capable of working out a critical position to varying degrees.

Over the course of her studies, Kate developed a representation of science as remote, detached and objective. Her discourse also links science to a particular concept of masculinity. She described a recent activity in which she and her peers from PDP took a group of children to Science World. On the wall were pictures of animals and forms based on geometrical shapes. The children were asked to manipulate shapes (triangles, squares, hexagons, etc) to make similar pictures. Kate did this activity with two children, a boy and girl of similar ages. She said the boy had no difficulty with the activity. He completed four pictures in the same time as the girl was stuck on one.

She just couldn't understand how that fit to make that, she couldn't make the connection from there to there. But if she had been give more time, and had done it week after week in her center time whatever. I think she just needed more time and more practice...think they say that women have a more difficult time with spatial concepts than men because the way the brain is set up. Our brains are a little different. If that is a proven fact, that is OK but maybe we have to teach girls in a little different way so that they do get the concepts a little more clearly.

As she negotiates her identity as a teacher, Kate's understanding of her students' difficulties are overshadowed by her own school experiences. Her physics teacher's comments echo here. "*He used to say it in class...things like "now the girls are going to have a more difficult time grasping this concept."* Implicit in her approach is the rhetoric she has

heard. She has developed a representation of science ability that is dictated by gender. However, Kate is not condemned to replicate her educational past. She seeks to create a learning environment that acknowledges and adjusts to different ways of learning. Rather than excluding participants, she suggests “*maybe we have to teach girls in a little different way so that they do get the concepts a little more clearly.*” She suggests there is a gender difference in ability, but desires to find a way to accommodate different ways of learning.

As a teacher, Haley also realized how the past seeks replications of social roles. Reflective of her lived experience, she had internalized teaching strategies that were discriminatory. She taught the way she had learned, and unwittingly treated the boys preferentially. She encouraged the boys to partake in hands-on activities, while the girls hung back and watched. The realization that she participated in their silencing distressed her.

During my first year of teaching, I remember catching myself doing to girls exactly what had been done to me. It was as though there are certain ways of doing things, there are certain ways of teaching and girls aren't part of this process.

Haley's words confirm what other studies have shown, that school science takes place in a gendered social context (Guzzetti & Williams, 1996; McLaren & Gaskell, 1995). Despite the ideology of gender neutrality, it remains highly gendered in practice. Haley, herself a victim of sexism, realized that she was perpetuating discriminatory practices. What made her cognizant of her behavior was not reflection or examination of her practice, however. The girls brought to class their own expectations that were gendered, divisive and indicative of social relations.

Another funny thing I caught my first year of teaching...was that the girls automatically stood back and let the boys take charge. If you set up a discovery hands-on kind of lesson, the boys would jump in and take over and the girls would step back and watch the boys do it all. And I think that is probably what made me catch myself. I could have probably gone on for years setting things up and not noticing that I was setting it up for the boys if it hadn't been so blatantly the boys here, and the girls lined up watching.

As Guzzetti and Williams (1996) have written, social pressure requires that females be good listeners; “their verbal participation is seen as less important than their ability to be

attentive to others” (p. 6). Thus conditions for change are complex. Despite a teacher’s intentions to be gender fair, our culture -both inside and out of the school classroom- may subvert these attempts. Unequal access to talk/discourse/power in school mimics realities existent within a larger context.

On connections and understanding

While the preceding sections are concerned with the structure of science experience, this section asks whether change is possible. Can feminist research lead to a more informed and inclusive science curriculum? Are these approaches less likely to sever experience from knowledge, and allow students greater claim to knowledge? Can science and science teaching accommodate a diversity of approaches rather than one intellectual tradition?

In her examination of science, Harding (1991) delineated standpoint theory as an important strand contributing to a feminist epistemology of science. Proponents of this theory argue that knowledge and our beliefs are socially situated. Thus, in a gender-stratified society, differences in the social experiences of men and women render different understandings and ways of interpreting events. These in turn give rise to different standpoints (Harding, 1986, 1991; Roychoudhury, Tippins & Nichols, 1995). Because women’s lives and experiences have been neglected within scientific research, however, their views, and hence standpoints, are largely absent from science. It is thus not surprising that for many women scientific knowledge is incompatible with their understandings. It is foreign to their life experiences and ways of coming to know.

Proponents of feminist standpoint theory argue for the need to situate research within women’s lives. As a result of different lived experiences, women can bring different insights, skills, understanding as well as knowledge to scientific endeavors. Without a more inclusive approach to science, standpoint theorists believe the generation of scientific knowledge will remain alien to many women. Traditional science practice demands a commitment to beliefs, and conceptual schemes, which are outside many women’s experience. From a surface level

where curricula and teaching practices emphasize masculine interests, to a deeper epistemological level where science is proclaimed as objective, value-free and apolitical, science acknowledges the contributions from only one gender (Fox Keller, 1985; Harding, 1986, 1991; Rosser, 1989). But knowledge, in any field, is incomplete when derived from a single perspective.

A number of recommendations about science teaching have emerged from feminist research including: situating science in the interests and personal experiences of students; providing a cooperative, less competitive environment; and increasing project time to foster a connection between students and the subject of their study (Rosser, 1990). Indeed, the importance of making connections to real life experiences recurred in many of the participants' stories. Participants cited relevance and the need to see science as part of their own lives, before they could construct meaning of everyday events in terms of science.

As a young child, connection formed a vital part of Nancy's relationship with science. Her elementary school classroom was filled with animals; she played, fed and took care of them. Students grew vegetables from seeds and ate what they harvested. She did not view science as an abstract entity divorced from everyday experience. It reflected the interests, as well as the realities, of the children's lives. She described her classroom in detail.

We had a big science center, and the one thing I really enjoyed about it was that we had a lot of animals. We had guinea pigs, fish, salamanders, newts and turtles, we had birds, we had chickens, we had rabbits....I remember sitting in front of the salamander tank just watching them. I could just sit there and observe. I was able to feed the animals and pet them, collect the eggs from chickens. It may have seemed that we were running a farm, but it did hone up to science.

By integrating the children's lives into the classroom, Nancy felt this experience made her think about science in larger terms. Science was embedded in the context of everyday life. Its presence influenced her, but she also had the power to shape it. Humankind was not separate from the rest of the natural world, but part of a complex interrelationship. Her understanding of science was based on interaction.

I think, too, the way it was set up in open area school with all the animals, it taught the child responsibility about the caring and feeding of the animals. Even environmentally. If it lived in the wild, how would you protect it, how would you feed it. The same thing with growing our own food. We grew snow peas and got to eat them afterwards.

Claire also described her science experiences in terms of personal connection. She recalls high school physics as having little meaning for her. She viewed the lab work and experiments as uninteresting, and not belonging to her everyday experiences. *“With physics, all I remember is the little cars, and ramming them against the wall and measuring distance. That is all that really stayed in my mind and yet I took a year of physics.”*

In contrast, Claire valued greatly what she learned in biology class. In addition to regular lab work, the teacher taught biology around situations and landscapes that were familiar to students. The Vancouver Aquarium served as the focal point for a study of marine biology. There were trips to the planetarium, medical laboratories and botanical gardens. In doing so, the teacher helped cultivate a link between scientific endeavors and life experiences of his students. The practical context gave the students a framework upon which they could anchor their knowledge.

Having personal involvement is integral to Claire’s understanding of science. She needs to touch, feel, explore, manipulate. Real science is embedded in personal activities. She recalled taking an outdoor education course, in which the student teachers were paired with children in schools. Through this class, Claire reclaimed what she loved about science: the exploring, playing, discovering and having *“fun.”* She became part of a community, learning with her students. Claire looked to experience as providing insight into practice. Interaction was critical to meaningful discourse.

We took classes of kids on camping trips. We took them to the bird sanctuary and on day field trips...We did all these trips and it brought back what I had done in university. It gave me the chance to get into the community and learn and be a part of things rather than locked away.

Anna also identified field trips as providing a vital connection to her science learning. Indeed, she said her experiences here have carried over into her teaching life. Anna described one field trip in particular.

We had a biology student teacher who took us to the beach and we did some seashore ecology. That was excellent and has stood with me for a long time. I use what I learned from that student teacher with my own kids when we are down at the beach. So I think those kinds of events are really important.

Kate also needed personal connections to further her science understanding, and floundered when she found none. Physics proved particularly enigmatic to her. Presented with principles and concepts, she was unable to construct ideas or knowledge that made sense to her.

I remember having problems [in physics]...and I think it is because the underlying concepts aren't built in an individual way you can relate it to. All these numbers and symbols don't mean a whole lot. Although we did experiments and saw what was happening, I had a really hard time making the connection. Problem solving was my real enigma. And in every exam we took, there were always word problems. And so what I would do is try and get through the numbers part and then I would get to the problem solving, and I would just freeze. I couldn't get beyond the words. What do they really want? I don't see it.

While hands-on experience provided the gateway to connection for many participants, it did not provide Kate with the understanding that she sought. Experiments and laboratory work did not make the endeavor meaningful, nor give her greater insight into scientific concepts. Put in psychologists' jargon, she was unable to "transfer" hands-on activity into a coherent system of ideas about science.

I didn't really enjoy science experiments that much. Didn't really care about that chemical reacting with that chemical. So big deal, it makes a big brown spot or big poofy thing. It doesn't tie into anything.

Kate's words offer considerable insight. Current approaches to science emphasize hands-on activities and practical work, but experience alone may not be enough. Students like Kate require context. They wish to know how science interrelates to other subjects and personal experience. Applicability to real life imparts greater understanding and gives science meaning. However, students may not always be able to make the link between science events

and real life themselves. It may require the guidance of a teacher or more expert peer. In our zeal to adopt constructivism as pedagogy, requiring students to take an active role in the learning process, the importance of “teaching” may be neglected. Berrill and De’Bell (1995) address this point: “In our enthusiasm for student construction of meaning, we may easily overlook the vital teaching role in helping students become familiar with new concepts and equipment” (p. 31). Driver (1983) holds a similar view:

The slogan “I do and I understand” is commonly used in support of practical work in science teaching. We have classrooms where activity plays a central part. . . To what end? In many classrooms, I suspect, “I do and I am even more confused.” (p. 9)

Indeed, Kate came to an understanding of statistics only after her professor showed a link between her experiences and conceptual themes in the course. She failed her first university statistics course, but did well her second time through when the professor made connections to context explicit. *“She taught concepts so that it was easier to grasp. . . She spent a good week with us saying, this is why we need to learn stats. This is how it applies to psychology. This is why it is important. With that, you were able to put connections together. . . Now, I understand why we had to have it.”*

Andrew’s earliest memories portrayed an image of science as something that he could not touch. Textbook knowledge and memorization dominated the curricula and teaching approach. There were pictures on walls, facts to be memorized and “*regurgitated*,” exams to pass, but science held little personal meaning.

In contrast to many of the other participants, however, Andrew saw physics as something he could use. His teacher stressed relevancy, teaching theories and concepts through familiar events. *“If we were playing pool, for example, we could think of how this ball would react if you hit it on certain angles.”* For Andrew, physics was validated by personal experience. It enabled him to interpret and make sense of everyday experiences using theoretical ideas.

Taken from a feminist perspective, situating science in lived experience means that students - male and female alike- will be given the opportunity to ground their science learning within their own experience. Fox Keller (1985) cautions against establishing a dualistic (male versus female) view of science, but instead developing a multifaceted, more holistic approach toward understanding the world. Thus in respecting and inviting difference, feminist standpoint theorists maintain that science learning should accommodate a variety of approaches. Roychoudhury, Tippins and Nichols (1995) suggest one way to achieve this is to provide flexibility in assignments rather than making students do all the same thing. They also suggest science courses should make provisions for both individual and cooperative learning opportunities. "Both men and women need to experience canonical ways as well as connected ways of doing science" (1995, p. 902). Further, students should be given the option to choose in hope that this might engender empowerment of knowledge as well as ownership of learning.

Indeed, one of the factors that drew Eric to science was the autonomy that it gave him. He spoke of high school science, in particular biology, as being different from his other courses. He valued the opportunity it provided for individual exploration. This autonomy enabled him to take ownership of his learning.

The memories I have of science is that the teacher made it enjoyable. We had a lot of individual investigation. You could work on your own, there was a lot of autonomy there. Kids could investigate and find things out for themselves, rather than being dictated to or having things just shoved down your throat. I liked that about science, it could be more fun that way.

Eric's comments indicate that he prefers to work individually and felt encouraged by his science teacher to do so. Obviously, he would not benefit from a situation that required him to participate in group projects with no options for working alone.

Although feminist standpoint theory refers to the differing standpoints men and women may hold, it does not imply that *all* women share the same standpoint. Obviously women will have diverse, as well as similar standpoints, as a result of their varied experiences and different positions in race, class, culture and ability. No woman constitutes a pattern.

Postmodern theorists have also brought to the fore the shifting nature of individual experience, replacing the notion of a single identity with the idea of “multiple” selves (Alcoff, 1988). Within any learning situation, then, an individual may have different needs at the same or different times.

Kate, for example, emphasized the importance of making connections and situating science learning in her personal experience. On the other hand, she said she did not always learn best in a group situation. She greatly preferred to explore a new concept or activity by herself, before discussing it with others. She commented:

I get really anxious when I am forced to work in a group and I am not ready to. I can work in a group but I need to do my own bit first. Let me explore it, and feel it, and touch it, and think it and analyze it first. Then OK, I can get together with another person and share my ideas and work on a group project. But I always got really apprehensive in school when we were given the idea, given the lesson and then thrown into a group.

Although considerable research recommends collaborative work as creating a classroom environment more friendly to women, obviously for Kate this is not always the best approach. She requires connection to make sense of her learning, but it does not have to take place within a group context. Pat, on the other hand, feels like she missed out a great deal by not having the opportunity to share ideas and discuss science concepts with others. For Pat, interaction with her peers fostered connection, understanding and construction of knowledge. She considers this as central to her learning even now. Recall, again, her words:

I don't think we were given enough opportunity to work together. It was such a competitive thing. Like you had to pass this exam...So I lost out on that whole aspect of my education because I don't think high schools cater to the female mind or a girl's way of learning.

Working collaboratively has been cited by many researchers as a facilitator of learning particularly for females (Belenky *et al.*, 1986; Rosser, 1990; Roychoudhury *et al.*, 1995; Willis, 1995). It provides a supportive environment where girls and women may feel freer to participate, express their ideas as well as gain interest and confidence in their science abilities. It may also help disrupt the power imbalance in which boys dominate classroom discussions, or the instructor is viewed as the absolute authority. Yet as Roychoudhury *et al.* have written,

one approach will never provide equal access for all students. The diversity of individual experience, as well as the intersecting differences of class, race and gender, defy a single approach to any educational endeavor.

In looking to a feminist epistemology of science, then, theorists caution against adopting a feminist method which claims one particular worldview. As Fox Keller (1985) argues rather than making a hasty retreat to a “different science” we need to look for a “difference in science.” Longino (1989) furthers this point when she cautions against replacing one absolutism (feminist versus androcentric) for another. Instead, she suggests “we focus on science as practice rather than content, as process rather than product; hence not on feminist science, but on doing science as a feminist” (p. 47). In the science classroom, this means fostering educational experiences that invite diversity in interest and practice. The different voices of girls, as well as boys, need to be heard. Strategies which integrate personal experience into learning, enabling students to reflect upon the meaning of that experience, may be one way to approach this goal. Standpoint theorists have drawn our attention to the need to listen to others. The classroom is a place to begin.

On scientific representations

Throughout this chapter, I have discussed how experience informs, shapes and leads to an individual’s representation of science. The assumption is that students do not automatically accept educational authority. Rather, scientific knowledge is mediated, refuted, constructed and reconstructed within the discourse and context of schooling. Britzman makes the point when she writes: “This approach to school knowledge recognizes the contexts in which knowledge is produced and interpreted and attends to the subjective investments of those who produce it” (1991, p. 43). Ultimately, though, an individual’s representation of science has implications for the way she thinks about science and her ability to partake in this knowledge.

The concept of representation is very broad. Jodelet (1989) uses the term to denote a complex phenomenon which comprises many elements such as beliefs, values, postures, opinions and images. Flick's (1995) notion of representation is based on the work of Moscovici, who emphasized how knowledge arising from collective (or social) representation is used in both social and individual construction of reality and meaning. Desautels (1995) stated that representation embodies a relation between "official" and "unofficial" knowledge that can be inhibitory or emancipatory to varying degrees. Abric (1987) describes it this way:

A representation is the process and the product of a mental reality through which an individual or a group reconstruct and assign a specific meaning to the reality they are confronted to. (E-mail correspondence with Desautels, Dec., 1995)

In this sense, representation is part of the process of constructing reality through social interaction, social expectations and socially shared knowledge.

Although not looking at representation per se, a number of researchers have examined teachers' beliefs and worldviews about the nature of science (Aguirre *et al.* 1990; Bloom 1989; Munby 1984; Proper *et al.* 1987). Similar to these studies, I found participants responses to the question "What does science mean to you?" fell into two overlapping categories. All nine participants defined science as a study of the world (a body of factual knowledge), together with a process (the methods of science and scientific inquiry). For many, the feature that distinguished science from other ways of understanding was the experimental test. It implied an authority, an agreed upon way of understanding, which gave scientific knowledge greater validity. Eric put it this way:

The way people must have learned about science, the reason it probably progressed kind of slowly is because it takes a great deal of rigor and trial and error and a lot of recording of stuff. You have to be very careful. I can't see the discovery of the microchip or transistor or something just coming through trial and error. It took millions and millions of different individual discoveries to be able to put together that one thing, whereas studying English or reading a book or drama it is a totally different way of learning something. It is a lot more amorphous, vague-type, artistic subject, there is a lot of creativity involved there. There is creativity involved in science but it seems like it is more, follows a fixed pattern of going about things.

Already in this chapter are woven representations of science with respect to beliefs, gender and connections. However, the question, “Do you see a difference between scientific knowledge and everyday knowledge,” evoked a particularly compelling critique. From their positions as students and teachers, the participants’ responses told much about their relationship to science. Their representations served to give their experiences a certain shape. Participants constructed representations that portrayed science as relevant, fair and accessible as well as inequitable, privileged, and detached. Their words provide detailed evidence of diverse, complex, and often contradictory, processes at work. My methods here diverge from preceding analyses, however, in that the participant’s words are removed from context. The following responses were not included in the main narratives in an attempt to look at meanings more generally. Because the participants speak to a theme based on a specific question, I thought their words could stand outside their stories.

Kate’s response dramatically illustrates the exclusion that she felt from science. As a result of her high school experience, she has established a view of science as structured and remote. She sees little room for subjectivity, with personal connection rigorously excluded. When describing the differences between scientific knowledge and everyday knowledge, her analogy to cooking seems particularly apt.

A recipe can be viewed as science where you do it exactly. You have the measurements and if we did it 10 times the exact same way, our product would be fairly similar. But we could vary it. We could put a dash of this, or a dash of that. Or say I don’t like marmalade, and it calls for marmalade, I could put raspberry in because that is what I like. So it is going to come out a little bit different. That to me is everyday knowledge. And following the recipe is more like science.

Over the course of her studies, Kate has constructed a representation of scientific knowledge as rigid. It is a something to be followed exactly, producing similar results each time. Ordinary knowledge, on the other hand, takes into account variability. It makes room for individual differences and personal preference. Ordinary knowledge implies a personal relationship to knowledge whereas scientific knowledge transcends this. For Kate, science is

mechanical. Her experience with science has been so constricted, that she can no longer conceive of science as a subject for imagination.

Anna, in contrast, sees very little difference between ordinary knowledge and scientific knowledge. Both represent an interpretation, and understanding of our world. Science is nearly synonymous with all knowledge, rather than representing the only kind of knowledge respectfully attained. For Anna, the difference lies only in its language.

Science may have different vocabulary, but I don't know if it is different thinking...a scientist...doesn't describe things in ordinary language but uses scientific language. So that is part of the difference there. But underneath it all, I think knowledge is similar. I think they are all connected - knowledge in general. The vocabulary and the language associated with science determines the difference.

Although hesitant about teaching science and lacking confidence in her subject knowledge, Pat also feels that most scientific knowledge is no different from other kinds of knowledge. Science, like other disciplines, requires a foundation or a grounding in a particular subject matter. However, she feels that its real worth lies in its relevance and relationship to other aspects of her life.

I think science knowledge is something you need to be able to use. What is the point of learning something, if (a) you don't use it or (b) it doesn't make sense to you, or (c) is totally useless. Why learn useless information that you are not going to need in every day broad spectrum life span. Somewhere down the road you may need this information that you learned back here. And that is what science is to me. Not some very finite pieces of knowledge that are so removed from everyday life that it is almost like I am waving a flag and saying look how smart I am because I know this and you don't.

Andrew left high school with an image of science as something he could not touch, but later negotiated new representations. He now envisions science as an exploration, “*the chance to explore your world or any aspect of it.*” It also means communication. Talking, sharing, and testing ideas are what make science come alive for Andrew. He believes science belongs in a social context. It is interactive. Science is not separate from people, but depends on our worlds, histories and representations.

Science means talking, communicating so that you may come up with a theory, and I may come with a theory, and a third person comes in and has a theory. They are all a little different, but we can talk and we can clarify - without

communication we can't. If you keep that knowledge to yourself it is not useful. So science to me is something that needs to be discussed and needs to be reasoned out so everyone knows and everyone understands and gains more knowledge, and develops some real understandings with having their own little theories or little bits of knowledge.

Ideas are shaped through our interactions with others. Different interpretations give rise to new knowledge. For Andrew, scientific knowledge is ever-changing. Theories are constructed by people and thus open to change. New phenomena may be discovered, new observations made, or else people may form different interpretations of similar events. Alternate frameworks develop and theories are discarded over time. Unlike other types of knowledge, Andrew has constructed a representation of science as something that is never static.

I think the thing with science knowledge is that we look at textbooks and we see a theory, and a theory can be written through a whole book but it is a theory. And I think a lot of times we forget that. Take for example, [in history] the Fathers of Confederation, it is already written down and that doesn't change. Some of that knowledge may not vary. But when it comes to science, things change and it could affect theories and it could affect our understandings and we may discover something later on that changes. So I see science as not being constant. 100 years from now it maybe a different theory out there relating to something we talked about in class. But we started the ball rolling somehow. Whereas if you get into certain areas, then there are more definites.

The difference between history and science lies in the nature of their respective contents, as well as the certainty of that knowledge. Ironically, Andrew now looks upon dates and names of history as factual; scientific theories are just interpretations.

Claire, on the other hand, is drawn to science because of its promise of certainty. For Claire, the difference between ordinary knowledge and scientific knowledge lies in the scientific method. Although she recognizes that it is not infallible, she feels that scientific methodology provides a more exact way of acquiring knowledge. Ordinary knowledge is not rigorous. It is subject to individual interpretation. She feels that scientific knowledge, through mathematics and experimentation, can transcend this.

I respect the way they [scientists] come up with their process and of usually of finding their answers, whereas with some things, other forms of knowledge, I kind of doubt where they have gotten their ideas from - they have just made

them up or whatever - whereas with science, I usually hope they have done some kind of testing or evaluation to find their answers.

Claire takes comfort in the traditions of scientific methodology and research. Science has an order to it. Its development is marked by an accumulation of individual discoveries and inventions. For Claire, scientific knowledge is rational and more objective than other kinds of knowledge. It is not influenced by opinion, but based on a precise way of gathering data. Embedded in her words is a representation of science as something quite distinct from the social, cultural or historical conditions that surround it. Science is a thing in itself, existing independently of us.

Susan's representation of scientific knowledge encompasses the tensions of her educational experience. When comparing it to everyday knowledge or knowledge other than science, she confers upon it a privileged status. The image of science as objective, rule-bound and exact comes through. At the same time, she sees science as subject to change.

Scientific knowledge is something that is always growing and it is always changing, and there will always be new things to learn. It will never be a complete body of knowledge that you can close the book on, say this is all there is to learn. Mind you, I wouldn't say that with other knowledge either. But it is different. I think it is different partly because it is like the old thing where you have a hypothesis and try it out, and it doesn't work, you start from scratch. And if it does work, you do it again to make sure it is going to work every time whereas in other knowledge, let's say, if you were doing a novel study it's purely your opinion, maybe. It is not something that is right or wrong. And a lot of science, I think it can be right or wrong. It is not all that way because it is not all clear cut, but if there is a law of science it is going to be the same every time. The same thing is going to happen, whereas if somebody is interpreting a poem they are not going to interpret it the same way every time and it doesn't need to be interpreted the same way every time, so in that way I would say that it is different.

Unlike poetry, which is open to individual interpretation, or a novel that can elicit different opinions, Susan sees science as defined by its laws. According to Susan, "a law of science is going to be the same every time." Science provides a reality, a sense of sameness, which is universal and true. It is right or wrong, transcending context and socio-historical conditions. But at the same time, Susan recognizes that not all of science is absolute. New discoveries can lead to new understandings of the world such that "what is true today may not

be true in a few hundred years.” She sums up this dilemma when she said, “Science is a search for some universal truths, but not all universal truths.”

In reflecting on her experiences, Nancy said that seeing, feeling, touching and doing are integral to her understanding of science and scientific concepts. She likes to try out new things, to manipulate, to explore with her hands and senses objects and concepts related to the subject matter. The knowledge she constructs from these lived experiences is more meaningful to her. Experience frames her understanding of science, and is what distinguishes scientific knowledge from other types of knowledge.

I think the hands-on experience is really integral to scientific knowledge. You have to do the experiments, see how it is done, to really be in it, whereas with other knowledge, I think it is important, but it is important to a lesser degree. A lot of things with ordinary knowledge, we can read about it and understand it...In English, if you want to learn a play, it is reading the play, whereas if in science if you want to learn about how to make match heads, for example, you have to go in there and physically mix the formulas. I think there is a lot more hands-on activity to gain scientific knowledge than there is to gain other knowledge. I am not saying there isn't, but just to lesser degree.

In looking at knowledge, an emerging literature surrounds the notion of representation and its influence in everyday life (Flick, 1995; Jodelet, 1989; Moscovici, 1984). From these works, a series of assumptions can be made, one being that representations imply a relationship between knowledge and the producer of that knowledge that renders them capable of participating in that knowledge to varying degrees. It seems that through representations, an individual will interpret discourses, issues and knowledge connected to that representation. This may, in turn, influence action or practice.

Teachers whose task it is to teach science in elementary school are faced with a formidable task if they seek to present a more holistic view of science and scientific theories. We must then ask how do their own representations of science affect the way they teach science? How do such representations manifest themselves in the classroom, and do they affect students' learning? What do these representations mean to their own life and ability to partake in issues related to science in society?

The findings from this study emphasize the importance of interaction, experience and context in the construction of knowledge and scientific representations. Knowledge, as seen from this perspective, is not separate from the knower but situated in the lived experience. Its construction is a social process, mediated through the understandings and representations embedded in our language, customs and institutions. As individuals, we negotiate between multiple tensions to develop our own representations of science. Yet within our representations lies complexity. A representation may suggest a personal orientation to knowledge, but in no way does it prescribe action. Representations are developed, interpreted and acted upon in numerous and contradictory ways.

Over time, for example, Andrew forged a new relationship with science. He abandoned his adolescent image of science as something remote and inaccessible for one that stressed communication, dialogue and social interaction. Yet despite his ability to intellectually engage in science, he still remained fearful of it. His discourse did not automatically translate into action.

It is interesting. I think I still perceive that I could get it wrong and there may be a wrong answer. I think that itsbecause I have to overcome my own feeling that I am not a boy in grade 8 in physics class or chemistry, that I will get it wrong. So I feel like if I don't push myself I will fall back into that trap. If we are talking about something in class and it is science related...I feel that there is a wrong answer so I will be quiet and not say anything.

Claire's words also reflect the contradictions that are often inherent in our thoughts, beliefs, actions. She sees scientific knowledge as less arbitrary than other forms of knowledge. Its alleged objectivity gives it more value. Yet her classroom practice reflects a far more reflexive approach. She is committed to helping her students learn the science curriculum, but wants her students to investigate something that is meaningful to them. She recognizes there may be no right answer, and that a scientific investigation may only lead to further exploration. She places more value on their confidence about being able to learn, that what they learn. But the scientific method dictates the way their explorations are conducted. It is paramount to getting at "*the truth.*" Her students' research may be open-ended then, but

certain rules guide the work. It is these rules that make their discoveries more valid, more real, more true. In looking over the transcript from our conversation, Claire was the first to recognize and draw attention to these contradictions in herself. She said they reflect a struggle between her past (what she was taught) and what she has come to know as a teacher.

Representation, like learning, implies a relationship to knowledge that is rarely static. It involves a constant shifting and negotiation between what is lived, perceived, and valued. It reflects a struggle between internal and outside voices, as one develops a relationship to knowledge that may shape our capacity to participate in that knowledge. Situated in the discourse and context of our experience, the process is dialogic in nature. Britzman (1991), in her analysis of teacher education, discusses the dynamics involved in individualizing the social process of teaching. Her discussions of the dialogic seem applicable to the process of constructing representations as well.

A concern with the dialogic..allows us to move beyond the conversation itself to attend to the conditions of its production: the words we choose, the way we reinspect them with past and personal meanings, the style used to position meanings, and the mix of intentions that are inevitable when speakers interact...A dialogic understanding, then, acknowledges this multiplicity: the ways talk, practice and understanding are mediated by difference, history, point of view, and the polyphony of voices possessed by those immediately involved and borrowed from those who become present through language. (p. 239)

Chapter 6

Conclusions

The findings from this study emphasize three important features of learning science: the role of belief in science, the contextual nature of learning, and the importance of connecting science to lived experience. But the question, what is the structure of science experience, is not easily answered from these narratives. The teachers' discourse captures the complexity involved in the construction of scientific knowledge. We learn that science can silence. It also has the potential to transform, giving individuals insight and access to new understandings. Between these two extremes, lies a multiplicity of meanings. The participants' ideas and representations are striking in their diversity. Each story is unique.

Nonetheless, this study brings to bear the importance of context and lived experience in learning science. Both society in general and school in particular play critical roles in shaping students' views about the nature of scientific knowledge. We do not acquire our knowledge neutrally. As Britzman (1991) writes, within any given culture there exist multiple realities, "both given and possible that form competing ideologies, discourses, and the discursive practices that are made available because of them" (p. 57). To make sense of these, we search for meanings within our own subjectivities and histories. Learning comes from our ability to critique, mediate, refashion, construct or reconstruct understandings of experience within current practice and knowledge. Experience becomes knowledge and knowledge experience, although this relationship is rarely simple. As Britzman so aptly observes: "meanings shift as experience becomes lived" (p. 217).

The traditional view of science education makes use of a conduit metaphor (Roth & Roychoudhury, 1994). Here learning is conceptualized as the transmission of knowledge from a cultural authority (teacher, curriculum, textbook) to the student. This metaphor is also deeply rooted in the positivist representation of science as authoritative, certain and exact. Indeed, the conduit metaphor accurately describes the experiences of most participants in this

study. With the exception of Eric and Claire, in part, all described their science education a process of memorizing facts and acquiring knowledge developed by others. At the same time, however, the participants took varied routes in interpreting these experiences. Some questioned their relationship with science. Others criticized it. Still others accepted it, enjoyed it and believed what they were told. What they came to know, the representations they developed, were shaped by how they came to know it. Most participants spoke of their own teachers as being instrumental in influencing their attitudes towards science. Yet learning is rarely linear. Contradictions prevail. Eric, for example, holds very traditional views about science despite having the advantage of a more inquiry-based program. He has constructed a representation of science as “objective” and contingent on universal laws. Anna, on the other hand, sees science shaped by the same values, beliefs and commitments as other kinds of knowledge. Yet in comparison to Eric, her science experiences were far more restrictive.

The participants’ narratives evoke as well the complex relations between education and the culture within which it occurs. Affecting learning was not only belief, or the ability to believe, but struggles of gender, class, and race. Despite public discourse on equality, gender remained problematic for many participants in the study. Pat, Claire, Kate and Nancy described school cultures that fostered different science expectations for girls and boys. For Haley, gender defined what she could or could not do. Nancy encountered teachers for whom both gender and ethnicity were divisive. Not only did her school support an environment where “girls do arts, and boys science,” but her science teacher judged his students’ abilities according to race. Recall her words:

Nancy: One teacher there had such a negative attitude about people from ----- Bay. He said if you get an A or B in ---- Bay, here at ----- that means C or a D. So right away, he shot you down, and he was a science teacher. So it was like, hey, I don't want to be in his class if he is going to feel that way towards me. That kind of negative attitude, this time from a teacher, can really affect how you see the subject he is teaching.

Lori: I wonder why he held a bias towards students from your town?

Nancy: A lot of that was because the town I lived in, half of it was a First Nations reserve. And there weren't a lot [of First Nations students] who actually made it through Grade 12. I think he was just thinking, oh they are going to drop out right away, they shouldn't even coming to school if they are going to drop out. That type of mentality was really something you had fight against.

I did not ask about economic background, nor did the participants frame their science experiences within those terms. Yet Pat clearly hinted at class when she remarked, “*Being East End kids, I guess we had a reputation of being a tough school...We weren't encouraged to inquiry about anything.*” Even profession led to discrimination for some participants. Claire encountered a disdain for the teaching profession when taking biology at the college level. She was told by her peers that if she was to do well, she must remain silent about being in the education program. Andrew thought his university science course lacked credibility because it attracted teachers. “*I took the earth science group, as a lot of teachers did...because we were all afraid of science....There were a lot of people who said oh, those are the teachers that are going to do that. It can't be real.*” Obviously, discrimination within school science and our science culture takes many different forms.

Constructivism has evolved as an alternate approach to science education and learning. At the heart of this epistemology lies the belief that “knowledge does not reflect an ‘objective’ ontological reality, but exclusively an ordering and organization of a world constituted by our experience” (von Glasersfeld, 1984, p. 24). Teachers, like students, bring ideas to science which are derived from their own experience. These influence the meanings they construct, as well as the nature of further exploration. In a constructivist environment, then, scientific knowledge is not seen as absolute truth but tentative and exploratory in nature. Students are asked to draw upon their own understandings, experiences and interactions with others to make sense of a scientific phenomenon (Wideen *et al.*, 1992).

But while a constructivist approach typifies what is considered to be good science teaching, it does not challenge many of the underlying policies that sustain current science culture (Haggerty, 1995). It emphasizes social construction of knowledge, but does little to

change internalized attitudes or beliefs about science which arise from social conditioning. As seen from the preceding discussion, our classrooms still reflect a science culture that discriminates in many different ways. Unequal access to knowledge continues to privilege certain students over others. Dunne and Johnston (1992) argue that change requires we make problematic the structures underlying our knowledge and beliefs:

Although the social construction of knowledge is recognized, the structures which organize this knowledge are not problematized. Consequently, the categories of 'girl' and 'boy' are assumed to represent difference and this is left unquestioned. The influence of the social environment is seen to mediate the realization of this assumed difference....

In this critique of gender research in science and mathematics education we have established that an acceptance of the social construction of knowledge is not a sufficient condition. What is needed is a way of explicitly addressing the political processes which structure the organization of this knowledge. (p. 520)

Are there any alternatives? What are the implications for teacher development and educational practice in science? Haggerty (1995) argued the challenge for those involved in teacher education is two-fold. First, educators and teachers need to become aware of the power relations involved in science and science teaching. Secondly, it is important to promote strategies for science teaching that make science more hospitable to females and different standpoints.

Obviously, many new teachers come to university already apprehensive about science. If this study is any indication, high school appears to be the time when students are most often estranged from science. Those involved in teaching science methods courses, or science for non-science majors, need to be aware of the anxiety beginning teachers may have about science and look to approaches that will foster interest and lessen their fear. Findings from this study suggest that making connections, embedding science in everyday activities, and promoting interaction with peers help make science more accessible to female as well as male students. Others have shown that giving students the choice to pursue projects based on personal interest, either individually or through group work, may also engender greater participation (Rosser 1990; Roychoudhury & Tippins, 1995). These strategies imply a

flexibility in pedagogic approach in accordance with a feminist perspective. On a more theoretical level, educators need to help students deconstruct the myth that science is a search for universal truth, but is instead a pursuit for understanding. Too often theories are misrepresented as facts, their acceptance becoming a matter of faith.

Critiquing the power relations involved in science requires that beginning teachers examine their own attitudes about science. As Dunne and Johnston (1992) argued, simply exposing students to a constructivist epistemology (and to which I would add, feminist standpoint) is not sufficient to bring about change. Both women and men need to recognize the processes by which patterns of participation in science are organized, produced and made normal. Perhaps time should be given in science methods courses to discuss the historical and social issues surrounding science. By understanding that science is fashioned by our social, political and cultural environments, beginning teachers may be able to gain a more critical perspective. Teachers also need the opportunity to examine their own experiences, and how these have shaped their beliefs and representations of science. So far, we have not been very successful in changing the status of elementary science education. Perhaps the potential for transformation lies in making our stories explicit and exploring their ramifications, ambiguities and insights.

Concluding thoughts

Although academic work requires that we seek conclusions, I feel this does disservice to the stories that I was told. Concurring with Alcoff (1991), Clifford (1988) and others, I recognize that these stories are not objective representations, but narratives told from my positioning. The writing of others' lives is hardly neutral and I cannot escape the significance of this. Still I return to the individual stories to find the meaning of this thesis. Through words, images and details, the teachers' stories capture the complexities of current science culture. The voice of each participant provides insight into the dynamics at work in a science classroom. Without context, potency, depth and real understanding are lost. Research requires

that we theorize, interpret and reflect on what we read, hear and see in order to construct new knowledge. Indeed, I have gained many new understandings as I grappled with this process. Listening to the participants made me watch for new things. The research became an interaction, a dialogic of experience and interpretation. But to make sense of a new framework, we must understand the story in which it is embedded. Here, we find both authorship and authority. The participants' stories are vivid, their words poignant and voices passionate. And from the passion comes the lasting impressions of this work, leaving behind the theories and labels which so often obscure meaning. Yet I recognize that the story is a starting point, not an endpoint. It is a piece that goes into the text. It seems appropriate, then, that in ending I go to where the work began. Although her story is still evolving, Susan's words linger in my mind.

Kids, especially in the elementary grades...really enjoy the science experiments especially if they are not labeled as science. The label kind of turns them off sometimes, whereas if you study living objects and study plant growth or something and don't label it as being science, the kids find it interesting and really enjoy it and learning about that kind of thing. For me too, sometimes the science label kind of scares me. It is like way out there and I don't understand. I think how can this work and it kind of scares me (Susan, January, 1996).

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