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DISCOVERING:
Students' Meanings for Research

by

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Abstract

The call for science education reforms in the mid-1980s resulted in the implementation of a new Alberta senior high school science curriculum in 1992. The reformed curriculum reflected the call for increased authentic practice in the sciences. Part of my interpretation of this curriculum included a month long field biology research project. The students' scientific understandings while involved in this project have been a source of wonder and curiosity for me. As teacher researcher, I sought to interpret the meanings students held for scientific research as they progressed through their self-directed investigations. In an urban high school two of my Biology 20 classes comprised of a total of fifty-four students were involved in this study. Using data collected from student questionnaire responses, student field notebooks and recorded conversations my interpretations were developed. Based on these interpretations it appeared that students' understandings of research altered slightly through the course of the field project.

Initially, I interpreted students' meanings for scientific research to include the notion that an independent external world exists which may be methodologically studied. Research was both purposeful and personal, seeking to discover new knowledge through the use of advanced technologies. Over the course of the biology project the students' meanings came to include the sense that research involved dealing with the uncertainty of novelty. Research became dynamic in nature and was seen to be never ending.

It became apparent from students' conversations with me that students were aware school social structures and responded to the research project through their understandings of these structures. The potential benefits desired in the reformers' call for authentic scientific practice may have been subverted to a degree by the students'

acceptance of school social structures and their underlying discourse. As a result, the implementation of authentic science within the parameters of contemporary school discourse is questioned.

I also realized my personal connection to the discourse and structures of schooling. As a result, my initial assumptions and practices in the biology project's implementation had to be reconsidered. This is one of the benefits of teacher research considered in my reflections.

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CHAPTER 1
INTRODUCTION

Socio-educational Context

Competition has been one of the driving forces in capitalist systems. The scope of competition has widened as technologies, particularly those related to computers and telecommunications, have opened the possibilities of a global marketplace. As North American business faltered economically and faced increasingly effective competition with not only European but new Asian counterparts, businesses and indeed governments have scrambled to regain a competitive advantage. The current social and economic context reflects a period of "downsizing" initiated by business and more recently taken by the public sector in an effort to gain this advantage. The business model has increasingly come to dominate decision making processes outside the business sector. The influence of competition therefore has been felt throughout the social system.

Science education, as an integral component of the social system, has been modified in response to international competition several times in the past fifty years. The launch of Sputnik heralded a major reconceptualization of science education through the 1960's. Fueled by fears of Soviet scientific and technological superiority, with its attendant threats to global security, science education was modified in North America. The economic recession of the 1970's highlighted the competitive power of a new and previously ignored marketplace, Asia. The quality of science education was again challenged. Once again the threats of technological superiority by a competitor fueled the curriculum changes. Modifications developed through the late 1980's included the relationships science holds with technology and society. The STS (Science-Technology-Society) form of science education sought to foster personal and social goals for science education. It was hoped that students would gain decision-making skills and the requisite knowledge necessary to be employable and effective citizens in an advanced technological society characterized by the "Information Age." Even as this dissertation was being written and only four years after the most recent Alberta curriculum change (STS) another change to Canadian science education was underway.

The Council of the Ministers of Education had requested the development of a Pan-Canadian Science Framework. This would constitute a national curriculum framework standardizing science education across provincial jurisdictions, in theory providing each Canadian student with a common body of science skills and knowledge. Once again employability and decision-making were the primary interests of the intended change. It was also believed this would ease the problems encountered by students moving across the country. Competition of Canadian business was thought to be enhanced when employees and their families could move easily between jobs located in different provinces. Economies of scale for resource production would also be created in the process. Textbooks and other resources are produced in a competitive marketplace. Resource costs are high due to the high cost of production relative to the low volume of materials required by separate provinces following different curricula. It is hoped that a national framework would encourage publishers to produce resources on a larger scale, decreasing production costs and pass the savings on to the consumer. Curricula are dynamic; shifting as social, political and economic trends require them to change.

The recent changes to curricula had caused concern for science educators. Given these concerns it would be prudent to determine if the changes accomplished that which was intended. Teacher research may assist in this process. By the time this study began in early 1996 I believed that students held varying ideas about science. This belief was based on personal research, modeled after Ledbetter's 1993 study in the United States, which I had conducted in my present high school situation (Rymer, 1995; Rymer and McLennan, 1996) and examination of the literature (Gardiner, 1975; Aikenhead et al., 1989; Blackwood-Malayko, 1992). Some notions that students had presented in these studies appeared very sophisticated, others could be described as quite naive. I did not know what students understood science to be after involvement in the new curriculum. Some preliminary work I had conducted collaboratively with a colleague (Rymer and McLennan, 1996) suggested that a change in the proportion of students holding particular views was occurring, but the types of conceptions had not changed. The data collected had indicated that the changes in students' views were not in the direction desired by the curriculum change.

School science activities have tended to be disconnected and decontextualized from the activities of scientific communities. As a result they may not have provided an accurate insight for students into the practices of science. Since the mid-1980's there have been suggestions that schools should begin to emphasize "authentic practice" to enculturate students into the practices of scientists and mathematicians (American Association for the Advancement of Science (AAAS), 1989; Brown et al., 1989; Hawkins and Pea, 1987). I did not know if authentic scientific practice was possible in the social context of schooling, or how such authenticity might be accomplished. I did not know what it meant to a student to conduct scientific research. To provide such an opportunity and appraise its outcomes I designed and implemented a month long field biology project in an urban high school. It is, however, too simplistic to suggest that this project arose merely as a pedagogic response to these suggestions. The field project was intimately related to who I am as a result of my past experiences.

Coming to My Question- Autobiographic Reflection

Growing up with television as a child of the 1950's and 60's afforded opportunities to be exposed to science as no previous generation was. Increasingly science became part of popular culture through the television and motion picture industry. My initial dreams about science careers were not unlike dreams I have heard from students today, something glamorous, an archeologist perchance discovering opulent tombs like King Tut's. My first desire, to be an archeologist, gave way to being a biologist under the influence of my Grade 8 teacher, Mr. Bateman. I recall a shift in my thinking due to the success I had in biology under his instruction. My interest in biology was further fueled by the marvelous wildlife spectaculars featured on television. Not only productions of the Disney corporation, but safari travelogues, and even John Wayne movies like *Hatari* kindled my interest. Certainly my senior high biology teacher, Mrs. Fuller, further whet my appetite for biology to which I coupled scuba diving as I became fascinated with National Geographic specials on the *Undersea World of Jacques Cousteau*. I entered university with a firm desire to be a marine biologist, another of the adventure-filled, glamorous scientific careers.

The latter years of my baccalaureate offered me the opportunity to be a research assistant in endocrinology and parasitology. Prior to this, science was a class in which the teacher/professor lectured and we did a few labs. The Honors Zoology program also required me to conduct original research so I developed research questions in the areas of animal behavior and endocrinology. The animal behavior research involved testing for the effect of pheromones on schooling behavior in fish. The more detailed endocrinology project explored the diurnal variations in thyroid activity in fish. As I reconstruct those experiences in my memory I recall the sense of mystery and the excitement of discovery associated with the questions I had posed. There also existed for me the joy of really seeing myself as a scientist for the first time. This excitement certainly outweighed the tedium of the research process, the blood sampling and research-imposed time constraints. Collecting radioactive blood samples at 3 am. on a cold November night was a task I will always remember but not likely repeat. More importantly, the communal nature of science was revealed in part to me when my research findings contradicted those of my supervisor. I recall a Ph.D. student at the time telling me after repeated rejection of my final paper that my findings would not be acceptable due to that contradiction. Needless to say I was surprised and dismayed, for my results were not flawed in my estimation.

After graduation I was one of a fortunate few to find work as a biologist. I spent two years contracted to the Canadian Wildlife Service in their environmental assessment branch. A truly glamorous job traveling widely over northern and western Canada investigating environmental concerns. I was active in the scientific community and developed research studies as directed by the bureaucracy of the federal government. The idealized vision I had of science was shattered there. I had firmly believed that the purpose of science was to unearth truths about the world around us. As a scientist I believed I could objectively accept these sometimes harsh truths. I could not believe it when a study I had conducted into repeated oil spills was relegated to the shredder when it was seen to be unpopular in a year in which provincial oil royalties were being raised. I was totally disillusioned when my northern pipeline corridor research results were "invited" to change after government policy changed. Science was and is intimately related to the daily life of people, including politics, but I held a more idealized or romantic notion of science.

It was then that I found my way into education, teaching at all levels and on two continents. I spent fifteen years working in special education settings developing new programs for a variety of disabilities. All the while my interest in science, particularly biology, continued and was fulfilled in part through the teaching of science. After those fifteen years in the classroom I returned to university part-time to complete a Masters degree, but one which I believe to have been very unusual. It opened up a possibility in science and research which I had not heard of and to which this text is in part a testament, the teacher as researcher. As one of the "barefoot researchers," analogous to China's barefoot doctors, we were taught research design and techniques while we were still in the classroom full-time. The classroom then became a very different place, a laboratory of sorts. Assumptions and intuitive understandings that had been acquired over years of practice were challenged and tested. The sociological theories and methods taught at the university were also examined in the context of teaching. When people speak of a life-altering experience, I believe this was one. I was then able to research classroom activities and investigate in a more serious manner what was actually happening in the classroom for both myself and my students. My primary interest since that time has been to question what it is that students are thinking or believing to be true about schooling. Prior to my graduate program I had naively assumed that students knew what science was after ten or more years of the subject and that when we spoke of scientific things we held a common appreciation at the end of our discussions. I was sorely mistaken and thank my graduate experience with altering my praxis. I questioned my teaching style and modified it to include an ongoing researcher component. One example of my altered teaching praxis was the biology field project (see Appendix B).

The field project developed because of unique situational factors. My school's location permitted ready access to a seventy hectare parkland comprised of seven vegetation communities. We could be in the forest in less than five minutes. My background as a field biologist afforded me greater comfort with extended field work than it may have done for my colleagues. My years of special education experience also provided a classroom manner which was different from most teachers I knew. The curriculum as mandated by the Program of Studies (Alberta Education, 1994) required active scientific involvement for students thereby favoring a field project. My personal beliefs played a part in this context. I personally believed that students learned much more by being active in a holistic sense than if they were confined to sitting in a classroom. I also believed that I could not control the learning that students may have but rather that I facilitated the situation in which students learned through interactions with me, others and the environment. Initially there was also the fact that I had miscalculated the time needed to complete the new biology course and had four weeks to fill with something meaningful through the sunny months of May and June.

I believed that the field biology project was an effective learning situation and devoted approximately 20% of the allotted instructional time to it. In this project students, individually or in groups, defined a research question for themselves. implemented a methodology, analyzed and presented their findings. Although I defined the physical area of the study and determined the evaluative criteria, students had the opportunity to negotiate changes. Few students took this opportunity. One student in this study, sought to define her question in a context surrounding her home residence. Another student defined a question which allowed her to complete the project requirements while traveling in Britain. Interestingly, students never sought to negotiate or change the evaluation standards, although given the opportunity to do so.

From the outset of the field project in 1993 I must admit I possessed a sense of wonder and at times amazement. The project was one of the most successful activities I had encountered in my teaching career. It was immensely satisfying for both the students and myself. In conversations between students, younger students had been told by those completing Biology 20 to take my classes because of the project. Colleagues had students asking why they couldn't do a research project as well.

I was animated in this research by my curiosity as a teacher and curriculum researcher. I wondered what makes this activity so special to the students. I also wondered what they believe they have gained as a result of the activity. I became increasingly curious about the manner in which students developed their research project and how they came to understand the project they pursued. I had suspected that the project development was linked in some manner to their understanding of science. I also sensed a shift in this understanding. Scientific research seemed to take on a new meaning for the students. As my own research question developed I recognized that I as a teacher had an intuitive sense of these changes but little systematically gathered evidence to support my intuition. My research task then became *to interpret the meanings for scientific research as they were understood by senior high school biology students engaged in a self-directed investigation.*

Nature and Intent of the Study

The intent of this study was threefold: to interpret the meanings that students had for scientific research, to determine if this meaning was altered through the experience of the field project; and finally, to seek aspects of that experience which had influenced the changes that may occur. Such interpretation was by definition a hermeneutic task.

During the students' research process I had, from a sociological perspective, "acted" in many "roles." Teachers always claim to be playing many diverse roles in the schooling process. I believed the primary one had been that of a role model of scientific manner (Fenstermacher and Soltis, 1986; Roth, 1992a). In addition I was a facilitator, observer, evaluator, confidante, critical friend and many others as is typical of the nature of teaching. From the outset of the field biology project there had been a growing teacher-as-researcher component. As I engaged more frequently with students as a teacher-researcher I noticed the tangible shifts between the various roles I played. I reconsidered the sociological perspective and was more inclined to view these roles as shifting subjectivities, fragments of a larger personal subjectivity. I, as any person, am in contact with numerous forms of discourse, competing and often contradictory. Throughout this text different subjectivities may appear, however two "perspectives" will directly interact and impinge on the research processes of the students and myself: the teacher and the researcher.

I chose the term perspectives because of its connotation of viewing the world from a vantage point. When one typically imagines a view of the world from a vantage point, such as a roadside lookout in the Rockies, the nature of the vantage point appears purposeful, to focus on a particular aspect of the view. Perspective may cause one to think of a view trailing off at great distance, but it does encapsulate many depths of perception from very near to very distant. If one turns about at this point and absorbs the view in all directions the nature of the vantage point changes. By incorporating senses other than just viewing the nature of the vantage point again shifts. A vantage point then affords multiple possibilities to be utilized in perceiving the world.

The vantage points of the teacher and the researcher were used as points centered in this research from which to interpret the students' worlds of research. Although the metaphor perspective is linked to the dominant sense of viewing, this research was more the product of voices. Students' voices were interwoven with my own in a symphony or possibly cacophony. In writing this text I decided that voices would be heard in layers, from the voice of the individual to that of a small group, several groups, an entire class and even classes. As best I could I would have students' voices express themselves; however the stated interpretation would always ultimately be mine. The intent was not to inspire universality. Themes, images and metaphors that were presented may highlight commonalties held in lived experience but they also spoke of the uniqueness of that very same experience. The challenge was to present to the reader my interpretation in concert with the voices such that you may reach your own interpretation and as a result gain a deeper understanding of human experience.

In conducting this research I assumed that the communities of school and science were radically different. Through exposure to traditional classroom activities this difference limited the students' understanding of the nature of science and research. This study was premised on the belief that it was possible to determine and examine personal and social cognitive aspects of an investigatory process as used by adolescents. I assumed that students may be aware of the processes they used and that they were capable of describing those processes. I also assumed that students would be willing to freely and genuinely share their ideas about their experiences, thoughts and feelings. In this regard the challenge for the teacher and the researcher were similar, to achieve a level of confidence in the information being provided by students-respondents as an accurate description of their actual thoughts.

Significance of this Study

The study is significant on several levels. At the most basic level this study is significant to me personally. I am intimately linked into the study as the teacher who implemented the curriculum and as the researcher investigating this particular form of implementation. The process and findings are significant in my professional growth as both a teacher and researcher. I believed that considerable separation existed between school-based scientific activities and science as it is practiced in the scientific community. As a result I suggested to colleagues that students' understanding of science would be enhanced through experience in "authentic" scientific practices. The use of authentic practice was an attempt to create a scientific community in which to focus the situated nature of students' question posing and investigation. This open-inquiry in an experiential framework offered the opportunity to narrow what I had described as a separation between school science activities and inquiry as conducted by scientists. On this level I satisfied my curios · ` a degree · and developed possible directions for future investigations.

This study is significant locally, for the staff of my school. In 1995 half of the science staff began an action research group as a result of my graduate contact with that concept. Some resistance encountered in action research was due to the idea held by some individuals that teachers cannot conduct rigorous research within the time constraints imposed by teaching. The difficulties of acting as both teacher and researcher are acknowledged and have been documented (Corey, 1947; Hodgkinson, 1957; Kemmis and McTaggart, 1990). This study and another that was presented at an international science education conference by members of this action research group (Rymer and McLennan, 1996) may offer further evidence that teachers are capable researchers.

This study may contribute to theoretical and practical pedagogic knowledge in the broader teaching and academic communities. Our understanding of the processes high school students employ when applying their knowledge and understanding to solve problems of their own design will be extended. It may highlight both the learning processes of students and the degree of benefit they derive from experiential learning. Research of this nature will provide an opportunity for teachers and others to visualize the strengths of the inquiry method and self-direction as pedagogic tools. This study may provide some empirical evidence which will assist teachers in the development of pedagogic activities based on inquiry or self-direction.

As this study was conducted in a teacher researcher format it will be instrumental in illuminating some of the insights and difficulties teachers experience when investigating and promoting student conducted research. Although a fledgling research genre, the teacher-as-researcher had been endorsed and promoted by writers such as John Elliott. I continue to argue however that the vision being promoted for teacher-researchers is limited (see Chapter 4). Elliott suggested this new genre will give teachers "control over what is to count as knowledge about practice" (1994, p.133). I maintain that teacher researchers should not limit themselves to studying mere practice, but take an active role in theory building and investigating praxis. I trust this study will provide further evidence whether teachers may contribute in a significant manner to academic pedagogic knowledge.

CHAPTER 2
THE ALBERTA SENIOR HIGH SCIENCE CURRICULUM

Rationale

Curricula are social constructions and social artifacts created by groups of people to address specific beliefs and concerns that exist in their perception of reality. This chapter seeks to investigate the intent of the current curriculum and illuminate what the current curriculum "counts as knowledge" (Cherryholmes, 1982). As curricula exist within a specific context and have a historical basis, the educational, philosophical and ideological assumptions that underlie the senior high school science curriculum are considered.

Curricula define important parameters within the classroom situation (Goodson, 1991). The science curriculum, as written, mandates the topics of study, essential learnings and curricular emphases, thereby setting definite boundaries for teaching and learning. Through examination, the external forces, including ideologies, politics and economics, that inform and influence curriculum development are exposed. These external influences are historical and are defined in a spatial and temporal context External forces also impact on teachers and students directly as they live within the same context as the curriculum. The external forces by influencing teachers also secondarily impact on students through teachers' implementations of the curriculum.

This analysis investigates the external historical social forces which led to the current curriculum. Another critical element of this analysis is the investigation of the roles defined for teachers and students. The analysis, as well, illuminates the nature of knowledge as the curriculum framed it. Power relationships are evident through implicit, and occasionally explicit, means within the curriculum.

The forthcoming analysis highlights my personal curriculum perspectives preceding the implementation of the study. This is important relative to the teacher-researcher model adopted for this study. It will provide insights into the beliefs, values, biases and intentions that I had. As the project being studied was a result of my personal response to the curriculum as written, this analysis will inform the reader of my intentions for my students relative to the curriculum. This analysis having been conducted prior to the research will thus be a form of bracketing, providing both myself and the critical reader the opportunity to frame the research within my perceptions of and perspectives on the current curriculum.

This analysis was focused on the science curriculum itself of which Biology 20 was only one facet. Being a subunit of the science curriculum the expectations of the Biology

20 program were subsumed within those held for senior high science. Secondly the focus of this research was on the meanings held by students for scientific research. As a result the primary concern was with the broader curricular expectations of the science program.

Background to the Current Program

The Pre-1991 Alberta Senior High Science Program

Prior to 1991 the senior high school program consisted of two academic tracks leading to a General High School Diploma and an Advanced High School Diploma. Only one science course (3 credits, approximately 75 hours of instruction) was required for the completion of the General Diploma (100 credits). Students seeking an Advanced Diploma (100 credits) only needed to complete three science courses totaling eleven credits (approximately 275 hours of instruction). For all senior high school courses a final grade of 40% was required to receive credits, but 50% was necessary to proceed to the next higher level of course. The two academic tracks also posed different degrees of rigour. The General Diploma science requirement could be met through a single general science course of limited difficulty. The Advanced Diploma required the completion of at least three courses in a traditional science discipline (biology, chemistry, physics) culminating at the Grade 12 or "30" level. Only "30" level disciplines were examined by a provincially standardized Diploma Examination.

The disciplinary nature of the science program was seen to "make it difficult for students to get a sound, well-rounded education" (Alberta Education, 1989, p. 7). The high school program was further criticized for appearing to require fourteen year old students to make career choices. Students needed to determine which sciences they would take in senior high school while still involved in Grade 9. Although a "good foundation" in the sciences was seen as being desirable, the pursuit of more than one discipline was seen to limit other opportunities for personal investigation beyond the sciences (Alberta Education, 1989). On the other hand, those students opting for only one science discipline in high school were not seen to be achieving a sufficiently broad science education.

Origins of the Current Program

The senior high science curriculum underwent considerable change though the period 1984 to 1991. Curriculum change of the magnitude undertaken is historical and occurs within a given context. Just as the American, and later Canadian, science education programs were altered after the Soviet Sputnik launch, pressures outside of education led to the current revision of the science program. In the case of the current revision I believe economic and social concerns arising from the 1970's contributed to the revisions. This historical analysis was based on my interpretations of events that I believe were sufficient to lead to the critiques of science education in the early 1980's.

In the early 1970's western economies began an economic recession that has continued into the 1990's. It was characterized by periods of stagflation: high unemployment, high inflation and reduced economic output. The economies of Asia during this period did not demonstrate the same problems and were seen to demonstrate positive economic growth, outstripping their North American counterparts. Asian industrial and technological products gained a large portion of consumer confidence and allegiance at the expense of North American industries. This period could also be characterized by rapid technological advances and equally rapid modernization of technological industries. Computerization and its associated benefits to telecommunications and industry led to the realization of a fledgling Information Age. This trend has led to the concept of an information highway or superhighway, knowledge of which may be necessary for future competitive ventures in business globally.

As a result of this economic situation it was envisioned that the average citizen would need to be better prepared to function in a highly technological marketplace such that economic advances may be realized. The science program that was believed to best address this economic perception was determined to be one which would train those with special interests in further studies involving science and technology, yet also provide adequate preparation for others for the modern work world (Science Council of Canada, 1984).

A further implication of this situation was a series of international comparative studies contrasting North American education with the educational systems of our major competitors, primarily Asian. One example of these studies was particularly illuminating in regards to the perceived connection between science education and economy in the Alberta context. Alberta Education (1991) jointly published with the Alberta Chamber of Resources a document entitled, *International Comparisons in Education : Curriculum, Values and Lessons*. In the preface of this document Eric Newell, CEO and President of Syncrude Canada, stated that "we must recognize the forces of global competition and the role of science and technology in reducing cost, improving reliability and quality." He continued to say that "the business community views with alarm the low level of interest in science and technology... among Alberta youth" and that this community held concern for the "quality of education." Roger Palmer, Assistant Deputy Minister of Education, in the same preface, claimed that we "must have a strong economy" and that this economy "depends upon educational excellence... the two are inseparable." This report went on to contrast education in Alberta with Japan, Germany and Hungary. One of the conclusions was that there was "a serious quality problem with education - particularly with math and science education - in Alberta" (p.2).

A second trend over this period involved the realization that some technologies had been inappropriately applied. Rapid industrial growth and output without concern for potentially hazardous environmental damage led to the formation of a large number of environmentally conscious protest groups and ultimately to environmental lobby groups. The "Green Movement" had become a powerful economic and political force in North America capable of initiating changes in government policy and possibly initiating limited social change.

To function in society in which ethical, moral, social, economic or political choices must be made by an informed public, citizens must be prepared to participate fully in the choices necessary. Such participation required an understanding of science, technology and their relationships to each other and the society. This required the intellectual and moral development of a rational, autonomous individual (Science Council of Canada, 1984).

The economic and social concerns of the period 1970 to 1984 caused governments to initiate a review of science education practices. The Science Council of Canada (1984) suggested a realignment of science education with an emphasis on the interactions of science, technology and society (STS). Shortly after the Science Council's report, Alberta Education completed its policy statement on secondary education (1985) and its Instructional Program Review (1987). Through investigation and consultation it was determined that the existing science education program lacked rigour and high standards, as well; it failed to provide the strong scientific foundation believed necessary to participate in the economic and social/political world (Alberta Education, 1989). The courses were seen to present a narrow perspective of science and overemphasize scientific facts. Problem solving was conducted in a "lock-step" fashion and ethical judgments were overlooked. Senior high science courses were determined to be "scaled-down versions of university courses" (Alberta Education, 1989, p.7). The courses were thought to be meeting the needs of a small portion of society seeking to enter universities, and therefore not addressing the needs of the larger population. Science was presented didactically as a linear system of ideas with occasional laboratories to support the information already presented. The program was determined to contribute to a reluctance among students to take any more science then what was required. The meaningfulness and usefulness of science was also questioned by students (Alberta Education, 1989) for the links between sciences were not established nor were the links to the broader community, provincial, national or international dimensions constructed. Due to the context in which society was operating and the findings of the investigations conducted, science education in Alberta was redesigned.

The Current Program

Form and Organization of the Course of Studies

Prior to discussing the intent and meaning of the current senior high science program it may be informative to consider the form and organization of the program of studies. The focus of this analysis is upon the current science program as described in the Program of Studies: Senior High (Alberta Education, 1994) as revised to May 31, 1994. The program of studies is divided into sections based upon disciplines. The first page of the science program section outlined the vision statement of the program. This is followed by the rationale and philosophy. The third section is comprised of general learner expectations which are developed in two categories: program expectations and course expectations. The final section contains specific learner expectations for the particular courses described. Also included is an inquiry model which describes the inquiry component believed critical to the successful completion of the intended outcomes for this program.

Of particular interest to this study are the vision statement and program general learner expectations. It is these sections which define the intentions of the new program as a response to the economic, social and political context, for as Goodson (1991) stated, "curriculum is a social artifact, conceived of and made for deliberate human purposes" (p.58).

The Intention of the Curriculum

Several alterations were made to the structure of the senior high science program to increase the amount of science in the senior high program. Three new courses were added to the program: Science 10-20-30. These courses are often referred to as integrated or interdisciplinary, although they tend to be taught in discrete disciplinary sections. The minimum requirement for a General Diploma increased by 125 hours of instruction to eight credits. The Advanced Diploma requirements were increased by about 100 hours of instruction. The introductory course for all students in the Advanced Diploma route became an interdisciplinary course, Science 10. The minimum grade for receiving credit or passing any course was raised to 50%. It is the intent of these changes to provide the students with a broader, more challenging, and rigorous science education.

The stated intention of the science program is to develop in each student a level of science awareness and understanding that is needed to function as an effective member of "a scientifically literate society". This form of literacy remains undefined. One may presume the definition to exist within the learner expectations. It is clearly an intent of the government to provide a curriculum that addresses political concerns about the economy and the technological trends that have become evident. Skilbeck (1991) had noted that there had been "a strong move by governments, in recent years, to use curriculum as part of a wider strategy of economic restructuring and development" (p.122). Given the historical dependence of Alberta on petroleum products and agriculture there had been efforts by consecutive Conservative governments to foster diversification within the industrial and business sector. Among the initiatives pursued were several advanced technological industries. It is clear that the intentions of the government was for students to be prepared for employability in industries defined by perceptions of economic trends.

The Null Curriculum

The framework that the Curriculum Branch presented for "all the senior high school programs" included the following programs: Science 10-20-30, Biology 20-30. Chemistry 20-30 and Physics 20-30. What is immediately striking and curious about this explicit definition of science courses within the senior high school science program is not the stated curriculum, but what may be termed the null curriculum, that which is not included. Those courses omitted from the science program were cause for my speculation about the beliefs and attitudes held for the nature of students and the nature of knowledge in courses. Absent from the declared science education program are the following senior high courses: Science 14-24 and Science 16-26. The courses included in the definition were those which would be necessary for an Advanced Diploma; those omitted were the minimum requirements for the General Diploma and Integrated Occupational Program (IOP) Certificate respectively.

When I considered this situation, several lines of speculation were valid given this omission. One line of speculation allowed that the omission was merely an oversight in the development of the new program. This omission has not however been acknowledged in any subsequent alteration to curriculum documents since 1991. A second possibility was that the Science 14-24 program had been revised in 1989 and was not brought up to date in the 1991 program. In some ways the 14-24 program may have been the forerunner of the new program. It was unusual that the 1991 documents and those subsequent to that date never redressed the discrepancy. The revised general learner expectations did not supplant the Science 14-24 expectations as would have been the natural course of events in a total science program revision. When contacted in 1994, officials claimed that the expectations would be revised in the near future such that Science 14-24 courses were included. This has not yet happened.

The Science 16-26 courses are not even included in the science section of the program of studies. They are found in the description of the IOP. This distinction is no doubt due to the segregated special education origin of this program. It is conceivable and reasonable to argue however that the omissions reflect an unspoken, but recognized, belief that the General Diploma and IOP Certificate were less valued. Certainly the very term "certificate" connotes a diminished value relative to the term "diploma." So too "general" is diminished relative to "advanced."

Subsequent to my serious consideration of this curriculum, the terms "advanced" and "general" have been dropped from reference to the Diploma. These terms became a concern for Alberta Education. As of September, 1995, qualified students, who began high school after that date, except those enrolled in IOP, will be awarded an "Alberta High School Diploma." In this research situation any students in Grade 11 or 12 would have been seeking an Advanced Diploma but the Grade 10 students would be receiving an Alberta High School Diploma.

Are the natures of students in the three different tracks defined in different terms? The nature of the students commonly found in the courses omitted from the science program as defined in curriculum documents is considered to be markedly different by the majority of teachers involved in the sciences. These students continue to be commonly viewed as more difficult to teach because they are perceived as lazy, not interested in school or possibly not as "bright."

I also speculated in my analysis as to whether the curricula of the omitted courses were considered to be at a senior high school level. The level of the material taught may be best reflected in the quality of the resources used, particularly the textbooks. To the critical reader the textbooks for these courses do not appear in size, text, graphics or quality to be senior high school texts, and resemble in many ways upper elementary textbooks. Many students have indicated to me when I taught these courses that they were offended by having to use these texts. In addition these courses have never been examined by provincially standardized examinations. Accountability to the public had been the province's expressed concern for reinstituting the Diploma examinations yet this accountability has never been applied to Science 24 or 26 courses even though these are terminal high school courses. The standards of achievement and rigour of these courses were definitely not comparable to those of the Advanced Diploma route.

Alberta Education is seriously considering reviewing the minimal science requirements for graduation. Although Science 26 will remain as the terminal course for the IOP Certificate, Science 24 may be revamped or discontinued. It is currently viewed as a "joke" which is not taken seriously by teachers, students or administrators. Ministry officials are very concerned with the low level of science understanding required to graduate from high school.

It may be seen that the omission of these courses from the current senior high school science program reflected the difference in attitudes held toward the "lowly" courses in schools. Not only did many teachers not care for these courses due to the perceived nature of the students and the quality of the content, but administrators frequently staffed these classes with teachers other than those regularly teaching sciences. Often the teachers recruited were from other specializations suffering decreased enrollments in recent years and required another course to fill their timetable. Staffing practices in my school situation have altered such that all science courses are taught by science teachers.

The reasons for the omissions of these courses from the science program have not been made explicit. The education system prevalent in Alberta is clearly multi-tiered and reflects a societal idea that some individuals are less capable and therefore may be provided less valued knowledge. The science program defined in the Program of Studies was oriented toward the Advanced Diploma requirements and remains oriented to the more academic stream of the Alberta High School Diploma..

The Program General Learner Expectations

The "legitimating rhetoric of schooling" (Goodson, 1991) contained in the vision statement and program general learner expectations constitutes a symbolic function by legitimating certain expectations for the science program. The program general learner expectations focus on four major areas of outcomes: attitudes, knowledge, skills, and the connections among science, technology, and society. The outcomes in all areas, except attitudes, are measurable through some manner of student evaluation. For these areas there is a relatively high certainty that these outcomes may be achieved. Ambiguities are couched in some undefined or non-measurable outcomes of the attitudinal section, making realization of these expectations less certain. For each of the areas, except knowledge, there are reasonable concerns as to the manner of implementation and evaluation given the climate of accountability in education. The intended curriculum as written implies particular beliefs about both teachers and students. These implications are discussed and questioned in the latter sections of this chapter.

Attitudes

Attitudes are problematic. The return to a focus on accountability by the government has reinforced Freire's notion (1970) of the "banking model" of education. In this model students were taught and the students' learnings were in some way measured. Some attitudinal outcomes desired in the science curriculum, such as "enthusiasm toward science" or "tolerance of uncertainty" are not readily measurable. Others, like "lifelong interest in science," are not measurable nor easily demonstrated through performance within the temporal context of schools. Quantitative measures are lacking and I suspect teachers would feel uncomfortable with qualitative indicators of attitudes, as these are often interpreted as being highly subjective. Given that teacher culture has historically attempted to strive for objective evaluative measurement, there would be resistance to any form of qualitative evaluation in this area. Due to the possibility of resistance, the course of studies directs teachers to "encourage" the development of desired attitudes. Even so students are "expected to show" and "will possess...attitudes." As a result this leaves a question as to how difficult it would be to ensure that the desired attitudinal outcomes are attempted or given serious consideration in program implementation. Being academic courses suggested to me that these courses, particularly at the 30 level, would be driven by the Diploma Examinations. As these examinations have not normally addressed any of the outcomes covered under the heading attitudes, there is little doubt that attitudes will not be a major focus of curriculum implementation, except in those few situations in which the individual teacher values such outcomes.

The current model of teaching that is generally favoured administratively and was identified in teacher effectiveness literature placed teachers in an executive role (Fenstermacher and Soltis, 1986). The executive position was described as placing teachers "outside" the process of teaching and learning where they regulated the content of the courses and the activities of the children. This model stressed attention to task, performance, achievement results and accountability. This model of instruction may not readily accommodate the development of attitudes. Attitudinal development appears more in line with the liberationist approach (Fenstermacher and Soltis, 1986). Content was described as an important component of this approach as in the executive model. This approach differed from the executive model in that content was developed with an emphasis on modeling the appropriate "manner" to students. Manner was an active demonstration by the teacher of the attitudes and values inherent to the discipline being taught. This was not done in the executive approach.

I considered the inclusion of attitudes from a slightly different perspective. The curriculum intends that students possess both enthusiasm for science and positive attitudes toward science. Why should a person appreciate science in these ways? Certainly science is intimately related with post-industrial society through its influence on and dependence upon technology. It should be clear that society determines the priorities for scientific research through funding. Students should realize that in a society so heavily governed by economics, the capitalist imperative would influence the direction of scientific discovery and ultimately technological application. These aspects of science are important to realize but is it important to view such science positively and with enthusiasm?

The history of scientific and technological advancement may be viewed quite negatively. Prior to the end of the Second World War it would have been reasonable to believe that science was capable of providing the control over nature we desired and that it was capable of proving the certainty that was believed foundational to the universe. With the blossoming of quantum physics and the advent of chaos theory science may seem to be increasingly subjective. Scientific study became more directly linked to the nature of the observer's question. As Heisenberg stated in the 1960's, "What we observe is not nature but nature exposed to our method of questioning" (1963, p.57). Outcomes were immediately restricted in possibility by the question and the limitations of human senses. Certainty and predictability were no longer guaranteed by science. Furthermore, some of the discoveries and technological applications for the benefit of business or government created negative impacts on contemporary society.

Suggesting that students should attain a positive and enthusiastic attitude toward science is to support a particular economic and political worldview. These attitudes uncritically support a positivistic outlook on the world and create a limitation of imagination and human possibility by the very paradigm they support. The positive attitudes desired are necessary for students to proceed into scientific or technical careers. Such careers continue to be viewed as desirable for the creation of advanced technology industries in Alberta. Attitudes of this nature might have impacts on students as consumers in later life. By viewing technological advancement positively one might be encouraged to consume new products without critical appraisal of their impact on the environment or society.

This curriculum would be more appropriate to engender critical attitudes such that students could appraise for themselves the merits of science and the resultant technologies. Critical reflection is not akin to specific ideologies but may support any or none dependent upon the arguments provided. I was curious that the science program of studies did not, in its vision, philosophy or rationale, make explicit reference to the development of critical attitudes. Critical thinking skills were, however, referred to in the biology section of the program of studies. Was it merely that critical attitudes were implicit or assumed within the science curriculum or ignored purposefully to foster the development of a specific product? From a theoretical perspective and that of a rational human being seeking increased humane praxis in society, critical attitudes are desirable for they will lead over time to social change.

Knowledge

The new program was intended to weaken the artificial divisions that reductionism had developed over time in simplistic science thinking. Science has historically been viewed by lay people as composed of distinct disciplines, principally biology, chemistry and physics. Ledbetter (1993) and I (1995) had found that students tended to define science in terms of these three disciplines. This definition was derived primarily on the basis of schools isolating the disciplines from each other. Contemporary thought, as seen in the new curriculum, attempts to reunite these disciplines as a more interactive, interdependent whole that reflects an expression of integrated science. This curriculum went part way in realizing this potential. The Program of Studies (Alberta Education, 1994) stated that students were to "focus on learning the big interconnecting ideas and principles."

The science program approaches the concept of scientific knowledge from a thematic approach. The major themes include: change, diversity, energy, equilibrium, matter and systems, the process of developing scientific knowledge. It had been hoped that it would be implemented with an appreciation for the transcendent nature of scientific knowledge as opposed to limited discipline-bound knowledge. An integrated approach was a novel manner of instruction and has tended to be limited to the Science 10-20-30 courses. The other science courses continued to be highly discipline oriented and taught by subject area specialists.

The thematic approach was an attempt to break away from the heavy content orientation of the pre-1991 curriculum. Unfortunately teachers approached curriculum change by transplanting those workable components of the old curricula to the new situation. This happened throughout the implementation of the new curriculum. The appropriate units and examinations from the old Biology course were transplanted into the new Biology 20-30 program. As a result the manner of teaching and much of the content remained the same. Small innovations in instruction occurred as teachers became confident with the new curriculum. The intent of a thematic framework was to stress principles and concepts, the teaching practices and the reliance on the Diploma Examinations kept the specific knowledge component central.

Skills

The nature of knowledge in the new program is intended to be focused on understandings of broad themes that run through the natural sciences. A greater curricular emphasis appears to be stated in relation to skills. The vision statement intends that "programs place an increased emphasis on developing methods of inquiry." Skills are obtained as a result of active experience with the scientific process. Where knowledge outcomes are outlined in less than half a page of general themes, skills are described over three times the space and in considerably greater detail. In fact, skills are outlined in far greater detail than any other component of expectations. The skills detailed are not possible to develop through "traditional" science teaching styles that involve lecture followed by supportive laboratories. These skills can only be derived from freer inquiry approaches in which students define the question and follow scientific processes to completion. It is conceivable that skills could be interpreted as the central component of this curriculum.

Contemporary evaluative techniques are inadequate to examine skills of the nature desired in this program of studies. I perceive evaluation to be a driving force in classroom teaching, particularly in "30" level courses. As a result, teachers are rather pragmatic about what should be taught. Things which cannot be examined are given lower priorities. I think attitudes would be ranked lowest followed by skills. Student skill levels can only be determined in a cursory manner using traditional evaluation. The process generally is to "design an experiment" on a paper and pencil examination. This provides a very limited snapshot of students' scientific skills and does not demonstrate critical understandings of science. Many other examination questions are deemed to be "process items" but cannot effectively assess many skill outcomes.

The skills outlined in the program of studies are best developed through a series of experiences which allow students to actively define and research topics of their own personal interest. The only effective measurement device appears to be performance assessment. Students are required to actually demonstrate the required skills through a performance. This type of assessment has yet to appear on a government standardized final examination in Alberta. What would be required is a laboratory skills examination similar to the Cambridge University "A" level examinations. Such a practical test increases the likelihood that the skills expectations of the curriculum would be implemented. In recent years there have been initiatives by Alberta Education and individual teachers to develop performance assessments in the sciences (Ritter, 1996; Wozny, in press).

Another limitation of the stated vision is that through application of skills it is assumed that students "will better understand the knowledge they have acquired." This assumes that the students will reflect on their knowledge. It further assumes that students will develop the linkages between the specific content they have learned and their existing knowledge. There seems to be a belief inherent in curricular statements that knowledge is acquired and that the skills taught will reinforce or explain this knowledge in some way. This approach does not suggest that the skills may be necessary for the construction of knowledge or the co-emergence of knowledge in the classroom. The curriculum is not particularly clear on the value of scientific process skills in their own right and not merely as support for the knowledge component.

Connections Among Science, Technology and Society

The expectations determined for the science program appear to address the concern held for citizens to understand the relationships between science, technology and society. Our post-industrial society is founded on the modernist paradigm which had elevated the importance of science through its ability to reveal knowledge about the world around us. The expectations described reflect the intention to create effective members of society. Given the dependence upon science and technology it is believed important that the "common man" should be able to make informed choices.

It appears that the expectations held for this section conflict with the expected attitudes. Where positive attitudes and enthusiasm are desired, the connections which students are expected to realize would identify the limitations of science and technology Students will also be expected to realize the responsibility society holds for the judicious use of scientific knowledge and technology. It is possible that in addressing these expectations negative attitudes may develop toward science.

The expectations are stated in positive terms but allow for the student to be presented with, or to present, conflicting points of view. The pedagogy most appropriate for these expectations appears to be dialogic. Developing genuine dialogue is a difficult process requiring the sharing of equal participants. Unfortunately schools are inherently hierarchical and unequal social structures exist. As a result attaining these goals is problematic.

Evaluation is again problematic. The historical emphasis on knowledge detracts from this component of the program as it does for skills and attitudes. Framing evaluative tasks for this component is difficult. The amount of information needed to make a good question does not endear this component to examination builders.

The Teaching and Learning Situation

It was not readily apparent to me whether this program would have a positive or predictable effect on subsequent student achievement. It is conceivable that if all the expectations were met then an individual would emerge who would be successful in scientific endeavors and function effectively in a particular type of society. The key to making this program work is the manner in which students are educated. The manner described in the program of studies document is one which possesses relevance to students' lives, thereby providing for personal meaning. It is also characterized by viewing students as active learners, responsible for personal learnings. A cooperative team format is suggested with a focus on positive contributions and a climate of concrete experiences. It appears that the intent is to utilize a constructivist epistemology, which had become popular in academic literature at the time the curriculum was developed. When the role of the teacher, the nature of the student, and the nature of knowledge are examined relative to curricular documents it is evident that a strong traditional epistemology remains.

The Role of the Teacher

Based on the program of studies the teacher's role remains in the traditional executive approach. Teachers continue to manage the activities and experiences within the classroom such that the program expectations are attained. Although the curriculum stated that students are placed at the center of the program, the attainment of expectations is driven by the teacher's executive role. Teachers are charged with the creation of an appropriate learning environment to meet the objectives defined, yet this is to be relevant to students and largely concrete. It is recommended that teachers vary the curricular emphases as the course unfolds. Program expectations require that students view science as interesting and dynamic, yet the traditional inequitable social structures of school are maintained. Students are not active in the key elements of the program development, particularly the determination of relevance.

The Student

Although described as active learners responsible in part for their own learning, students are not explicitly described as active participants in the learning process. They are not given the authority to define the learning process such that it may be personally relevant. A degree of manipulation is apparent in the expectations as defined. Students are to enjoy science, find it interesting and dynamic. Critical thinking skills are desired but a positive attitude to science is also desired. I interpret an active student as one who is not merely taking notes and listening to lectures, but presumably is involved in some form of action like a debate or a lab activity. Students are therefore objects to be shaped by the education system, not "autonomous learners" to which curriculum rhetoric refers. Autonomy cannot flourish after receiving an education which is prescriptive. Foucault (1977) viewed knowledge as the power to define others. He saw it as a mode of surveillance, regulation and discipline. Traditional education has sought to define students in these ways. The current curriculum seeks to define the nature of the future citizen. Knowledge and the skills taught will shape students to meet a predicted future societal demand based on trends that had been perceived in the recent past. There is the ongoing, possibly mistaken, belief that hindsight can meet the needs of the future

The Nature of Knowledge

The nature of knowledge is reflected in modernist thought found across the breadth of curriculum documents. All the documents I studied indicated that knowledge could be acquired, possessed and demonstrated. It could be transmitted from one person to another. The knowledge which is valued is clearly defined in the program of studies, the texts and the standardized Diploma examinations.

Knowledge is referred to as personal. Knowledge can be developed by students recognizing connections and relationships that exist between their initial knowledge and what they encounter through reading, seeing and hearing (Alberta Education, 1990a). This position indicates the modernist primacy of visual sensing. The notable factor, excluded in the description used, is knowledge derived through experiences based on movement, action or intuition. The sources of new knowledge in the descriptions given by Alberta Education, reading, observing and listening, are predominantly associated with traditional passive classroom learning. Students are increasingly expected to " assume responsibility for their learning." This suggests to me a limited realization on the part of curriculum developers that students are active participants, but does not indicate realization of the critical factor that students may be the active constructors of knowledge or that knowledge may co-emerge in the collectivity of classroom activity.

There has been an increased mercantilization of knowledge (Sarup, 1989). Knowledge, often scientific, has increasingly become a force of industrial production, an aspect of industry's capital assets (Drucker, 1994; Stewart 1994). The goal of scientific knowledge is no longer couched in the rhetoric of truth but blatantly augments power, industrially, economically and politically. This has been evident in shifts within science education. Increasingly emphasis has been diverted to developing scientific skills, through which individuals may serve the industrial complex. This was obvious given the explicit expectation for "increased emphasis" on skills and the fact that the skills expectation included triple the expectations of any other section of the curriculum. It is evident in curriculum documents that concern for future employability in an increasingly technically competitive world is paramount. Skills taught in schools are supposed to be transferable to the work world. Many expectations held for senior high science students indicate the belief that it will be "important for students to have the capacity to actualize the relevant data for solving a problem here and now, to organize that data into an efficient strategy" (Sarup, 1989, p.125). The nature of knowledge from this perspective ceases to be that of an end in itself, but rather a product which will be sold. As Sarup suggested, the question applied to knowledge was no longer, "Is it true?" but rather, "What use is it?"

Two myths fundamental to the justification of scientific knowledge are evident in the curriculum documents:

1. Scientific knowledge is capable of liberating humanity. This myth is evident in how the knowledge supposedly gained from senior high school science will make the student an "effective member" of society. This myth is also evident in the intention for students to derive enthusiastic, positive attitudes toward science, because of the benefits derived from science and technology. In part these benefits would include attraction of industry and business to Alberta. This is analogous to the "build it and they shall come" fantasy where it seems that industry and business are attracted to locations with skilled labour. Unfortunately for Alberta, other more serious economic and market forces have limited the growth of industry and business due to Alberta's location, remote from the larger marketplaces.
2. Within science there is the "speculative unity of knowledge" (Sarup, 1989). The knowledge section of the learner expectations is based on the premise of "big interconnecting ideas" or themes that "transcend and unify the natural science disciplines" (Alberta Education, 1994). As a result of this unity, fundamental to the modernist paradigm, nature is seen as predictable and thus controllable. This myth is critical to the extension of technical rationality in society.

These myths reflect Sarup's question about knowledge, "What use is it?" Knowledge and myth serve a variety of purposes. They provide the basis for the creation of a work force to support a particular view of post-industrial society. The question arises however, what is knowledge? Knowledge may be defined in numerous ways. Knowledge as it appears in curricular documents tends to be defined as an entity which may be possessed and transferred. It may then be contained within books and other language-based resources. Alternatively knowledge may be individually (von Glasersfeld, 1995) or socially constructed (Vygotsky, 1978). Knowledge may also be seen to co-emerge through human interaction with others and the environment. In such a situation knowledge may not exist until it is enacted in the interaction (Varela et al., 1991).

The nature of knowledge has a direct bearing on two aspects of science education, thinking and researching. I believe a better understanding of the manner in which the curriculum portrayed knowledge can be informed through examining the manner in which curriculum documents deal with thinking and research.

The Nature of Thinking

Reference to thinking within Alberta Education documents is problematic. Conflicting perspectives on thinking are presented in different curriculum resources developed to support the current curriculum. In the Alberta Education document Teaching Thinking (1990a) the discussion suggests strongly that thinking and doing are prized within our culture and that thought is primary. "First you think and then you do." This notion creates an artificial linearity which is not indicative of human reality. It also creates an artificial separation between thought and action, theory and practice.

Documents also suggest a definite linearity within thought. Thought is reduced to a series of steps, a mechanistic process. This is evident in the discussion on research found in Focus on Research (Alberta Education, 1990b) where the research process is viewed as a series of discrete steps or phases in a "comprehensive process."

The Program of Studies (Alberta Education, 1994) conflicts with this approach. This document aligns itself more with the reality of thought. Thought is rarely linear in real life. "Effective thinking appears to be nonlinear and recursive" in nature. If we hope students achieve an understanding of scientific knowledge and its development, this approach is important. Many outstanding historical scientific discoveries were probably achieved because of the nonlinear thinking or patterns of recursive thought on the part of scientists.

The Nature of Research

There is a strong tendency toward a means-ends or process-product model of research in the document Focus on Research (Alberta Education, 1990b). The perception that thought has primacy over action and that action will occur within a linear framework support a modernist perspective of knowledge. Thought and action, specifically research, are mechanized in a manner that seeks to minimize risk. Yet risk is at the very heart of advancing scientific knowledge, individually or socially.

There is also a strong suggestion that a best or all-encompassing, "comprehensive research process" exist. This process is transferable to others and to the world of work for which this education is preparing students. This leads me to question whether the purpose is to train or educate students.

Linearity of thought is evident in the ideas and wording presented. Research proceeds in "steps," "stages," or "phases" through which students progress in order to produce a "desirable research project" (Alberta Education, 1990b, p.4). A limited body of valued knowledge permits one to form the connotation of "desirable." Creative research projects may be constrained by denotative, prescriptive and evaluative statements used to determine the desirable. Desirable may be defined by the degree of congruence and conformity the project had with standards that had been socially determined by legitimate authorities. Knowledge, thinking and research that vary from such a standard may not be appreciated.

Comments within Focus on Research support the modernist notion of science The elements of knowledge are discovered through research as if this knowledge were pre-existent and merely awaited uncovering by rational processes. Knowledge derived from research appears to have an intrinsic "final value" thereby suggesting knowledge exists as discrete units and has a terminal point. It also suggests that there is a universal "organized whole." Knowledge seems, from such a description, to be analogous to pieces of a puzzle which must be found and then fall into place to reveal a total picture.

It is curious that in a period of human thought which pays lip service to elevating the importance of the autonomous learner, the teaching of thinking and research is mechanized and risk is minimized. For students to appreciate authentic science as advocated (Chapter 3) the current approaches to thought and research appear to be at cross purposes.

A Critique

The science curriculum and its supporting documents contain both problems and contradictions. These documents do not adequately define scientific literacy. In the absence of a clear definition this term is used as another educational buzz word. As a result it is difficult to determine if such a form of literacy has been achieved.

The curriculum development process draws on selected individuals to assist policy makers. The curriculum and its supporting documents are developed separately with limited interaction between the parties involved. This has been illustrated in this situation by the differing and conflicting approaches taken to key elements of the curriculum. Specifically, Alberta Education needs to reconsider the definition and perspectives taken on knowledge, thinking and research. These elements are central to implementing school science.

The recurrent problem with curricula rests in interpretation and implementation. Curricula tend to be general in nature. The wording tends to imply the nature of the relationships that are expected. The vocabulary used also implies the desired or suggested teaching methodologies. Interpretation of these statements is left to the teacher. A simple example from the science curriculum would be the statement suggesting that students should be actively involved in science. What is the nature of active participation? How would it look in the classroom? Students are active when they write notes. They are active when they are listening to a teacher lecture. They are active in orchestrated laboratory activities. Active participation may also be interpreted as the students defining the topic that will form the central theme for a class' investigation or debate. It may be the independent actions associated with students defining and researching their own investigations. To ensure that new curricula are interpreted in a manner consistent with their expectations it would be helpful to use more direct explanations or illustrate examples.

Teachers' freedom to interpret the curriculum leads to problems of implementation. Developing course materials for a given curriculum is a time consuming venture. The most pragmatic manner to implement a new curriculum for a teacher pressed for time is to peruse the desired outcomes and determine which activities, notes and assessment tools currently being used may be transplanted to the new curriculum. The rationale and philosophy of the new curriculum need not be examined when implementing a new curriculum in this manner. Given the general nature of the wording in the curriculum it is possible to justify the pedagogy used. For any given curriculum each teacher puts their own particular spin on the classroom practices. The problems of curriculum interpretation and implementation need to be more closely considered by Alberta Education.

Conclusion

Competition and economic concerns were driving forces behind the science curriculum reforms over the past fifty years. Shifting economic fortunes and socio-political concerns raised by historical environmental events contributed to the perception that the pre-1991 curriculum was flawed. The current curriculum was developed for the purpose of addressing the shortfalls of the earlier curriculum. The curriculum was written using then contemporary notions of the constructivist basis for cognition. As we seem to be poised "on the cusp" of changing paradigms, from modernist thought to post-modern

(Doll, 1993), confusion appears to exist relative to notions of knowledge, thought and research, resulting in conflicting or contradictory positions taken by the writers of the curriculum and its supporting documents. The curriculum development process did not entail an overriding concern for a consistent worldview.

The current curriculum is a document designed to address pressing economic and political concerns. The stated attitudes, skills, knowledge and STS connections are in line with a strategy to effect economic and social change. The potential effectiveness of this curriculum to accomplish these goals is suspect. This curriculum is a political tool designed with an intent to meet specific interpretations of the economic world.

As a teacher I am required to interpret and implement this curriculum. This is implementation is not conducted as a mere instrument of social policy. The implementation is based on many aspects of my person, including among others: my understandings, beliefs, values, intentions and expectations. My interpretation of the curriculum expectations requires that I become more familiar with the concept of authentic science. I need to derive a personal understanding of it and how it may appear in my classroom. If active participation in science activities is determined to be central to authentic science then my implementation would include an experiential framework. This choice of approach is linked to my preferred teaching strategy. I also interpreted the curriculum to be written in a manner which suggested a constructivist approach to cognition was underlying the curriculum design. By interpreting authentic science to involve actual science experiences my implementation would include both experiential education and constructivism.

CHAPTER 3
AUTHENTIC EXPERIENCE

Introduction

In implementing the curriculum I, as teacher, determine which aspects of the curriculum are going to be central to my teaching process. My decisions about what will be taught, the depth of the teaching and how it will be taught are influenced by my personal beliefs about teaching, my skills and preferences in teaching, the teacher culture in which I find myself working, the students' attitudes and several other factors.

The teaching of biology is an excellent opportunity in the context of my school to study the processes of inquiry. The common practice in my school for teaching biology was to provide students with lectures, including notes, and support the concepts presented with lab work and other related activities. Field biology was at best limited to one period (eighty minutes) of specimen collection followed by a period of specimen examination. I broke with the common practices regarding the teaching of biology in 1993 by developing a month long field project. The biology project was designed originally without detailed knowledge of the concepts discussed in this literature review. It seemed to be an interesting way to achieve curriculum expectations that were not, in my opinion, being adequately dealt with in the classroom. A later understanding of these concepts allowed me to recognize within the project the praxis inherent in the project's development. This project specifically addressed the skills expectations of the curriculum. Certainly knowledge, attitudes and/or STS connection expectations might be achieved by students but these would vary with the individual and have tended in the past to be broader learnings about the nature of science and the environment. One possible benefit of the biology project was the opportunity for students to experience how scientific knowledge was developed.

The biology project I developed included the notion of authentic science as I believed was intended in the 1984 Science Council recommendations. I also believed the project was a form of experiential education derived from the attempt to utilize authentic science. The project was viewed to contain aspects which were supported by a constructivist view of cognition. This chapter establishes my relationship with the current literature and continues to provide a form of bracketing for the critical reader. The topics considered further unfold the "storied" nature of my experience.

Authentic Science

I selected the term "authentic science" due to its presence and recent usage in science education articles rather than for any post-modern connotation or association with the post-modern concept of authenticity. The choice of this term was intended to link my work with the recent discourse in the science education literature. Although the literature called for a shift in science education practices to emulate science as it occurs in society, I believe this had a contextual link.

The strength of the call for authentic science coincided with a shift in thinking about cognition. Authentic science gained popularity as the ideas related to constructivism became increasingly known and accepted. In the 1980s existing science curricula were seen as failing to meet the ends desired socially and economically. Constructivist theories provided a new perspective from which to interpret the situation. Earlier curricula had been content oriented, emphasizing knowledge. Science education was delivered in a didactic manner with limited supporting lab activities using a cognitive model that suggested knowledge could be possessed and transmitted. If knowledge was constructed, as constructivists asserted, this may well explain the perceived failure of science education. The new curricula emphasized process skills and reduced the knowledge component to understanding broad, interrelated concepts. It was thought active participation in scientific activities would enhance students' understandings of the processes of scientific knowledge construction.

Authentic science is problematic. Like the term scientific literacy it does not have a single clear meaning. The term "authentic" poses problems. Authentic simply has too many meanings. Authentic may denote a first hand experience of science. It may refer to an experience which is considered authentic because it is in accord with commonly agreed upon understandings of science. Authentic implies reliability or trustworthiness. To be authentic the experience must then reliably represent what science is. The crux of this problem rests upon who shall define an activity as authentic. Is authenticity defined by the individual student, scientist or teacher, the scientific or teaching community, or others? The use of "authentic science" in science education was never consistently established. This has led to masking differences in conceptualization much in the same manner as the concept "social context" has done in sociological writing (Seddon, 1986).

Martin, Kass and Brouwer (1990) discussed the limitations of the concept of authentic science. Science was seen to be multi-faceted philosophically, historically and socially. In their analysis it became increasingly difficult to define a given activity as authentic. It appeared that it was easier to define an activity as inauthentic by its failure to include the important dimensions of scientific activity.

Gaskell (1992) suggested that the concerns for authentic science education and the remedies offered are similar to those advocated in the 1960's reform. He questioned the effectiveness of the new reforms. From Gaskell's perspective teachers' classroom behaviors are unlikely to change because teachers have a vested interest in the "status, resources and territory of school science." The basic failure he described is related to the discourse of science education that has continued for decades. A fundamentally positivist discourse, it characterizes science in a disciplinary fashion and has created a hierarchy of difficulty for the sciences.

To develop the field project, I had to consider what I believed authentic science would look like in school. In so doing I was not only defining authentic science but interpreting it in relation to my understandings of the curricular expectations. At the time I was not cognizant of the limitations I was creating for students. My later understandings, resulting from conducting research, illuminated these limitations for me.

The elements which would define this project as authentic science were established through the following considerations. Scientists practice science in what my students term the "real" world, a world outside the institution school. A real world in which the scientist, interacting with the environment, perceives the existence of a problem, dilemma, or challenge. Curiously, the coming to existence of a problem as scientists define it will, in turn, define scientists. I believe that scientists are largely, but not completely, in control of their own activities. They interact with the environment to determine and manage the problem solving processes that are to be engaged in. Scientific activities are not arranged linearly, as a journal article might portray, and they defy a fixed methodology. The findings made by scientists may even arise as the result of sheer luck or by a simple error in methodology, as in the case of the discovery of penicillin. Although scientists do not follow a single defined scientific method, in a discipline-bound community scientists tend to agree on appropriate methodologies.

I believe it is popularly assumed that scientists are free to study anything they desire. The degree of a given scientist's personal control is variable, for the practice of scientific research tends to be governed by the presence or absence of financial support. Increasingly science has become associated with research and development departments within the corporate sector and some government departments mandated to conduct research. Funding has become a determining factor for scientists in that it defines the direction of research and the type of research which is acceptable. Gibbs (1996) has criticized the increased mercantilization of science, particularly in medicine and biotechnology, for contributing to "profit minded secrecy" and retarding scientific progress. Industrial scientists are told by corporate superiors which research will be conducted and the type of product desired. Alternatively non-corporate scientists apply to governing bodies for funding support thereby competing with others for limited financial resources. The selection of research to be funded is determined by those persons controlling the funding based on whatever criteria they had been provided with. In either instance the amount of personal control for the scientist is limited.

It was my impression that students did not practice science in the same situation as scientists. Outside the classroom problems were regular daily events; students did, in the course of their daily lives, recognize and define problems. Once in school students rarely experienced the source of the question or problem, and as such were not positioned to identify and define problems. Within the classroom however problems were framed either by a teacher or the writer of a text or lab manual. As a result the essential component of true problems was missing; identifying and defining the problem (Schön, 1987; Qin and Simon, 1990). According to Roth (1992a), the real problem for students became determining what the teacher really wanted from them.

The corporate perspective was not a view of science which I thought students normally experienced. The classroom context did not afford the opportunity to recognize the influence of business decisions on the practice of science. Students were not going to experience in school the ramifications of financial constraints and pressures with which scientists personally engaged. Students could not experience the threat to livelihood and the pressure to "produce" which the scientist might have experienced.

Fundamentally school science experiences tend to proceed along a prescribed pathway. Laboratory experiences are selected and defined to provide support for the particular concepts which have been taught in the class. The materials and methodology have been tested and determined both to be productive and safe for students. There are two primary purposes for school science activities. The first has been to provide an experience which illustrated or reinforced a particular concept. This experience is generally conducted after students had been taught the concept. Occasionally the activity may precede the teaching so as to raise students' curiosity. The other reason for school science activities has been to develop the manipulative and observational skills normally associated with science.

The disconnection of classrooms from the "real world" and the decontextualization of school problem solving might be contributing factors to the students' alternative understandings of science. Studies (Blackwood-Malayko, 1992; Ledbetter, 1993; Rymer, 1995) had found that high school students' understandings of science were markedly inconsistent with the understandings held by scientists and science teachers. Student understandings of science were often school bound, as might be expected given the lack of authentic science in school. Their alternative conceptions were often limited to "science is physics, chemistry and biology" or "science is a subject I have to take in school."

I recognized that the school was not the environment in which scientists flourished. The social structures and community dynamics were markedly different from those of science. As a result of these beliefs I have about the limitations of school science, I had defined the learning situation for my students on the basis that inquiry is the foundation of a scientist's work. I wished to convey the idea that the inquiry scientists engage in throughout their careers is the product of social interaction within scientific culture. This culture includes the present scientific communities and the traditions of the past as well. The standards and expectations set for scientific behavior and manner in the scientific community would form the basis for scientific education. I would attempt to replicate as scientific a community as possible. I felt learning would be more "powerful" if the situation included the conceptual, practical and social contexts of scientific work (Brown et. al., 1989). The American Association for the Advancement of Science (1989) suggested that real-world problems be integrated into curricula as taught. To maximize the potential learning, real-world problems would be identified and defined by students.

Typically, scientists are immersed for a long time in the environment from which the question ultimately emerges. Therefore, in the case of this project a local park which students were known to frequent had been selected as an environment with which a degree of familiarity existed. It was a degree of familiarity which I hoped would allow students to develop meaningful questions for study. Students would then determine the appropriate methods for solving problems. The social interaction of students, living the experience of scientists, would include: dialogue about the existence of the problem or issue being studied, dialogue about the methodologies that were appropriate, discussion about the analysis and interpretations made, and critical questioning about the findings. The learning situation was addressed through use of techniques I had labeled experiential.

Experiential Education

Although in reality all education is experiential, I used the term experiential education to refer to a particular type of educational practice. The origins of experiential education find their roots in the works of Dewey (1938). There might not be an absolute feature that defines a particular activity as experiential education but there are three essential dimensions. These dimensions are:

1. the high degree of learner control over the learning experience
2. the high degree of involvement of the self in the learning process

3. the high degree of correspondence of the learning activity to the world outside the classroom (Boud, 1989; Weil and McGill, 1989).

Experiential education is a form of interactive knowledge creation and might be simply described as "cognitive activity coupled to an appropriate contextual action" (Letiche, 1988).

In my opinion, experiential education is less controllable and more situation dependent, requiring careful thought on the part of teachers. Curricula identify and limit the knowledge considered valuable for teaching. Teachers are then expected to create situations through which students could construct or enact this knowledge. The differences in approach among teachers are largely philosophical. The "traditionalist" might present knowledge didactically with experiences designed to verify the knowledge base presented. Experiments or demonstrations are used after lectures in a manner such as to confirm the factual knowledge transmitted. This approach loses the power of inquiry because the experiential component is limited to reinforcing known answers (Cohen and Harper, 1991). An experiential educator might develop a program jointly with students such that all involved could question the taken for granted ideas and concepts. Such a class would utilize a variety of experiential methods (Henry, 1989). These methods may be appear similar to those practiced in a traditional classroom but differ largely in the philosophy and value base which underlies the approach. This difference is significant for it influences the tactful thought and action (van Manen, 1991) teachers employ.

Efforts have been made to clarify experiential education from theoretical and practical perspectives (Weil and McGill, 1989). The experiential learning model continuing to be in vogue in the literature appears as:

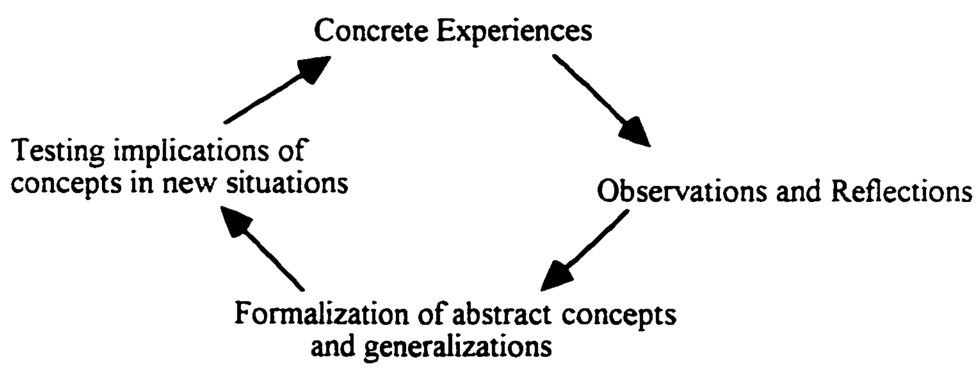

Figure 1. **Contemporary Experiential Learning Model** (from Kolb and Fry, 1975)

This model (Figure 1) provides a limited guide to allow a science educator to develop effective experiences. Learning in an experiential framework is viewed as an integrated cognitive, social and emotional process. Seen as holistic, experiential learning involves the individual physically, perceptually, affectively, cognitively, socially, politically and spiritually (Heron, 1992). Being holistic it was believed by Mulligan (1992) that a variety of internal processors each made a distinctive contribution to learning. These processors included the will, memory, reasoning, feelings, senses, intuition and imagination.

Experiential learning is believed to be best facilitated in an environment where there is dialectic tension and conflict between the experience and analytic reflection (Kolb and Fry, 1975). This is commonly termed a discrepant event. Such an event is thought to be a critical element of discovery. Discovery begins when nature violates by anomaly a personal "paradigm-induced expectation" that governs operative conceptions (Kuhn, 1970). This creates a conflict which is believed to require resolution. The resolution may take various forms (Kuhn et. al., 1988). Personal theories vary in the degree to which they are held, but invariably individuals hypothesize and test for a variety of errors within the experience before reconsidering their theories.

For me the idea of the discrepant event as a learning tool relates to the concept of self-organization (Doll, 1993). This concept held that as the result of perturbations in the environment that were recognized by the individual a transformation of knowledge occurred. According to Bruner and Postman (1973) there were three critical features postulated for this transformative process. The first feature required that the perturbation was not denied nor avoided. The individual must have recognized and accepted the existence of the anomaly. Second, there was no pressure on the individual to "succeed." for such pressure implied the finding of a "right" answer. Finding an answer did not necessarily create new knowledge. This atmosphere allowed the individual to play with the anomaly. Finally there must have been sufficient time for the new knowledge to develop. Although the knowledge may have emerged spontaneously, the time before emergence required a nurturing of the framework for the new knowledge.

It was imperative for me from the experiential learning perspective that students learned to use the methodologies and logic of science in a self-directed experience. This could be described as a cognitive apprenticeship model (Roth, 1991). The basic argument that underlies the pedagogic use of authentic science in an apprenticeship model is that students would learn more about science through doing science. This is, from a teaching perspective, a common sense notion. It is common knowledge that students learn by doing. It stands to reason that if students practiced science in a situation that approximated the use of science in the scientific community they would have a better "grasp" of science. Their knowledge would be greater. This notion is not new for it dates back to time of Socrates and Aristotle (Rakow, 1986).

The logic of science is no longer limited to the positivism of Comte, which had been fundamental to the search for modern paradigm's "truths." Auguste Comte defined a system of philosophy basing knowledge solely on the data of sense experience. Knowledge was based on observable, scientific facts and their relations to each other. Science and scientific knowledge are now thought to be socially constructed (Kelly et. al., 1993). Science is a cultural phenomenon and operates within a social context. From the perspective of experiential education knowledge is constructed by the individual through interaction with the social and physical environment. The discourse of constructivism has influenced discourse surrounding experiential education by providing possible explanations for the processes of knowledge construction personally and socially.

Constructivism

Constructivism has been an important paradigm in science education for almost two decades. True to Thomas Kuhn's (1970) concept of paradigms, constructivism provided a fresh perspective from which to investigate, prompting hundreds of research inquiries. Two differing disciplines of thought have characterized constructivism. The first, psychological constructivism, originated from the works of Piaget and was characterized by two seemingly different traditions: the personal, subjective tradition largely centered on the ideas of von Glasersfeld (1984, 1995), and the sociocultural tradition derived from the writings of Vygotsky (1978). Science education, including research, textbooks and reform programs, has been dominated by this psychological approach. Science education may have been somewhat limited due to its reliance on this school of constructivist thought. Although considerable valuable knowledge developed through this paradigm, it has been failing to offer new directions for inquiry (Solomon, 1994). Viewed from a Kuhnian perspective, psychological constructivism may have reached the point as a "normal science" by the early 1990's at which it offers fewer possibilities for new research and it may be expected that this paradigm will be replaced

The second school of constructivist thought is based on the works of sociological constructionists stemming originally from the concepts of the structuralist, Emile Durkhiem. Social constructionism was articulated theoretically by Berger and Luckmann (1967) and specifically related to science by Latour and Woolgar (1986). Constructionism de-emphasized the role of the individual by instead focusing on social processes and social structures which were believed to determine the beliefs of individuals. Scientific communities, not science education, have been the focus of most social constructionist inquiry into science.

Although formally based in the disciplines of psychology and sociology these perspectives are not mutually exclusive. They are highly complementary and I view them as different layers of investigation. Each tradition recognizes that "science is a creative human endeavour which is historically and culturally conditioned and that its knowledge claims are not absolute" (Matthews, 1994, p.139).

As a science educator I am concerned not only with learning theory but the development of appropriate pedagogic praxis. In this regard the ideas of constructivism become a referent rather than a pedagogy. The ideas I have developed as a result of contact with constructivist theory have altered my teaching praxis. I have adopted a broader interdisciplinary perspective that acknowledges and draws on the strengths of each of the constructivist/constructionist traditions.

Radical constructivism, at one extreme of the personal, subjective tradition, was founded on two principles. Knowledge was not passively received but was actively built. Second, the function of this constructive process was adaptive and served to organize the experiential world; thus we knew the world only through our experiences (von Glasersfeld, 1991). As such cognition did not produce a "true" picture of the "real" world but rather was comprised of heuristic fictions which enhanced the management of experiences. Knowledge therefore needed not be true in a strict modernist sense, but merely personally useful and thus viable.

Vygotskian social constructivists acknowledged this radical stance but relegated it to a secondary position. The social dimension of consciousness was believed to be of primary importance. Social constructivists suggested that language communities played a critical role in the personal subjectifying process (Wertsch and Toma, 1994). Mental functioning from this perspective was mediated by the tools and signs of language. These mediational means served to organize knowledge and action.

The two constructivist traditions need not be considered at opposite extremes of the debate. They too were complementary from my perspective and each may have been seen as constituting "the background for the other" (Cobb, 1994, p.19). I took the position that the social and individual traditions reflected a "layered" view of the constructive process. Experience, beliefs and attitudes were brought to the classroom by the student. These factors "colored" the student's views and interpretations of what occurred in any situation. Students engaged in social discourse which was instrumental in the organization and construction of personal knowledge. To better understand learning a sociological perspective was also needed. The students engaged with social structures in schooling which contributed to their understanding of the world and valued knowledge.

As a teacher, constructivist discourse had influenced me over the past six years. My acceptance of the language of constructivist discourse had altered the way in which I understood knowledge thereby democratizing my teaching practice. Students' ideas which may have been termed "wrong" or "misconceptions" were acknowledged as alternative conceptions. The shift from terms like wrong to alternative was a "softening" of my perceptions of students' ideas. It had increased my acceptance of other ideas. This created an opportunity to inquire into these ideas attempting to seek a greater understanding of the worlds such ideas described. I also believed that this discourse had resulted in a shift in power relations. Teachers could no longer be experts, the source of correct knowledge. Viable constructions existed because they had the ability to explain the realm of personal experience. Being persistent, functional and viable these alternative conceptions were accorded deference and respect (Solomon, 1994). No single construction could be said to absolutely represent the truth.

This acknowledgment was founded on the belief that students' ideas were functional and viable, based on their experience and current understandings of that experience. Alternative conceptions, although viable, are potentially restrictive. Viability suggests that the knowledge possessed fits within experiential constraints. As a result it limits the possibilities of acting and thinking. Referring to the criticisms of science curricula (AAAS, 1989; Alberta Education, 1987,1989) and the studies of student constructions (Ledbetter, 1993; Rymer, 1995), it became evident that the experiences students had in traditional science classrooms might have been limiting the possibilities of action and thought through the students' construction of alternative and potentially limited conceptions of science. For example, students who perceived science as a "subject I have to take in school" (Ledbetter, 1993; Rymer, 1995) were not likely to entertain science as a career, or apply the understanding of fundamental scientific principles to critical interpretations of information presented in media. Students may also have employed conceptions which were "inferentially incompatible" with each other (Kelly, 1955). From my perspective the task of educators became facilitation of conceptual change resulting in expanded opportunities for students.

In science education psychological constructivism and Kuhn's concept of scientific revolution have been instrumental in the development of the pedagogy of conceptual change (Posner et al., 1982). Kelly (1955) believed that teachers have been able to play a social role involving students based on their ability to construe some of the students' constructs. I believe that science educators should understand the legitimacy of the alternative conceptions students hold, then strive to create educative social situations which allow these conceptions to be called into question by students. Constructivist theory, as I understand it, held that knowledge which did not explain experience was normally reconstructed to increase the manageability of experiences. As the concepts were reconstructed the possibilities for action and thought were modified, hopefully broadening the possibilities for the student. This approach to science education was fundamental to the Biology 20 project. I accepted that students would possess viable knowledge about scientific research yet this knowledge may have been in the form of alternative or possibly naive conceptions. Experiences they had through the course of the four week project might provide opportunities for discrepant events to arise which might then have challenged the conceptions held and, given time, allowed for the conceptions to change.

Psychological constructivism adopted an empirical position toward knowledge. Knowledge of the world was limited to experiences of the senses but could include a "mental" sense of thought, which formed the "activities" which could be labeled intentionality. Knowing reality was impossible but "a relatively stable 'experiential reality' could be built up without presupposing an independent world-in-itself" (von Glasersfeld, 1995, p.88).

This raised for me the question, if scientific knowledge was not necessarily about the real world why would we seek to be involved in conceptual change? Did it become impossible to justify the intent of changing student conceptions in opposition to student, parental or cultural beliefs and values? If the student's conceptions were already viable, change may be far from being seen as necessary. I maintained the position that alternative conceptions, although viable, held the potential for being limited and restrictive. The purpose of education then seemed to be to broaden, alter or layer personal constructions of knowledge such that the individual might demonstrate knowledge appropriate to the situation encountered. A naive conception of the relationship between heat and boiling might have been totally functional and necessary for personal safety in most day to day circumstances. This same conception did not explain why the soup was cooler when boiled while hiking on a mountain top or why water carried from Earth in a closed vessel would boil away instantly in the frigid near-vacuum of space. Having an education allows people to apply the better fitting explanation to the situation encountered.

Problems I Encounter with Constructivist Thought

The radical constructivist approach is fundamentally individualistic. The individual is the assembler of knowledge and the arbiter of that knowledge. This raised the question as to why the student should choose to replace one viable conceptual scheme with another. Constructivists claimed it was because experience could not be effectively explained by the currently held concepts. Yet we function very effectively with simplistic "commonsense" notions of concepts like gravity and boiling. It appears that people do not erase these simpler notions when confronted by challenging experiences. Personal conceptions are amazingly resistant to change, and can be likened to an old scientific tradition which resists the new paradigm. People, including scientists, appear to layer knowledge such that commonsense notions are used for day-to-day living and more sophisticated notions are applied in the situations needing them. It seems "trivial" to characterize cognition as simply replacing conceptions of the world or adding simplistic modifications to existing schema. Cognition it would seem is contextual, yet radical constructivism decontextualized it. The social constructionist traditions recognized the importance of context and utilized it in understanding cognition. The human context is primarily social, not individual.

Individual knowledge of science is dependent upon public knowledge. Learned or known concepts are not knowledge merely because they are personally viable but because they are publicly sanctioned. The nature of schooling requires teachers to evaluate the congruence of students' ideas with a publicly sanctioned standard of knowledge. In science these standards have been drawn from a large body of scientific concepts The ideas held for scientific concepts are the result of discipline-bound discourse in science communities. Discourse is based on words and their meanings. These meanings, although arguably constructed by the individual, are learned through engagement with others. It is on this point that the sociocultural tradition separates from the radical position. Based on this approach some science educators had adopted the stance that learning science was a process of enculturation (Driver et. al., 1994). This position, as described, maintained that the "objects of science are not the phenomena of nature but constructs that are advanced by the scientific community to interpret nature" (Driver et. al., 1994, p.5).

I have maintained that the pedagogy which resulted from constructivism was misleading. Driver and others(1994) referred to the pedagogic approach using Bruner's (1986) term "scaffolding" whereby teachers developed a scaffold upon which students build their knowledge. It was curious to me how language betrayed subtleties. Constructivism drew on a metaphor of constructing or building. Certainly one might build alone or in groups, as was acknowledged in constructivist theory. Metaphorically it was reasonable to believe that construction of something complex, like scientific knowledge, required scaffolding. Yet building is rarely a spontaneous activity and most commonly follows a prescribed plan with clear understanding of the nature of the finished product. Examples of constructivist teaching illustrated this (Driver et. al., 1994). Adults in her examples already knew the "truth," the "facts," and had developed a line of questioning to engage learners such that they came to the same knowledge of the world as the adults held. How then was constructivism as portrayed different from the often maligned traditional didactic approach? Teachers were still experts. Students were still required to learn a specific objective. All that had changed was the illusion of passivity. The questions remained, whose knowledge was being learned? Who was learning?

It appeared that when constructivists spoke of conceptual change only students changed. This suggested to me a deeper attachment to the traditional unequal social structures that reside in classrooms. The constructivist model did not explicitly consider changes that might occur for teachers. I have often had insights and new understandings while engaged in the teaching process. These understandings occurred through dialogic interaction with students. Students' interpretations or conceptions often had provided a framework from which to view anew the idea being taught. It would seem, based on my experiences, that both teachers and students may undergo conceptual change as a result of the social interaction. Teachers and students were complicit in teaching/learning for the actions of each had meaning for the other. In essence the classroom contained a teacher-student with students-teachers.

Psychological constructivism provided us with a learning theory suggesting how to teach, but it did not indicate "*what* and how *much* should be taught to *whom*" (Matthews, 1994, p. 145). Authority and power associated with social relationships play significant roles in the educative processes we inflict upon children. Authority has been accorded by society to those in certain positions. In classrooms authority has been vested in teachers and is legitimated by law. The "processes (used by teachers) necessary for public production of authority are hidden from the student" (Gergen, 1994, p.31) thus further contributing to the myth of teachers' authority. Teachers exercise "authority in agenda" through determining the manner of instruction, the pace of instruction, and the subject matter to be taught even though this may be governed in part by a larger social unit (department of education). Decisions are made about personal needs, social needs, the relative merits of domains of knowledge and political ideology when teachers exercise authority (Matthews, 1994). Students engage teachers within a complex hierarchical social structure and are automatically placed in a subordinate, disempowered position. The main task for students becomes determining what it is that teachers want of them. Conceptual change may be little more than passively accepting the authoritative control of "experts," teachers.

For years I have asserted that passive acceptance of authority of the text, state, or another individual diminished humanity. Freire (1970) contended that we should strive for a pedagogy of liberation. This may be applied far beyond the developing world Freire writes about. Children learn the concepts, including scientific concepts, which the dominant social order has defined as valued. By learning the dominant order's language children are entrapped within that discourse and the opportunity for freedom is diminished. To be freed of being "beings for others" students must engage in problem-posing education. The essence of science is problem posing. The opportunity then for liberationist pedagogy in science education exists. Humankind does not live *in* the world as the mind/reality dichotomy of radical constructivism suggests. Humankind live *with* the world through complex relationships. Liberationist pedagogy shifts to a view of a teacher-student with students-teachers dialogically engaging with the world about them. Science education from this perspective would find teachers and students posing questions about the world and seeking to understand possible answers to these questions. The concepts of students are as respected as the concepts of teachers, both are open to restructuring their personal understandings of the world. Concepts are open to critical analysis and the resultant education permits us not to perceive the world as "a static reality, but as a reality in process, in transformation" (Freire, 1970, p. 71). One of the fascinating aspects of the Biology 20 project is that I cannot possibly know the answers to all the questions posed by students. As a result we are mutually involved in the inquiry process. As the projects reach their conclusion both I and my students have changed.

CHAPTER 4
THE TEACHER AS RESEARCHER

Introduction

After examining aspects of educational research, I have the impression that considerable attention had been focused on the teaching process due to the perceived importance of education to children, as potential assets for an industrial society. Accordingly, educational reform movements have swept periodically through the social system seeking to address concerns held for the quality of education. The school, therefore, has been identified as a legitimate site for educational research for about a century (Olson, 1990; McFarland and Stansell, 1993). The primary concern of a significant portion of educational research has been the improvement of classroom practices. The purpose of this research has been to generate a body of pedagogic knowledge, knowledge about teaching. Historically academics and teachers have been separate sources of pedagogic knowledge with somewhat limited contact. Rarely is a person both classroom teacher and academic. Common teacher perceptions hold that academics focus on theory, teachers on practice. The teacher as researcher movement changed this situation to a degree. In writing this chapter I set out to examine the relationship of teachers to research and the development of pedagogic knowledge. In the process I also frame my perspectives and concepts about teachers as researchers.

Pedagogic Knowledge

Although a literal translation of the term pedagogic knowledge is relatively easy, a general consensus about the nature of pedagogic knowledge, or its origin, is problematic based on the theoretical perspective held. One perspective that was evident in the literature suggested that pedagogic knowledge can come to be possessed and transferred to others as theory based on empirical study (Lewy, 1991). Simplistically stated, a knowledgeable educator could pass on theoretical knowledge to a novice through communication and that novice could, by application of the theory, teach.

For the majority of teachers, when questioned about where they learned how to teach, the answer would undoubtedly be, in the classroom. Actual teaching experience is critical to the development of pedagogic knowledge (Britzman, 1991). Several writers addressed the concept of experience in the development of pedagogic knowledge. Elliot Eisner (1982, 1985) believed in the primacy of experience. Knowledge of any sort depends on experience, which he saw as contact with qualities of the environment or the use of imagination. Eisner (1982) maintained that to limit knowledge to propositional discourse about the phenomenal world was to distort reality because knowledge embodied in proposition led to a separation of knowledge into affective and cognitive domains. These domains may not be, and historically have not been, considered equal. Experience, which is fundamentally qualitative in nature is reduced as it is transformed into cognitive discourse. Eisner argued that to limit knowledge to the primacy of the cognitive domain limited our understandings of the diverse meanings knowledge may contain. Pedagogic knowledge would therefore include an intimate intertwining of both affective and cognitive experience of equal and inseparable value.

John Dewey (1938) was an educator for whom experience was of great importance in pedagogic knowledge. Dewey advocated that in progressive education there was an "intimate and necessary relation" between the processes of actual experience and education. For Dewey all human experience was social interaction consisting of two important factors: objective aspects over which educators have some measure of regulatory control, and internal factors that existed within the student. Within progressive education individuals would grow intellectually and emotionally through being involved in experiences that enhanced the formation of attitudes of desire and purpose. This, Dewey said, enabled students to accept the challenge of the next experience of "deeper and more expansive quality." The greater life experience and maturity of teachers placed them in a reasonable position to evaluate the experiences of the young. Critical pedagogic knowledge for teachers included the ability to recognize that experience was shaped by "environing conditions" and the ability to recognize which surroundings would be conducive to students' growth. According to Dewey, teachers needed an intimate acquaintance with all aspects of the local community. These community aspects included historical, physical, economic, and social dimensions. Teachers surveyed students' needs and arranged the appropriate conditions for the students' experiences. Teaching knowledge was gained in a similar manner from teacher educators. New knowledge would be constructed by teachers through scientific investigation of their life world.

Another perspective maintained that pedagogic or professional knowledge was the result of reflective practice based in experience (Argyris and Schön, 1974; Schön, 1987). Schön spoke in terms of people holding theories of action, theories which explained the actions they or others may make. At one level people held espoused theories of action to which allegiance was given in word but might not be found in practice. Argyris and Schön (1974) coined the term theories-in-use to describe the understanding which could be constructed through the observation of action. Theories-in-use contained knowledge of the physical world, human organizations and assumptions about human behavior. People had a great variety of theories-in-use, one for every situation they encountered. This knowledge provided the means to attain chosen ends and maintain constancy in life. Theories-in-use might not be explicitly understood or verbalized. Like Polanyi's (1967) concept of tacit knowledge, theories-in-use were more than could be explained and more than behavior could show.

Although there is implicit acknowledgment that teachers gained pedagogic knowledge through experience there is little understanding of how this occurs (Russell and Munby, 1991). It seemed that theories-in-use were applied by teachers to classroom activities until a puzzling situation occurred for which the specific theory-in-action did not appear to work. Through a process Schön (1987) termed reflection-in-action, teachers contrasted the known with elements of the new situation and attempted to redress or revise the theory-in-use. It was essentially a process whereby the theory-in-use was reframed within the context of the puzzling situation. Once revised, action was continued. After the action was concluded there was opportunity for reflection on reflection-in-action and the generation of new understanding or knowledge. Russell and Munby (1991) contended that the reframing process was virtually impossible to observe but evidence of its existence was found in the new generative metaphors that were used to describe the understanding the teacher had.

Neo-Marxist literature provided another perspective of pedagogical knowledge. For the neo-Marxists schooling was a socializing rather than educative agency, and was seen as a direct form of social control (Harris, 1982). It was this control function that featured predominantly in pedagogic knowledge. Teachers were seen as "professional consciousness manipulators" and education as a "perception-altering drug" (Harris, 1979). Teachers were non-productive workers, set within the middle class to develop the labour process for the ruling capitalist elite while being supported by the exploitation of the worker through surplus value. Knowledge was of two types, non-theoretical, facts found in reality used as the base for social constructions, and theoretical, the ideas used to construct interpretations of reality. For Harris (1979) one must have had a theory about something to observe or work with it. Teachers therefore had theories for what a student was and should be. As teachers had been co-opted from the working class into the service of the dominant elite they held the theories that the elite deemed to be desirable. It was the teachers' task to transmit portions of that valued knowledge to children. Transmission included both content and process with students learning from both. Teachers were required then to possess pedagogic knowledge of what to transmit (content) and how to control the transmission (process). A significant part of pedagogic knowledge, from this perspective, would be how to exert and maintain control or domination over the behaviors of children. The result of this learning experience produced a certain kind of knowledge which distorted the students' view of the world through manipulation of consciousness such that a false consciousness was created which served the ruling class.

On the basis of my reading it was clear that pedagogic knowledge was not commonly understood. It was also clear however that there was a relationship between theory and practice. Theory informed practice, practice alternatively informed theory and there was a curious interwoven form of mutual interaction that was understood as praxis, for which there was not a suitable English translation. The notion of praxis was particularly appealing to me and was adopted in my reflections on my teaching.

Dominant Paradigms of Educational Research

A large portion of educational research, particularly in the last two decades, has been dominated by the process-product paradigm (Shulman, 1986). Recent discourse surrounding this paradigm has focused on teacher effectiveness literature. Teaching is viewed in this paradigm as a linear activity whereby teaching actions have a causal effect on student outcomes, particularly achievement. This resulted in the teacher being described critically as either a technician (Apple, 1986) or an executive (Fenstermacher and Soltis, 1986). Teachers were even seen to be acting outside the teaching/learning process, being more concerned with regulating the content and student activities (Fenstermacher and Soltis, 1986). In either case teachers were believed to manage student outcomes through the application of generic pedagogic knowledge. This knowledge has been based on empirically determined academic knowledge gained largely through positivistic research conducted by researchers from outside the classroom. It resulted in a form of technical rationality.

In research based on this paradigm the teacher was relegated to the role of a subject, little more than a guinea pig or lab rat, whose behaviors were "objectively" observed and evaluated, then related to a quantitative output. The results of such research were commonly limited to academic discourse. When the research did come to teachers it was often imposed by the authority of administrative structures as a means of generating improved student achievement. Understandably such research was perceived by teachers as something done to them. Pedagogic knowledge was divorced from the teacher and held within academic circles supported by volumes of quantitative data. Traditionally pre-service teachers had been informed of this knowledge through theories presented by teacher educators with the intention that this knowledge would be applied in their subsequent practice.

Shulman (1986) identified a second paradigm he termed "classroom ecology" which drew on the qualitative tradition of the social sciences, particularly sociology and anthropology. This paradigm viewed teaching as a complex, situation specific, interactive process characterized by differences at all levels of school structure. The studies that make up this body of research included teachers in two possible roles, subjects or limited collaborators. In either case the knowledge generated from the research was again destined for academic discourse. This paradigm, like the process-product paradigm, located pedagogic knowledge ultimately with the academic for the purpose of informing pre-service teachers of these theories. Again it was envisioned that the theories presented would be drawn upon by teachers when acting in the course of their practice. The insights of this discourse were, in some cases, slightly more accessible to teachers due to the nature of the language used or through case study descriptions. This discourse continued to "construct and determine teachers' roles in the research process, thereby framing and mediating teachers' perspectives through researchers' perspectives" (Cochran-Smith and Lytle, 1993, p. 7).

Knowledge has come to be associated with powerl. The circulation of power in a social body creates sites where knowledge is formed. Knowledge then may be used as a form of control and subjugation. Academic attempts to definitively guide the practice of teaching repeatedly failed to include the pedagogic knowledge teachers possess (Wittrock, 1986). The tendency to define "valued" pedagogic knowledge within academic circles effectively diminished teachers' knowledge. "The centralization of decision-making power in the hands of educational experts results in the reduction of teachers to mere executors of the experts' conceptualization of the teaching act" (Kincheloe, 1991, p.77). This opinion was consistent in my estimation of the contemporary understanding of teachers and teaching demonstrated by school administrations, governments and the broader public.

Indeed, Kincheloe drew a harsh, yet appealing, analogy between teaching and its workplace, with a Third World culture. Teachers operate within hierarchical power structures with scarce resources and traditional values. They are the disenfranchised, disempowered peasants whose primary preoccupation is survival. Cochran-Smith and Lytle (1990, 1993) also described teachers as disenfranchised. Based on the two paradigms described, the "valued" pedagogic knowledge had been based on academic research while ignoring the contribution of teacher knowledge, thereby disenfranchising teachers. An investigation into teacher research in South Africa (van der Westhuizen, 1993) suggested that the paucity of teacher initiated research was proof of the extent of teacher disempowerment. When viewed against the context, oppressive structural factors (including the positivistic research tradition, authoritarian decision making within the educational system and curriculum development based on academic and bureaucratic input) were seen to contribute to this disempowerment. Van der Westhuizen went on to identify the culture of isolation within which teachers operate as disempowering. Teaching is generally conducted in isolation from others with limited opportunities for collaboration. Further, there is considerable pressure for teachers to conform and be socialized in a particular manner which does not necessarily value research and may even be described as anti-intellectual. Our culture, including that of teachers, favors expert knowledge over community knowledge, empirical and scholarly inquiry over other forms of inquiry, and tends to hold theory as predominant over action (Bishop, 1993). It is therefore understandable that teachers' knowledge is not considered valued pedagogic knowledge.

Teachers as Researchers

The question then arose for me, did teachers have a role in educational research? Belanger (1992a) suggested that teachers may play a variety of roles. Teachers may be the subjects of research or act as junior partners. These roles were common to the two paradigms discussed. Teachers may however operate from the basis of two additional roles not encompassed by these paradigms: as equal research partners or as primary researchers. Belanger also identified a unique role that may occur in either of these manners, the teacher/graduate student. The role of equal partner was the product of the realization by many academics that teachers brought valued knowledge to the research, particularly insights into the classroom and theories, that were not readily available to the academic. The newest and most promising role for teachers in research was that of primary researchers.

Academics struggled with a definition of teacher researcher and some discounted it before even considering a definition (Pine, 1992). Certainly teacher research was still seen by many academics as marginal or "fringe" (Krasnow, 1993). Patterson and Shannon (1993) saw teacher research as a process through which teachers sought to understand "particular individuals, actions, policies, and events," or those aspects of their work environment that posed situations which required professional decisions. Frequently teacher research was equated with action research depending on the understanding of the academic (Elliott, 1991; Boomer, 1987). For others action research was a special form of emancipatory collaborative teacher research (Carr and Kemmis, 1986; Kemmis and McTaggart, 1988). Boomer (1987) saw action research as deliberate, group or individually owned, conducted and oriented to solving a problem. I adopted the position that action research was a particular form of teacher research characterized as emancipatory and collaborative. Lacking these two components I did not perceive my research as action research. This decision contributed to limitations which I will deal with in my conclusion.

The definition I adopted, due to its simple yet accurate description, stated that teacher research was systematic, intentional inquiry conducted by teachers (Lytle and Cochran-Smith 1990; Cochran-Smith and Lytle, 1993). By systematic they suggested that information was gathered in an ordered manner. Intentional indicated that it was an activity that had been planned, as opposed to spontaneous information gathering teachers may use. Inquiry suggested that the process of research originated from a question and "reflected teachers' desires to make sense of their experiences."

What has been lacking in educational research has been teachers' voices. Research and academic discourse were mystified and the language reified in manners that made it largely inaccessible to teachers. Terms like hermeneutics and heuristics, although descriptive and useful in academic discourse, are from a vocabulary divorced from the practical realities of the classroom. As such, most teachers choose not to invest the time to unfold the intricacies of the language given the demands upon their time. Discourse that is inaccessible to teachers is not going to have a direct influence on classroom practices. As the intent of much of research was initially to improve those practices it is unfortunate that teachers would not be able to make direct use of the information. Academics favouring a more active presence of teachers' voices in discourse advocated for teachers to take on the role of researcher in their classroom to demystify and democratize research (Stenhouse, 1975; Britton, 1987). Mystification was less likely and the processes of mystification were revealed when teachers were actively involved in research processes. Research is democratized when anyone is allowed to realistically test the truth of claims that might be made (Makedon, 1989). Through conducting research teachers might find what was common between deliberate research and the day-to-day judgments they made. Britton (1987) suggested that we were all researchers in our ordinary modes of operating. Mystification by academics was seen as preventing teachers from recognizing this (Britton. 1987; Stenhouse, 1975).

It was this body of commonality that recurred in supportive arguments for teacher research (Stenhouse, 1975; Ruddick and Hopkins, 1985; Bishop, 1993; Stansell and Patterson, 1987). The theories teachers had developed and used in the course of their daily activities were seen to have characteristics and functions in common with academic theories. Both sought to explain phenomena, guide actions and generate further questions for inquiry. As such teacher research was seen as a viable, although markedly different genre of research. I believe that theory building, albeit often implicit, is fundamental to teaching.

However, given the commonality between research and normal teaching practices, there were distinct differences that concerned some academics. Critics suggested that teachers did not bring the same knowledge to research that academic researchers did (Applebee, 1987; Queenan, 1988). Academics possessed methodological skills and training in specific disciplines. Neither of these critics however denied the value of the knowledge a teacher could bring to the research process. They suggested that the teacher and researcher should develop a symbiotic collaboration but keep the teaching and researching separate. I disagree with this notion and argue that the concept of the "barefoot researcher," a teaching professional trained in the methodological skills of research and with the theoretical knowledge base, is quite possible. There is no need to divide the labour as these critics saw necessary; however this is not to discount the power of collaboration.

Clearly the critics have not denied the role of the teacher in research but suggested that collaboration was the proper approach. This argument appears to be rooted in the belief that teachers are not capable of disciplinary rigour which academics bring to research. Indeed rigour was the central issue of criticisms. The consolidation of disciplinary rigour within the teacher as a researcher was not seen as plausible by the critics (Patterson and Shannon, 1993). Patterson and Stansell (1987) had attacked this position as they saw it to be based upon positivistic assumptions and stereotypic definitions of teacher and researcher. The notion was positivistic in that research was characterized by the critics in such a manner as to suggest it was "rooted in distinct disciplines," each of which was presented as "discrete, never-changing absolutes." The researcher was seen as an "objective observer" removed from the process observed. Teachers, being intimately related to the process being studied and interpersonally involved with the participants were too close, too involved and could not see the "big" picture (Pine, 1992); thus they could hardly be viewed as objective, and were therefore "imperfect researchers." Patterson and Stansell (1987) stated that neither role was truly pristine nor discrete. Each participant in the collaboration brought their distinct subjectivities to the effort. Both teachers and researchers possessed diverse experiences which might benefit or hinder the research process. Patterson and Stansell concluded that the teacher researcher could neither be a traditional researcher nor a "stereotypical expert-practitioner."

Academics advocating teacher research recognized that teacher were uniquely, if not ideally, situated to conduct research (Stenhouse, 1975; Stansell and Patterson, 1987; Martin, 1987; Elliott, 1991; Belanger, 1992b). Teachers were in the "lab," the classroom, daily and thus were far less of a perturbation to the research than an external researcher

They were intimately knowledgeable about the room, the children and the community. Teachers also held pedagogic theory rooted in experience. Teacher research was seen as an opportunity to develop practical theory separate from academic theory (Schwab. 1969).

The primary concern of educational research remained the improvement of classroom practices. Pedagogic knowledge was rarely addressed however. Teachers' knowledge was admittedly different than that of academics but what did it include? Due to the context of teaching, teachers' pedagogic knowledge was understandably more complex than others realized.

Relating Teachers' Pedagogical Knowledge to Research

Pearson (1989) stated that one cannot be engaged in practice in ignorance. He identified five types of knowledge teachers must possess to practice teaching. The first he termed causal knowledge. This type of knowledge was based on the causal theory of teaching which stated that a relationship existed between teaching and learning such that "a teaching action may be a causal factor of learning." It recognized that not all teaching results in learning and that not all learning is the result of teaching. Teachers did however understand that certain actions on their part may increase the likelihood that learning would occur for their students.

The second type of knowledge was called normative knowledge. This dealt with values. For Pearson, teachers brought to their teaching practice what they claimed to value. Although used in a variety of ways it may most easily be described through the use of goals. Goals suggested the values teachers held that set the standards to be achieved and defined the teacher's intentions. The source of this knowledge was varied, arising internally or under external influence.

The third type of knowledge, experiential knowledge, might have included the first two types of knowledge. Rather than characterize the nature of experiential knowledge Pearson described its source. He drew an analogy to Schön's concept of reflection-in-action (1987). The example given involved the teacher who changed strategies in mid-lesson because s/he sensed the initial strategy was not working. Experiential knowledge separated the teacher most significantly from others.

The fourth type of knowledge, subject matter knowledge, was rather self-explanatory. Simply this was the content that would be taught in a given lesson. Pearson limited his discussion of subject matter knowledge to its content component. This knowledge was not so simple when I considered it. I felt subject matter knowledge was different for each teacher dependent upon its intuitive, tacit and in-dwelling aspects. The greater the length of time a teacher had dwelt within a body of knowledge or community of discourse, the greater the subject matter knowledge and story that was associated with it.

The final type of knowledge was termed general knowledge. General knowledge encompassed all the learnings gained as a result of living, therefore it was not unique to teachers. Teachers needed to possess a broad general knowledge. They then had to work to enhance their students' stocks of general knowledge.

I believe that pedagogic knowledge maintained in academic discourse may inform some of the types of knowledge teachers hold. For instance, teacher effectiveness discourse may inform teachers' causal knowledge. Some academic discourse, Freirian for example, may inform normative knowledge. Academic pedagogic knowledge is limited, however, in comparison to the pedagogic knowledge of teachers. This is especially true as teachers draw heavily upon their experiential knowledge while in their practice and this knowledge is not directly informed by academic discourse.

Due to the nature of teachers' pedagogic knowledge it is important that teachers be involved in research. Stenhouse (1975) and Elliott (1991) claimed that curriculum research and development were the jurisdiction of teachers. Teachers may provide a truly emic perspective on learning processes. Research can offer hypotheses for testing and strengthen teacher judgment (Ruddick and Hopkins, 1985). As the classroom is a microculture created jointly over time by teachers and students, teacher researchers may address the complexities of classroom life and consider their situational decision-making (LaFleur, 1992). Through inquiry teachers may make contributions to their own knowledge, that of other teachers and academics as well.

Cochran-Smith and Lytle (1993) described how teacher research would generate knowledge for individual teachers relative to concerns about their own practice. They believed that teachers would understand how they and their students co-construct learning and curriculum in their own context. This would lead to further curriculum development. The relationships of the classroom to broader communities might then become apparent. Rationales for altering practice and the consequences of such change became understood more fully. Moreover, research developed a conceptual framework for the practice of teaching and student learning.

Generation of local knowledge is not limited to the individual, for it would influence the immediate community of practitioners. It provides, through sharing of ideas and collaboration, contextualized knowledge specific to a certain community of teachers. This informs curriculum development within that community. It also builds upon relationships between classrooms. Cochran-Smith and Lytle (1993) believed that conceptual frameworks were co-constructed for teaching, learning and schooling.

Public knowledge was also enhanced when teachers shared their research and knowledge across the profession. This knowledge informed curriculum, relationships between the classroom and community including cultural and institutional aspects, and generated new questions for inquiry. This had effects on professional growth and thought. It was conceivable and desired by some that teacher research would lead to school reform and social change (Kemmis and McTaggart, 1988; Kincheloe, 1991).

Approaches to Teacher Research

The growing acceptance of teacher research as a legitimate genre of research was made possible by the increased acceptance of qualitative research and the use of case study. Acceptance of qualitative research had influenced the academic community considerably, allowing for movement away from the once dominant quantitative tradition. Case study had been particularly influential on teacher researchers because it restored perceptiveness and accessibility for the reader. Teachers could rapidly and at depth interpret the situation described such that they may compare and contrast it with their own experience. Case study also restored prudence, the ability to discern courses of action, practical wisdom, or discretion (Ruddick and Hopkins, 1985). It provided documentary reference for collegial discussion and critique. Teachers have also developed, through theory and practice, a "strong, coherent conceptual basis for conducting case-study research" (Belanger, 1992b).

The discourse on teacher research has not reached a clear consensus on the type of research teachers may engage in. The dominant purpose of educational research has been the improvement of classroom practices. In a review of teacher researcher literature Hollingsworth (1992) stated that "all teacher researchers are concerned with improving their practices, changing the situations in which they work and understanding their practices within the larger society." Borrowing from Habermas' tri-paradigmatic framework (1972), teacher research may be categorized, but a hierarchical association should not be inferred.

Some writers advocated that teachers pursue an empirical-analytical inquiry orientation or, more simply, a technical orientation (van der Westhuizen, 1993; Belanger, 1992b). The technical kind of research addresses the questions "What can I do and how can I best do it?" The dominant focus is how instruction can be organized to optimize student learning. Language arts teachers have adopted teacher research as a means of improving their teaching practice. Their writings comprise a large portion of contemporary teacher researcher discourse.

Margie Krest's (1990) study of writing is an example of the technical approach. In this study she was concerned with examining her own growth as a writer and investigating how this growth influenced her teaching. Her personal reflections led her to adopt teaching processes that were derived from reflective issues she had identified. Another study by Ruth Knudson (1990) sought to determine how much help is "too much" in teaching writing. Through research and investigation of theory she developed hypotheses which she tested and shared with colleagues.

While examining teachers' technical research an interesting study conducted by Judith Boyce (1987) caught my attention. She studied her grade six students' comments about her responses to their journals. Using students' comments to evaluate her teaching she found that responding in personal anecdote was more powerful than responding with questions intended to improve the students' work. These findings struck a chord with my teaching experience in which I had discovered the same thing in a grade five class, the power of anecdotal responses for students who believed they could not write. This illustrates for me the power of case study as a communicative tool for teacher research as it allows for the comparison of experience.

The second of Habermas' categories, situational interpretive or practical inquiry, seeks to answer questions like, "What should I do and why should I do it?" It is an inquiry into meaningful descriptions. This kind of research is less common than technical but it appears more frequently in contemporary literature than it did in the past.

Rhonda Kanevsky (1993) highlighted a descriptive review technique that was used as a way of knowing individual children. Through description and questioning, teachers came to an understanding about a child. The insights and theories developed about individual children were thought to inform the teachers involved about children in general by creating a rich body of knowledge. The process helped the teachers understand what was important to an individual child, the standards the child held and the contexts for meanings the child had. Based on the experience teachers could then suggest recommendations to each other on how best to support the child's learning.

From Hollingsworth's (1992) perspective both technical and practical teacher research comprised studies for the purpose of improving curriculum and practice because they contributed to "actual change-in-action." She concluded that such studies changed the manner in which teachers were perceived as curriculum developers and contributed to teacher empowerment. Hollingsworth claimed that research was conducted by teachers to cause social change through either professional and structural critique or societal / emancipatory reform.

The last of Habermas' categories includes critical reflective inquiry or emancipatory research. Some researchers (Carr and Kemmis, 1986; Kemmis and McTaggart, 1988; Tripp, 1990) suggested that only when teacher research was conducted in the emancipatory manner was it considered to be action research. Topics for critique included existing structures: privilege, hierarchy and personal territories.

A teacher, B.B. King (1990), recommended that to overcome cultural forces which conspired to silence students, teachers should combine research and emancipatory pedagogy (Freire, 1970, 1993). He involved his biology classes in a process which allowed students and himself to collaborate in the development and investigation of critical questions posed in regards to a nearby toxic waste dump. He found this to be a powerful tool in the creation of critical thinking skills and active social change.

Transformative results have tended to be personal, less public (Hollingsworth, 1992) and certainly more localized. Emancipatory change of entire schools had not been identified but numerous collaborative emancipatory projects exist within schools and individual classrooms. It is clear to me that teacher research is considered among the possibilities for advancing educational reform.

A Typology for Teacher Research

In reviewing teacher researcher literature relatively extensively it was clear that teacher research was, like most educational research, focused upon classroom practices Certainly the primary professional focus of the teacher is the classroom. Calhoun (1993) suggested that research could be located in individual classrooms or collaborative ventures in several classrooms. School-wide inquiry was also identified as a possibility if the entire faculty was interested in addressing problem solving organization, or student equity. I was frankly angered by this limited perspective for teaching is, for me, a lifestyle and the life world of the teacher extends well beyond the classroom, even beyond the school. One is still a teacher in the hallway or on the playing field. Teachers inhabit the lounge and cafeteria. Teaching haunts teachers on the drive home, in evenings of marking and even in their dreams. A secondary school teacher might conservatively teach two hundred students per year to as many as three hundred. After a thirty year career it is little wonder that teachers frequently encounter former students, for they have taught the equivalent of the population of a small town. Such chance meetings in public places are part of teaching life and can be awkward given that students are often no longer recognizable. Teachers' life worlds are expansive and therefore it seems unreasonable to limit teacher research to only the classroom. It may be informative for teachers to investigate other areas of their life experience that may raise questions.

Wilfred Carr (1989) argued as well that teacher research could not be limited merely to the improvement of teaching practices. Drawing on Schwab (1969). he advocated that relying on technical language (the language of the theoretic which dominated educational discourse) fragmented educational thinking thereby impoverishing teachers and limiting their capacity to face the problems of their work. Instead Carr suggested that we shift to a language of the practical as Schwab advocated. This is a language concerned with choice and action. It is appropriate for thinking about how to act in situations to realize goals or ethical values. Teaching is a "practical" discipline and requires a language which allows teachers to make informed ethical decisions about specific situations. In essence Carr had adopted the perspective, as have others before him, that teaching is an art.

In this book edited by Carr, several of the authors argued sympathetically for the expansion of teacher research beyond the classroom (Lawn, 1989; Golby, 1989). These authors contended that teaching was impinged by structural factors (rules and regulations), as well as contexts of power and control beyond the classroom. They advocated that teacher research should investigate the influence of these factors on the education process. The result would be an empowerment of teachers and the resultant social change may contribute to an increased quality of education. Adelman (1989) in the same book argued that teacher research should be expanded to attain Schwab's goal of a practical language so that teachers improved the quality of education.

These suggestions to expand the realm of teacher research are a slight improvement on the limited perspective referred to commonly in the literature. To limit teacher research to the improvement of classroom practices is analogous to limiting scientific research to improving technologies for the quality of human life. Scientists would rebel at such a thought.

In response to the narrowness of current thoughts on teacher research from academic discourse, I developed the following typology (Figure 2). This typology was designed to capture the broadest spectrum of research possibilities. Teacher researchers may desire to study themselves in the context of their classrooms or within a larger community. They may study other teachers in these contexts as well. Studies of students would most commonly be limited to classroom or schools, but activities such as the Biology 20 field project require that the students be involved outside the confines of the school.. Other teacher researchers may wish to interact with students on field trips, at conferences, or sports activities. People other than students and teachers (parents, administrators, community members) could also form the basis for research possibilities. In keeping with the ideas of Lawn (1989) and Golby (1989) the curriculum and social structures might also be investigated as they relate to education.

This typology is more inclusive than the typical model that suggests teacher research should be conducted to improve teaching practice. I realize however that teaching is a profession oriented to the practical and is extremely time demanding. As a result it is unlikely that many teachers would become involved in the broader spectrum of this typology. There may however be a few who have the time and interest to tackle research questions beyond the realm of classroom practicalities. Teacher researchers may choose to be concerned solely with pedagogic theory or they may seek to gain an understanding of praxis. It is for this reason that I believe this research genre must remain open to the broadest range of possibilities.

Teacher Researcher Interacts With:

Context of Teacher Researcher	Self	Teachers	Others	Curriculum	Social Structures
Classroom					
School					
Community					

Figure 2. **A Typology for Teacher Research**

It has been recognized that teachers would most likely conduct and value research in a different manner than their academic counterparts. A two year study of a teacher research group found considerable differences between the manner teachers adopted toward classroom research when compared to academic researchers (Schecter and Ramirez, 1991). They found that teacher research was motivated toward creating theories of practice, seeking to identify what worked well in classes. This research sought to be generative and responsive to the needs of students. Although this research may inform academic discourse and the evolution of the teaching profession it was different from the nature of academic research. Where academics had to demonstrate the contribution of their work to an established body of knowledge, teachers did not see this as necessary.

Teachers did not recognize the traditional norms for reliability and validity judgments and were content to use experience as sufficient validation. For the academic this was unheard of. Academics needed the investigation to be problematized whereas the teachers did not see this as a necessary condition for research.

Elliott (1991) maintained that teacher research originated with teachers and must be developed by teachers. He accused academics of "hijacking" the discourse thereby imposing "academic imperialism." Teacher research is undoubtedly a different genre of research and needs to be developed by teachers. The decisions about the rigour that is acceptable and appropriate methodologies should come from teachers. The critique of teacher research should rest with teachers so that appropriate standards may be created collectively. The status and value of the questions investigated should be determined by teachers. Research requires a public sharing of the findings. This communication is essential for transforming knowledge. The means and manner of acceptable dissemination should again rest with teachers. In the area of educational research many academic researchers are, or once were, teachers and as a result have much to contribute to the discourse. The genre of teacher research would benefit markedly from a sharing between teachers and academics.

The Impertinent Question

Peeke (1984) asked the "impertinent question" (Queenan, 1988), "If good reasons exist for teacher involvement in research, why is it not more common?" Certainly from the perspectives given that see teachers as disenfranchised, disempowered and preoccupied with survival, research is the last thing teachers might wish to consider. Time is certainly the greatest limiting factor (Stenhouse, 1975; Russell, 1993; Vulliamy and Webb, 1991; Cochran-Smith and Lytle, 1993). However the time spent conducting research in the classroom might be seen as effective teaching time (Russell, 1993; Stansell and Patterson, 1987) or valued use of time because of the benefits accrued (Belanger, 1992b).

Part of the problem rests with the traditional attitudes held by teachers toward research (Ruddick, 1985). Research has been seen as the property of the university sector. Certainly the language of research discourse have proved an obstacle. There has not been a great concern for transmission of research to teachers and research is often seen as irrelevant. A change of attitude is necessary.

Such attitudinal changes can only occur if they were supported by the academic community and administrative structures. Given that there is a culture of isolation for teachers, there are many "effective, thinking teacher researchers but not many thinking schools" (Vulliamy and Webb, 1991). Administrations may contribute to a climate that fostered research in "thinking schools" by showing interest in research efforts and encouraging staff to test ideas (Bennett, 1993). School libraries may invest in appropriate journals and district offices may circulate updates on current research. Teachers should be encouraged to go to conferences and enter graduate programs. The academic community could support administrative efforts and stimulate the process through developing research skills and attitudes in pre-service teachers.

Ethics

The last topic to be considered involves the ethical concerns related to research. I found that many of the ethical concerns relative to teacher research were the same as those involved in any case study research or educational research (Simons, 1989; Burgess, 1989a, 1989b). These common concerns included what Burgess termed researcher relations and dissemination. Concerns for informed consent, freedom from deception, confidentiality and privacy were related to research relations. Confidentiality and anonymity were dissemination concerns. Ethical standards exist for all of these concerns in academic circles. Rather than "reinvent the wheel" teacher researchers are wise to adopt these standards for behavior. In this study I adopted the standards of ethical behavior that were currently acceptable in the research community.

I feel that the primary ethical obligation of research is to benefit students. As teachers are responsible and accountable for the educational process in their classroom, as well as responsible for the ethical research act, there should not be a conflict (Ruddick and Hopkins, 1985). It has been suggested that the ethical problems for teachers and researchers were the same (Isakson and Boody, 1993). This is not to take these ethical concerns lightly but to recognize that teachers are in a position which recognizes the importance of ethical guidelines. As I prepared for this research there were ethical concerns which I felt differed from those of an external researcher.

Teachers are obviously inside the organizations they study. This makes it difficult to escape direct criticism for the findings of the research should colleagues take exception to those findings (Simons, 1989). Commonly external researchers leave the research context at its completion, but a teacher researcher continues to work with students and colleagues. Such a position required the teacher researcher to operate in manners which are thoughtfully considered and respectful of others' rights.

Another ethical concern exists relative to emanicipatory research. There is a reasonable question as to whether some emancipatory research ventures are little more than indoctrination of a captive population (Kelly, 1989). Kelly's concern was relative to a specific example of feminist research which sought to increase the participation of girls in science and technology. She concluded that the researcher had the right to intervene but that this action was taken from a privileged position and considerable negotiation was required to diminish the threats of unethical behavior.

A serious ethical concern exists for teacher researchers in the dissemination of their research findings. I am intimately aware that teachers are directly associated with specific school boards, specific schools and specific classrooms. Any dissemination of research findings may cause attention, some of it unwanted, to be focused on the board, administration, school staff or student body. Anonymity is much more difficult to provide and in many instances it is impossible to guarantee. Each case would have different levels of concern for anonymity depending upon the scale of the study and the context. Teacher researchers should carefully consider the potential ethical implications of the publication of their findings.

The ethical concern which I spent the greatest amount of time addressing involved the maintenance of voluntary participation. I believe there is an inherent risk in teacher research for students to participate, not out of voluntary informed consent, but out of fear of how power may be exercised by the teacher. Student participation may be granted to appease the teacher due to fear of the teacher's ability to evaluate and ultimately assign grades. Participation may conversely be provided to help out a teacher students like. Students are inherently a captive population. This is true for any researcher but the classroom teacher has a greater potential to affect the student's success in school than does an external researcher. This is a serious consideration and students must be assured of their freedom to choose. Parents must also be assured that students' participation is truly voluntary. I found parents could be effective allies in assuring students were aware of their freedom. On a minimum of five occasions I stressed to students that they were not obligated in any way to participate in the study. They were equally assured that should they change their minds they could choose to withdraw from the study. Now this position is that of a researcher, for as a teacher I do make use of coercion. The students do not have a choice in taking part in the field project; it is an evaluated part of their biology program. To not participate in the project would be a reckless move due to the moderately heavy weighting factor it carried toward their final grade. For the teacher researcher there are definitely competing and contradictory subjectivities to be attended to.

Conclusion

The need for educational reform is generally acknowledged. The direction this reform should take is at best controversial. Educational research has attempted for a century to provide some insights and guidance for educational reform through studying classroom practices. Teachers had finally gained a voice in this discourse through the teacher researcher movement. Through teacher research and the associated discourse teachers may contribute to pedagogical theory as well as practice. This movement also holds the promise of professional development through empowerment. It is clear that teacher researchers will be a breed apart, neither stereotypic academic researchers nor stereotypic teaching professionals.

CHAPTER 5
METHODOLOGY

Qualitative Research

A research question defines the appropriate methodology by its very nature. In the problem posed, to interpret the meaning of scientific research as it was understood by senior high school biology students engaged in a self-directed investigation, a descriptive response conducted with qualitative methodologies was required. Qualitative methodologies are founded on the belief that reality is multiple, constructed and holistic (Lincoln and Guba, 1985). As I assume this belief about reality to be reasonable and functional, students involved in this study would not necessarily have identical understandings of research and inquiry processes due to their varied life experience Following from this it was reasonable to apply qualitative methods. Qualitative methodologies seek to interpret the data obtained into a coherent whole (Gubrium, 1988), yet it must be realized that "those who participate directly in qualitative research, who are physically, intellectually, and emotionally present in the research context, and who hear the interplay of voices for themselves are those for whom the understandings are most vivid and meaningful" (Oldfather and West, 1994, p. 23). From my perspective the challenge of qualitative research is to provide readers sufficient information such that they may develop their own vivid and meaningful understandings of the experience conveyed. Qualitative research embodies for me both deep structure and creative freedom.

I termed this a descriptive study based on a description of such studies outlined by Nisbet and Watt (1984). A descriptive study deals with a specific instance, the most common example being termed a case study. The choice of a descriptive format was based on the following advantages outlined by Nisbet and Watt (1984) and Adelman et al (1984). Descriptive studies have the ability to reflect reality and the uniqueness of the context in which the studies were conducted. A descriptive study is easily understood by a wide readership because it might be immediately intelligible. It also strongly outlines a reality which may be in harmony with the reader's experience. The data used in the description are in a publicly accessible form such that readers might judge the interpretations made by the researcher. As the description reconstructs reality in a particular situation it might provide suggestions for the interpretation of similar cases elsewhere. A descriptive study permits readers to recognize the complexity of the situation studied for it represents the discrepancies and the conflicts between viewpoints. Finally, this methodology is particularly suited to the single researcher.

Like any methodology, this methodology has some disadvantages. It is not likely to be generalizable beyond intuitive judgments about similar situations. Questions of subjectivity and the influence of the researcher's perceptions on the conclusion may be raised. However, I feel both these concerns are true when examining any scientific endeavour. The latter disadvantage is recognized as the basis for positioning the researcher and is discussed later in this chapter in reference to the interpretation.

The Study Population

This study was located in an urban high school with a total population of about 1100 students in grades 10 through 12. The school is located in a growing "bedroom" community located near a major city. Although originally a farming centre most employment in the city is service related. There are no major industries located in the community. Most residents are employed in the larger urban center twenty-five kilometers away. The school and indeed the urban area is predominantly middle class in make-up and possesses a racial homogeneity typical of small town or rural Alberta. Although culturally diverse, the school has very few students who might be identified as visible minorities. This school serves the needs of high school students who are registered in the public school system and live in the city or the modestly populated surrounding farming area.

The population studied was comprised of those students registered in my two Biology 20 classes in the second semester (running February 1 to June 28, 1996). A detailed account of classroom composition is found in Appendix A. a more general account is presented here. At the beginning of the semester students ranged in age from 15 to 17 years of age and with a mean age of 16.0 years. The majority of students (85%) were currently registered in grade 11. As students needed only Science 10 as a prerequisite for Biology 20, a small number (8) of Grade 10 students were enrolled. They had completed the prerequisite course the previous semester. In addition four Grade 12 students were repeating the course due to failing previously. By the time the field project occurred in mid-May three Grade 12 students and one grade 11 student had withdrawn. The remaining Grade 12 student was no longer attending. Twenty-seven students enrolled in my classes were taking other sciences, the greatest number taking chemistry. Three male students were studying all three sciences.

Biology class enrollments in this school are rarely gender equal. Contrary to popular beliefs about females and the sciences, biology tends to have a very large proportion of female students. In the two classes studied there was a total of 17 males and 37 females. Gender seemed to have a relationship with the reasons given for taking the biology course. Approximately 60% of my female students indicated that they were taking biology to meet the entrance requirements of a post-secondary institution. Only 18 of the 37 female students in these classes were taking a science other than biology so the other 19 needed biology for their science component of the diploma requirements. There were no females taking all three sciences offered (biology, chemistry, physics). Half of the female students (18/37) stated that they took biology because it interested them. This was also the most popular reason given by males for taking the course, accounting for 11 of 17 males.

Teachers intuitively hold the belief that classes are never the same. The "luck of the draw" in timetabling and the interaction of individual personalities along with other situational factors may provide conditions which lead to markedly different class "climates," each creating a different learning environment. This was true of these two classes. From the outset the climates were different.

On the basis of intuitively-based understanding I could never actually account for the differences I perceived. There were factors I believed were instrumental. The second class was very quiet compared to the first. The first block class contained 30 students. and they were nearly all consistently present. The second class was originally 29 students in number but dwindled to 24 by mid-May. Attendance in the second class was less regular and was actually 10% worse over the whole semester. The poor attendance could be largely attributed to the Grade 12 students who having previously failed. once again fell into a pattern of non-attendance which forced withdrawal from school.

I speculated that the gender composition of the classes was a factor. The first class had a near equal mix of males and females (13 male / 17 female). the second was overwhelmingly female (4 male / 20 female). I seriously considered the feminist critique of male teachers instructing girls in science. As a result I carefully tried to observe my behaviors and students' responses. I could not find a correlation. My treatment of females in both classes and their responses to me were the similar in my estimation. If any gender competition existed it was in the first class and the females there appeared to outperform the males consistently.

I considered as well the social relations in the classes. Twenty-seven of the students in the first class were in Grade 11 and seemed to have known each other somewhat as they sat in variable groupings. In the second block class students tended to sit apart and when groups did form they were static in composition.

In considering the differences I thought about students' involvement in other science courses. Where the classes had nearly equal numbers taking chemistry as a second science only the first class had physics students. Six students (three of each gender) were taking physics.

The first class was, based on my method of teaching, a "dream" class, the kind that one hates to see leave. They were actively involved in the subject and had free-ranging debates about the topics presented with a myriad of questions being raised. Even the chatter between students during class was about the topic of the lesson. The second class was "dead quiet," you could hear the proverbial pin drop. I found it very difficult to teach in the dialogic manner I preferred. Questions were rarely raised and curricular material could be covered in three-quarters of the time.

Certainly there was a larger proportion of Grade 10 students in the second block class and they were very hard-working. It could have been the approach that these serious grade 10 female students had to their schooling that kept them quiet, I don't know.

The difference in engagement with each other and me was noticeable and commented on by colleagues and other adults who visited the classes and by class members who had the opportunity to visit the other class. The difference in climate was evident throughout the semester in the class averages which maintained a 6% separation favouring the first class. This 6% separation continued on the common final given to all Biology 20 classes in the school.

The Study

The purpose and intent of this study were explained to the students briefly on the first day of classes as we discussed the program for the semester. I included the description of my research in the first day class orientation for two reasons. I was the only teacher to include projects as a large component of my evaluation scheme. Projects held a value of 30% of the final grade. In describing all the projects required I believed that students had the privilege to choose whether or not they wished to be in my class. One student did exercise this privilege in 1994, but no others since that time. I also included the description of my doctoral research at that time to allow students to once again choose whether they wanted to be involved in that kind of adventure.

A few weeks prior to the study students were again informed verbally in greater detail. Students and their parents were then provided with a letter detailing the study's nature and the informed consent of both parent/guardian and student was sought. The confidentiality of participants was assured. Participation was voluntary and all participants had the right to withdraw without prejudice or explanation. Anonymity was offered to students and requested by only four students. The remaining fifty students felt strongly that statements they made were theirs and should be treated as their own with due credit being given. The school and school division have not been identified such that they might remain unknown.

Data were collected from five information sources: (1) written student responses, (2) tape-recorded conversations, (3) the students' field journals, (4) the students' final reports and (5) the researcher's field journal. Samples of written responses, tape recorded conversations and field journals are found in Appendix C.

Information Source 1: Written Student Responses

On four occasions students were asked to write their thoughts about research and their project which I thought might be illuminating. These are presented in Appendix C with sample responses. The first questions given months prior to the field project were seeking students' initial conceptions for science and research. I also requested at that time an illustrative example or story of a time students believed they were conducting research. The second set of questions was given after the students' orientation to the project. This orientation included an explanation of the project, its location and a walk through the research area during which I identified for students five distinct forest communities. These questions focused on expectations and hopes for what the project might be. The third series of questions focused on the students' proposals. Four class periods (80 minutes each) after the orientation were allotted to the development of the students' research plans. These questions focused on aspects of the proposal generating process. The final written responses were requested after the project was completed and handed in. The responses sought at this time focused on similes, as a form of metaphor, generated by students after their experience. Metaphor is the epitome of creating and symbolizing new meanings (Gendlin, 1962). It is a vehicle through which new meaning may be expressed by drawing on recent experiences, using familiar symbols, and linking these together in novel manners thus building the new from the old. The written responses were drawn into categories, defined and analyzed using grounded theory (Glaser and Strauss, 1967; Glaser, 1978; Strauss and Corbin, 1994). I, like many other researchers before me (Bryman and Burgess, 1994), did not use grounded theory in its entirety. I used grounded theory as the basis for developing categories and using those categories in concept creation for analysis.

Information Source 2: Conversations

As students were actively engaged in the construction and implementation of the research project I interacted with them inquiring into the process in which they were involved. These conversations allowed them the freedom to express their ideas at length, and allowed me the flexibility to pursue strands of thought that appeared throughout the conversation without the restrictions of structured interviews (Wragg, 1984; Cohen and Manion, 1980). The conversations were recorded to provide for accurate re-presentation.

Students were aware of the intention to record the conversation and were asked for permission to do so. People in general have a degree of discomfort when they know they are being recorded, thus only a tiny microphone was attached to my lapel to reduce the intrusion of the tape recorder into the conversation. My past experience with this manner of data collection has led me to believe that as long as I did not touch the tape recorder students would not attend to it. The critical moments I had found were switching tapes or turning the recorder on. With only the microphone visible and the recording unit in a waist belt on my side distraction was minimized. I also turned the recorder on before I was seen by students. Only one student paid attention to the microphone by repeatedly looking at it during our conversation. The tape recorder was the most efficient data collection tool in this type of field work. As students were spread out over a potential 70 hectares I had to ride a bike from one research site to the next. A video camera was considered more awkward and distracting for students in this type of study although it may have provided valuable data.

In past experience with this biology project I had been able to interact daily with each group of students at their research site. The lengths of individual conversations were highly variable, often dependent upon the immediate concerns held by students and the degree to which they wished to engage with me in conversation about their work.

<u>Information Sources 3, 4 and 5: Journals and Reports</u>

All students were required, as a component of the research project, to maintain a field log and hand in a final report. The intent of the log was to allow students to capture data that might be pertinent to their studies. It also mapped the development of the project, including concerns, issues and questions that might arise through the process. Students' field journals were collected at the end of the research project and analyzed to determine if data pertinent to the research might exist.

The reports were the culminating activity of the project. According to the rules established in the Biology 20 course outline, the format for the final report was open to any form of communication (video, audiotape, essay, etc.) which could best convey the information. Most commonly, essays were chosen but this year one group created a child's activity book illustrating pond life. The field project outline (see Appendix B) provided a guideline in the form of questions upon which the final report could be developed. This outline provided students who felt they needed a framework one upon which to build their final report. It also served to meet their concerns about what would be evaluated in a final report. These questions provided for me a minimum standard of what I expected for evaluation of this project. As in the case of the journals these reports were examined for relevant data. The notebooks and reports were considered the student's property and were returned after the study.

As a teacher-researcher I was behaving in a manner that has been termed the "participant-as-observer" (Burgess, 1984). I maintained a field document, similar to that of the students, recording the insights and development of my investigation. This field document was intended to provide valuable personal insights into the process of research which might well be similar, analogous, or strikingly different from the students' experiences.

Three forms of field notes were anticipated: (1) substantive accounts, (2) methodological accounts and (3) analytical accounts (Burgess, 1984). Substantive accounts were notes of the events, situations or conversations I was involved in. Acting as a descriptive running record these notes focused my attention on conceptual issues relating to the research. Methodological notes were reflections made after observation in regard to the methods used. The intent of such notes was to "fine-tune" the methodology for effectiveness and efficiency of data collection. Analytic or interpretive accounts formed my preliminary hypotheses, or theories for testing, and might expose categories for analysis and interpretation of the data.

Students were informed about these forms of field notes and we discussed a framework in which to use them. Past experience demonstrated that not all students utilized the potential of field notes. The use of field notes is a learned activity, and for students this was the first situation in which they were ever required to keep a record of this nature. Even for a more experienced person, such as myself, the quality and usefulness of field notes has changed over time. These varied forms of notes functioned to focus my thoughts on the observations I made by drawing attention to my subjectivities, as well as raising questions of trustworthiness and credibility. Field notes have a major limitation in that one must have pen in hand to process the thoughts. Research, like teaching, engages the mind at any time. Thoughts about the research often arose at inopportune moments; unfortunately for me I would often be pondering aspects of this study while driving home from school or riding between research sites. I found that the tape recorder was very useful for capturing those thoughts when a pencil and field book were not at hand.

Trustworthiness

One question inherent in qualitative research has been the degree of trust researchers and others have in the findings (Lincoln and Guba, 1985). As findings are dependent on the analysis which in turn is dependent upon the data collected, safeguards need to be implemented to increase the likelihood that trustworthiness exists. Participants were invited to participate and this participation was at all times voluntary. It was thought that this improved the likelihood of participants sharing their thoughts freely. The fidelity of any transcripts produced from tape recordings was checked. The central themes of the study were approached from varying perspectives (the teacher, the researcher) using the varied data sources described. The interaction of my personal knowledge base, the existing literature and the data suggested theoretical foundations upon which to base my interpretations. Through the process of analysis as the interpretations were made they were shared with respondents in the validation process to verify whether or not the findings were consistent with the respondents' world views.

Four possible sources of distortion (Lincoln and Guba, 1985) were considered as potential problems and were addressed in this study. The first source of distortion concerned the involvement of the researcher with the informants. I had worked with the students involved in this study for a minimum of three and a half months prior to the beginning of the research project. As their teacher I was well known to them. A considerable degree of rapport had been established between us by the outset of the field project. The responses given by students were approached in analysis from two hermeneutic perspectives, trust and suspicion or, as I have phrased it, expectation.

My classroom teaching style and personality required me to automatically trust my students. As a consequence I believed that the responses given were a true reflection of the understandings the students had. As a researcher I chose to view the data provided by the students with a question in mind, "What was left unsaid?" This view stemmed from ancient Taoist wisdom that suggested what was left unsaid was of equal value to that which was said. The yin and the yang, the spoken and the unspoken, coexisted. The unspoken could be viewed with suspicion, but this had an undesirable connotation for me. I preferred to view the unspoken as a window upon my expectations. What were the things which I had expected students to say but they, for whatever reason, did not?

I believe that being sincerely interested in the efforts of students and demonstrating that interest minimizes the students' incentive to fabricate answers. As the answers to my questions were not used for evaluation in the course, I hoped that students would be encouraged to remain open and willing to share their thoughts. In this type of research one must always consider that any individual may perceive a personal gain possible in the most subtle ways. Alternatively, people may become more closed and circumspect. The use of a variety of data collection methods was in part aimed at corroborating the responses given to address these concerns.

The possibility did exist however for students to seek to please their teacher. A variety of socially legitimated structures and myths are commonly understood to exist in schools. The teacher is responsible for evaluation, determining the value of assignments and ultimately conveying a final grade. Teachers are responsible for discipline and control in their classes. Teachers may be perceived as "experts." Any of these structures and myths could cause students to not share their thoughts openly.

The second source of distortion was due to researcher biases. There is "probably a close and direct relationship between the degree to which bias is ignored, obscured, or lightly dismissed by the researcher and the probability that such a risk is present, high and an important contribution to the unreliability of the findings" (Kline, 1980, p. 58). Not all my biases were evident, even to myself. Due to my central role in the projects, I assumed that I had many biases. I developed this experiential activity to meet the objectives of the biology curriculum believing that the experiential framework in an open-inquiry setting was a powerful pedagogic tool. In this text I refer freely to my assumptions and the beliefs which were influencing me. Readers may then judge the biases implicit in these statements. I also used expectation as an interpretive tool. The data was interpreted by questioning what I expected students to state but was not stated. This should further expose some of my biases. I fully expected that I was not aware of all of my biases and the absence of any acknowledgment in belief or assumption may be taken as evidence of this unawareness. I also encouraged students to consider the biases they as researchers might have held.

The third source of distortion referred to the manner of data collection. Each manner of data collection had inherent risks which were addressed in accordance with accepted practices.

The final possible source of distortion involved the presence of the researcher. Researchers might, by their presence, modify the situation being studied. As a participant-observer my presence was acknowledged as an integral component of the situation. I believe that students did not discriminate between the participant or the observer in our interactions. My rapport with the students reflected my relationship to them as their teacher. Students in responding to a teacher-researcher were more likely to be inclined to consider their interaction to be with a teacher, and not with a researcher or stranger.

The tape recordings revealed that students were engaged with me in a variety of ways. At times I was an evaluator, a disciplinarian, a confidant, a critical friend, a student, or a presumed expert. When I asked a question that was obviously disconnected from the normal teacher student interaction generally the students carefully and at times painstakingly explained their answers, clarifying as was necessary. At worst and only rarely they appeared to think "now that was a strange question." This perceived response appeared to be in response to a poorly worded question, or a question which leapt from my mouth due to a flash of insight but for which the students were unprepared by the conversation to that point.

Credibility

The internal validity of this study was addressed in the following manners based on Lincoln's and Guba's (1985) discussion of credibility. Lincoln and Guba recommended that the researcher have had prolonged engagement with the informants. It was feared that limited engagement may cause the informants to view the researcher as a stranger and untrustworthy. As teacher-researcher I was not faced with this obstacle to credibility I had been engaged with these students for four months prior to the field project.

Lincoln and Guba recommended that peer debriefing be used. Toward this end I discussed the research with my research peers and supervisory committee as the study progressed. Also the analysis looked for negative cases which refuted hypotheses I held or which refuted aspects of the interpretation. Students had the opportunity to check the data collected, the analytical categories, the interpretations and the conclusions made, for errors that may have crept in.

The nature of this study took into account ecological validity (Roth, 1992b). To investigate the students' investigative or problem solving process, ecological validity may only be obtained in a context in which the students may frame a question. The use of investigative skills occurs in an interplay between tacit knowledge and contextual clues As a result I investigated the students' research process within the context they operated within.

Interpretation - Hermeneutic Imagination

Hermeneutics, drawn from the Greek word "*hermeneia* " meaning interpretation. suggested an appropriate responsible manner through which to approach this study Through the choice of wording, personal belief, intention and method I aligned this study more closely with the hermeneutic tradition.

As both the teacher and researcher in the situation being studied I was firmly and centrally "embedded" in the context and the question. It was fundamentally impossible to separate my subjectivity from this investigation or this investigation from my subjectivity. Hermeneutics became an appropriate foundation for interpretation of the data because it attempts to speak from the center, recognizing the interpreter's intimate relationship with the situation being interpreted. The interplay of the part and the whole in the process of interpretation was found at the roots of modern hermeneutics in the work of Friedrich Schleiermacher (Smith, 1991).

In this study I sought to understand the meaning students held for the concept of scientific research and also how they came to an understanding of this meaning as their personal meanings underwent change. By working in education, a human "science" and seeking understanding I was once again aligning with the hermeneutic tradition through the works of Wilhelm Dilthey. It was Dilthey's work which struck a sharp dichotomy between the natural and human sciences. He claimed that human sciences could not be explained objectively in terms of mathematical and ahistorical principles. Rather we developed understanding (*Verstehen*) because human sciences could never be impersonal to humans and were at all times historical (Oh, 1986).

The later work of Husserl in phenomenology further compounded the impossibility of me separating subjective thinking from objective thinking as my scientific background might once have suggested. His theory of intentionality suggested that all thinking and therefore subjectivity was connected to the world around us and thus an objective-subjective dichotomy was foolish. Husserl's influence on the hermeneutic tradition rooted words like *understanding*, *interpretation* and *meaningfulness* in the "dialogic, intersubjective, and conversational nature of human experience" (Smith, 1991, p.192) The methodology used in this study sought to interpret such a human experience.

Two questions arose as a result of the methodology which needed to be addressed The first question dealt with how the meanings held by students might be "re-produced." Re-production in this sense referred to the act of interpreting students' understandings in a meaningful way. The second question dealt with the "re-presentation" of these meanings. Re-presentation in this context referred to the ethical responsibilities in presenting the understandings that had been developed. Making meaning is intimately associated with language. The hermeneutic approach recognized that the pursuit of meaning was the pursuit of an elusive prey, for language both encouraged and constrained understanding. Heidegger claimed that interpretation is the "primordial work of human experience" and was not fundamentally methodological (Smith, 1991, 1995). As a result the "modus and temperament of hermeneutic work is predominantly poetic, imaginal and suggestive" (Smith, 1995,p.4). Any reproduction of the meanings held by another was a difficult task because one could never totally know the other. The choice of meanings re-produced and re-presented were determined by me; thus they were influenced by my subjectivity and influenced my subjectivity.

Through examining hermeneutic texts I understood that meaning was arrived at referentially and relationally. The final authority of concepts resided within the "dialogically arrived at agreement of people to consent to them" (Smith, 1991, p.197). I thus strove to understand the meanings held by students as I was best able through thought and dialogue, re-producing and re-presenting these as best possible. "The full truth of things can never be the conscious property of any one person" (Smith, 1991, p. 202). The interpretations presented were mine, meanings created by me through conversation with young people, and reflecting my "dialogical journey." The text of this dissertation reflects the "storied" nature of experience. Readers may draw from the text their own personal meanings and possibly a greater sense of unity with others.

CHAPTER 6
THE MEANINGS STUDENTS GIVE FOR RESEARCH

Introduction

Questions about the nature of science have been for the most part philosophical or sociological, thus tending to remove such questions from the normal day-to-day thoughts of the public. When I was a research scientist I did not focus my attention on questions about the nature of science. Questions about the meaning of scientific research also fell into this category. To the contrary, as a science teacher I have found philosophical questions necessary to consider. These questions not only have embraced the subject matter of science, but the curriculum as it was intended, the pedagogic manner in which the class would be conducted and consideration of how the curriculum would be developed, or possibly extended. Matthews (1994) maintained that the "teacher needs to have an idea of what science is, needs to have a sense of the 'essence' of science, an image of science that is going to be conveyed to classes and which is going to inform decision-making about texts, curriculum, lesson preparation, assessment and other pedagogic matters" (p.204). Lewis Wolpert (1992), a research biologist concerned about public notions of science, raised the provocative thought that the nature of science was rather unnatural for human beings. He claimed that "scientific ideas are, with rare exceptions, counter-intuitive: they cannot be acquired by simple inspection of phenomena and are often outside everyday experience ... doing science requires a conscious awareness of the pitfalls of 'natural' thinking (day-to-day common sense)" (p.xi). It was little wonder that students initially responded to the question, what is science, by saying, "Gee, I've never thought about that."

Everyday common sense thinking occurs naturally and we are for the most part unaware of its processes. It has generally provided us with sufficient decision-making power to meet the requirements of daily life. For example, if you have ever observed bubbling water on a stove, considered it to be boiling, and then associated it with high temperatures and the potential for serious burns, that was a form of this basic common sense. Such a common sense notion was far removed from the scientific notion of boiling which would have included a statement that water may boil at any temperature and therefore boiling water need not be hot. We have also developed common sense notions about forces, such as gravity, which scientific thinking also dealt with. We may each recall instances when our common sense notions of these forces has been foiled by a wily question. As an example, if a marksman in a large open field dropped a bullet to the ground at the same moment another bullet was fired horizontally from a rifle, which bullet would hit the ground first? Using common sense you might consider the short distance the bullet had to drop relative to the great distance the other bullet would fly. If this thought was compounded with our notions of the speed of the fired bullet, maybe the destructive force of a bullet and possibly notions of flight, it might have been obvious that the dropped bullet hit the ground first. It's just common sense. Strangely they both hit the ground at the same time because gravity worked equally on both bullets; it was not influenced by the horizontal motion. So understanding science and science thinking is more challenging than it may originally have been thought. This is true for adults, including teachers, and particularly for students.

This study examined students' understandings of research within a scientific framework. Drawing on Polanyi's work (1958, 1966) and Bruner's (1985) ideas of paradigmatic and narrative thinking, Martin and Brouwer (1991, 1993) explored the role of narrative in the notion of personal science. They illustrated the value of narrative as a tool in examining personal science. My analysis drew heavily on students' narrative thinking as a means to investigate their personally held meanings for research. By presenting many representative narratives to provide voice to individual students, I also offer an opportunity to consider my interpretations critically.

A Starting Point

The project is outlined in greater detail in Appendix B. To aid understanding of the findings the following chart outlines identifiable moments in the project. These moments may be used as references to which the data presented may be related to gain a better sense of time as it relates to the students' activities and thoughts.

May 9	The project is outlined in detail.
May 10	An orientation walk was conducted in the research area.
May 13 - 17	The students developed their proposals.
May 14	Question sheet #2 was given.
May 17	Proposals were due. Question sheet #3 was given.
May 20 - 31	Field work.
June 3 - 5	Class time for data interpretation.
June 5-7	Oral presentations
June 17	Written report was due. Question sheet #4 was given.

Figure 3. **Project Timelines**

In seeking to interpret the meanings that students held for scientific research I began with stories students offered about incidents when they believed they had actually researched something scientifically (see Appendix C, #1). Students completed question sheet #1 prior to being introduced to the field project on May 9^{th}. Students' responses were read and the emergent categories were identified using methods commonly associated with grounded theory. Three broad categories, with a few straightforward subcategories (see Table 1) emerged from this process.

Roughly one third of the students did not identify any time in their recollection in which they believed that they had researched scientifically. The second category included students who associated scientific research with something which had occurred in a classroom context. The final category included students who identified events occurring outside school which involved scientific research. The relative proportion of students from each of the two classes was approximately the same for each category.

As I examined the responses to the questions I had posed, several things immediately became apparent. I first noticed that although diverse meanings and examples were presented, there was a noticeable degree of congruence between the stories offered by students and their stated meaning for scientific research. The salient themes which initially emerged as I read the stories

Category	Subcategory	Male	Female	Total
No example		5	12	17
School based				
	Report	2	5	7
	Laboratory	4	6	10
Out of School				
	Book search	0	1	1
	Calculation	1	2	3
	Observation	4	7	11
	Experimentation	1	5	6

Table 1. Student examples by category of scientific research they believed they had conducted. (Total responses = 55)

appeared to differ. I believed that this was due to the interdependent nature of the story and meaning each student had offered. While the emergent themes derived from their responses held meaning for individuals, when presented themes that arose from others' stories, students agreed with these as well. As a result, some elements of commonality emerged.

In seeking a sense of the essence of students' meanings for scientific research I began by examining the meaning statements made by the group who felt they had not conducted research scientifically. Some representative responses which enlightened this examination included:

> Tanelle: Scientific research means trying to find reasons for why things occur as they do.
>
> Sherry: Scientific research means to study and learn more about why things happen as they do (causes - effects).
>
> Chad: Scientific research means asking questions or creating problems related to science and trying to figure out why or what happened.
>
> Andrea: Scientific research means studying things around us. I picture some fool with big thick glasses in a room with a microscope.

Given these meanings I thought it would have been difficult for myself in Grade 11 to think of an appropriate example which might be congruent with these definitions.

From these and related comments it seemed to me that scientific research was described as an active process of studying, through question or problem posing and experimentation. Research then sought to discover the causal relations explaining natural events. From this perspective scientific research seemed generally applicable to the world and seemed to address "why" or "how" questions.

School-Based Research

Coming to understand the students' meanings for research prior to the field project was greatly assisted by the use of students' stories. The narratives, although relatively short, clarified the definitions students had provided for scientific research. I was surprised at the near even split between the three broad categories. I had expected a larger number of students would describe school-based research activities.

The term research is used in secondary schools across disciplines. Commonly school research refers to a process of library investigation to produce a composition on a required topic. Research papers were common to English and Social Studies and it seemed that this might be something students would identify as research. The first subcategory of school-based research, report, was identified by the presence of report production. The following example written by Christina, an "honors student," described a research project she recalled from elementary school:

> One time that I was doing scientific research was in elementary. I researched DNA for a science project. It was one of my first experiences that involved looking in 'heavier' books (not as many pictures!). It gave me the opportunity to learn how to pick out material relevant to my topic, summarize material in order to condense it and understand it, and try to clearly present it in a report. It wasn't exactly university material, however I did learn a lot about DNA and research itself.

This example was typical of the types of responses given in this subcategory. The students I had grouped together in this subcategory also presented meanings like these:

> Christina: Scientific research generally means investigating all areas of an issue (ie. the greenhouse effect) and presenting the facts in a clear, objective manner (not swayed by the media, etc.).
>
> Erin: Scientific research to me means focusing on a concept, studying it, learning more about it and being able to present your ideas.
>
> Kelly: Scientific research is inquiry into the world of science, researching and expanding one's knowledge in that area.

Viewed from the information I had categorized as school-based - report, scientific research was an active process but conducted to learn more about a specific concept or issue. The result of the process was knowledge which could be presented to other people. Christina was the only individual who identified a particular manner involving clarity and objectivity as important. Her responses as presented here are also indicative of the degree of congruence found between a student's stated meaning for research and the example selected by the student.

The other subcategory I had suspected would occur involved examples related to science classroom activities. Chris, another honors student and later Christina's partner, had described his example of research in a science classroom as follows:

> When I was in Chemistry 20 one project that I did was to find out how to breakdown tars as far as I could. I had to find the right catalyst that would breakdown the tars and then I had to design an apparatus to get these products.

He also stated that:

> Scientific research is research that is factual and involves using math to understand a topic. It is also learning through logical reasoning.

Some of the other students who identified experiences in the classroom stated:

Kent: Scientific research is to find out facts about what you are studying.

April: Scientific research is hands-on experience, learning and working with stuff. Scientific research seemed to be an active process of studying and learning which placed the individual in a "hands-on" relationship with that which was being studied. For both subcategories related to school-based examples there was also a common theme that scientific research produced facts. Scientific research reduced the world's uncertainty by providing facts, which were generally presumed to be immutable.

Out of School Research

The final emergent category included those examples which described events happening out of school. The first subcategory, book search, was similar to a school research report in that it involved using libraries. It differed in the nature of the final product and the reason for which it was done. The book search, consisted of a single example described by Michelle:

> I was looking at medical books in order to see what kinds of effects the use of chemotherapy has on people because several of my family members and relatives have had cancer.

This was also consistent with the meaning research had for her:

> Scientific research is taking a closer look into something that you are interested in that deals with sciences.

Michelle's thoughts about the meaning of scientific research highlighted the personal nature of the research process. The research described was personal and as a result it interested Michelle in a profound way. The personal nature of research was more evident later as the students became actively involved in designing their projects. Students indicated in response to question sheet #3 (see Appendix C#3) that having a personal interest in the topic was critical to designing a research project.

A second subcategory in out of school activities, calculation, involved a small number of students who described a mathematical component to research. While earlier Chris had mentioned mathematics as one of his criteria for research, these students instead described the use of mathematics. The other fascinating aspect of these comments was that students did not conduct this research individually as all previous descriptions have been. In each case these students described scientific research in a framework involving other people. Mathematics was used to verify school knowledge or to satisfy some curiosity that had arisen. Mandy described her research as an instance:

> When my family was in Hawaii over the Christmas holidays I helped my father calculate the difference between the angle of the sun to the earth in Hawaii and compare it to the angle at home.

Another student, Mindy described:

> One night at work a co-worker and I tried to find the heat capacity of water. It took us a while but as all the science text books say the heat capacity of water is 4.19. We just wanted to see if it was right.

The comments of students in this subcategory illuminated the existence of a broader scientific community. Communities worked together; scientific communities researched to satisfy a curiosity that was commonly shared or to verify the work, or claims, of another community elsewhere. One aspect of the responses given in this category particularly fascinated me. The kinds of scientific activities and the situations in which they occurred were not the kinds of activities I would ever have contemplated attempting in those situations myself. They were activities which must have been the result of the interactions of the individuals present.

The third subcategory in the out of school category, observation, included examples which identified specific activities which focused on the use of observation as the primary research tool. Alicia offered a description about a summer long research interest she had:

> While trying to track a moose at my grandparent's farm one summer, I spent much time in the bush studying what types of vegetation the moose fed on. I then found ideal places with water and vegetation where I might spot the moose. I took into account the time of day the moose would most likely be out in the bush to eat and followed trails to resting spots. I noticed trees stripped of their bark, I did not however find the moose. I feel that I was spending that time doing scientific research.

Another student, Rob, described his example of research involving flaunting an unwritten school rule that students were not to ride the elevator unless injured :

> Since the beginning of Grade 10 I have occasionally been taking the elevators between classes, at lunch hour, etc. I have noticed that even though many teachers have seen me get both on and off the elevator, very few of them even say anything. I have on occasion taken the elevator with teachers - again with no hassle. I rarely fake being injured yet it seems that I almost always get away with it regardless of whether teachers have observed this practice or not.

Other students in this group made the following comments about the meaning of research to them:

> Jaimie: Scientific research is observing, analyzing and discovering the reasons for things to happen. I think its mainly done through observation of the problem and analyzing what is observed" (she included smelling, hearing, seeing and thinking in observation).
>
> Erin: Scientific research, to me, means finding out how things work and why they work the way they do.
>
> Marc: Scientific research is looking for answers to problems that already exist. It helps to better society because it broadens our awareness of different situations.

These comments and examples as well as those made by earlier groups reflected a meaning for research that considered explaining causal relations. Central to the observers' ideas was the idea that we have the ability to discriminate and associate cause-effect relationships.

The final subcategory in the out of school category included those examples which described an experiment. The experiments were occasionally conducted by more than one individual but each was conducted to achieve a particular benefit. Pam described her experiment in this manner:

> I own a horse and in the varying temperatures of summer and winter I must decide what to feed him. There are books and guidelines to go by, but I wanted to perfect his diet. Using suggestions I had been given I tried to feed him several different meals and found which had the best effect. This lasted several weeks and I came to a conclusion.

Other general comments included:

> Pete: Scientific research is used to figure out why something is the way it is using scientific methods.
>
> Beth: Scientific research involves long, extensive hours of work.

Scientific research was conducted in a lengthy, methodological manner to explain what goes on in the world around us. The findings of research would then have some correlation to this world. This relationship to the world allowed us as individuals and a society to use the knowledge developed through science for our purposes.

Contrasting Student Research with Scientists

During the first week of the project students were given an orientation walk through the research area and allowed time to develop their proposals. I asked students during our conversations that week if they thought scientists would conduct research into the questions students had posed in a similar manner. Students believed that in some ways scientists may have done some things similarly, such as identifying similar variables. They generally believed that scientists would have done things differently. The differences include comments about the nature of scientists as well as how they might actually work

I enquired of Celena her impressions about how scientists conduct research on the Monday following the orientation walk.

> JR: When you think of scientists doing research in the lab or wherever, how do you think they would conduct research?
>
> Celena: They would start with something new they had never discovered. That's probably why they're scientists. They get a thrill out of it. Trying to discover new things, new ideas.
>
> JR: So your perception is that they do it for the thrill of discovery. They work with a blank slate, starting out fresh.
>
> Celena: Yeah.
>
> JR: You said that when you do research you actually start with something you know about.
>
> Celena: I don't have a good imagination like they do and they are very smart.
>
> JR: So they have imagination, intelligence and a desire for the thrill of discovery.
>
> Celena: Yeah.

Celena identified in this conversation a concept held commonly by students; research was equated to discovery. Scientific research was seen as a form of discovery by most students. Although this was a reasonable conception to hold relative to their experiences with school and popular culture, the nature of discovery seemed somewhat naive in its conception. It seemed that discovery did not begin from a point embodied within existing knowledge. Scientists began with a novel idea and pursued it to the point of discovery, as Celena suggested for the thrill of it. Certainly there was a thrilling aspect to having a new idea, and students had probably experienced that very feeling at some time. Research, as discovery, seemed immensely personal, but the communal nature of science and research was not suggested by students' comments.

Scientists had specific qualities, intelligence being foremost. All scientists were smart. They were also believed to be dedicated and careful. Celena was the only person who said that they had imaginative qualities. Scientists were consistently referred to using masculine pronouns. Although I made the effort to refer to scientists in the same gender as the students to whom I was talking, they consistently referred to "he" or "his" in reference to scientists. The new curriculum resources had frequently highlighted the presence of women in active scientific roles. I had consciously used numerous examples of women scientists in class. Even so, this subtle indication of gender bias remained. Although everyone was aware of the existence of female scientists the term scientist still retained a masculine orientation.

The greatest differences students saw between a scientist's scientific research and their own related to technologies. Sandra and Tanelle were comparing the water quality of the local stream with a nearby river. They saw the technological differences in this manner:

> JR: How do you think a scientist would study this problem?
> Tanelle: They'd do it differently.
> Sandra: They'd have all the knick-knack thingeys.
> Tanelle: More high tech.

Another group studying water quality as it related to specific portions of the creek shared similar views:

> JR: If a scientist was looking at the same question as you would she do it differently?
> Terri: Probably.
> JR: How would it be different?
> Terri: You'd probably see them down there with vans and trucks. They'd have computers set up. They'd be in the water with all this high tech stuff.
> JR: So they'd have better equipment than you.
> Terri: Yeah, they'd have corporate sponsors and all that.

Scientific research was high tech. Technologies were known to be expensive, which was acknowledged in Terri's comment about corporate sponsorship. Scientists worked with the latest and best equipment. Students identified the numerous failings of our limited scientific technology at the school. Certainly the equipment was blamed on occasion for providing data discrepant from the hypotheses held by students. For example, if a difference in vegetation communities was visible then a difference in soil pH might be hypothesized. Finding that the pH levels differed by 1 to 1.5 pH units was interpreted by most students as the pH being the same. They believed there should have been a "big" difference. The failure to find a big difference was the fault of the pH meters until I reminded the students that they should check to see what a difference of 1 meant in terms of pH. After checking their chemistry texts they generally rethought the discrepancy.

The students' use of what might be termed scientific vocabulary was particularly noticeable by its absence. Scientists used "knick-knack thingeys" and "high tech stuff."

Scientific research also varied in regards to process. Tanelle and Sandra continued to say:

JR: Okay better equipment but what about the process they use?
Tanelle: They'd have the same idea, but they would probably test it in a different order.
Sandra: They would probably have more controlled variables. We'll be hopping around from area to area. They'd have it sectioned off. They'd be doing everything perfect.
JR: If a scientist ran into problems, let's say the data she found didn't make sense, it wasn't what was expected, what would she do?
Tanelle: Do more tests. Check it out.
JR: What would you do if that happened to you in this project.
Sandra: Go to you.
JR: Why would the scientist do it differently?
Sandra: The chances are that the other person wouldn't know either. Because if he discovered something new nobody would know about it. So he'd have to figure it out for himself.
JR: So if she was having trouble a scientist couldn't get help?
Sandra: He could get help.
Tanelle: I'm sure Albert (Einstein) didn't do it all by himself.
JR: Some people say he had his wife help him.
Tanelle: There you go.

Scientists would be more careful controlling the variables in an experiment. Curiously, in recognizing that they would not attempt to gain the same level of control they were essentially saying, "We are not scientists so those rules do not apply." Consistently students would indicate that a scientist needed this level of control but it was not required by them; they were not scientists. It required considerable effort to maintain that kind of rigour in research. The students were either unwilling to do so or alternatively really did not know how to proceed. I tended to believe the former reason explained the situation as the students could identify elements of the rigour associated with research, such as control of variables, but chose not to focus much energy on it. A further reason may have been that most students did this project in groups of two or three and the social dimension for adolescents tends to focus on movement and action, which may not be as conducive to scientific discipline.

The other interesting aspect of this dialogue with Sandra and Tanelle revealed assumptions inherent in the teacher-student relationship. Teachers are assumed by students to be experts or at least very knowledgeable. As teacher I had been the expert throughout the course, even though I had not sought such a designation. Students clearly felt that should a problem arise I would know what to do. In contrast these students indicated that scientists had different relationships with each other. A scientist may seek help from other scientists, but not expect answers. It was assumed that scientists were always working at the margins of the known world with no one else. Students appeared to assume that their research was not developing new knowledge and indicated that I would be able to provide answers. This was, to me, an amazing assumption given the diversity of research questions they selected.

These two positions seemingly adopted by students, devaluing control and viewing the teacher as the scientific expert, were events which attracted my concern. It was actions and comments in regard to aspects of the project like these which ultimately led me to reconsider my position on the possibility of authentic research in schools (see Chapter 8).

Desiring Discovery

I interpreted Celena's comments to suggest that research was intimately linked to discovery. The thrill of discovery was central to the research activities of scientists On May 14, a day after my conversation with Celena and four days after the orientation walk. I asked the students to complete question sheet #2. The final question asked the students to imagine or fantasize about the "best" thing that could happen during the project. The responses to this request fell into two categories. Students imagined that the best thing to happen would be to obtain very good grades. This was a very reasonable fantasy given the weighting of this project overall. Twenty-five students responded with a fantasy of discovery. This fantasy also seemed reasonable given the emphasis in popular culture on science as discovery. Books and television often portray the great discoveries of our scientific history.

Arizona was discussing a comparative study between two forest communities with her partner, Marc, when I asked the class to complete question sheet #2. She described her discovery fantasy as:

> I think the best thing that could happen for me is if I find something completely new, that no one has found before. For example, I would love to find some kind of new wildlife that has just recently entered this particular area. This would be great because I would be the one who found it.

Shannon had throughout the course indicated in her manner and comments that she desired good grades She offered a fantasy involving discovery and fame:

> I would find all the answers and my project would be in every science textbook written. My final mark would be 100% and I would win some science prize and travel to accept the award...I would be famous.

Arizona's and Shannon's fantasies typified the responses I received in regards to discovery. Students hoped to find something new in the forest, a new plant or animal, possibly a new scientific idea. In most cases the result of discovery was recognition, often fame.

For many students, the desire for discovery required the research question to be one which had never occurred before. As students went through the process of negotiating their proposal with their partners the possibility of discovery was considered in the development of the research question. While walking along the pathway through the park during the orientation walk Arizona had raised the following question.

> Arizona: Do you know of anything which hasn't been studied?
> JR: Oh there's heaps of stuff that hasn't been studied. What kinds of things are you interested in?

Scott, Justin and Chad were avid mountain bikers who had become concerned with the impact of mountain bikes on the soil and vegetation of the park. In the classroom on May 13th Scott was explaining a point to Chad and Justin as I approached. He asked me the following question as I stopped by the group:

> Scott: Mr. Rymer, is the question that we did a very common question that people do everyday?
> JR: No, nobody has done your question before.

It seemed that having a unique question, which no one had ever considered before, was important in setting the context for scientific research for some students. Possibly it established the primacy of their research relative to that of others. It may have served to fulfill the desire to be scientific. Alternatively it may have been believed that original research would receive higher grades from the teacher.

The fascination with discovery continued into the field work phase of the project. Kirsty and Kelly were thrilled with their personal discoveries about swamp life. They enjoyed not only telling me about their findings but they often told passersby who inquired about what they were doing. Kirsty described discovery in terms of figuring things out for herself. Kirsty shared her thoughts on the third day of field work during one of our conversations:

Kirsty: It makes you feel smarter if you figure something out for yourself. It's not like mosquito larvae are rare. Probably every scientist in the world knows about them. But we did it by ourselves. And we figured out that spiders don't like mosquito larvae.

Discovery was not merely a matter of finding something new to the world of scientific knowledge. As Kirsty identified, personal discovery, albeit not new for others, was desirable. In Kirsty's case this was contrasted to being told information in more traditional classroom settings. She felt her personal discoveries were more valuable personally than information transmitted to her by teachers.

Early Emergent Themes

My belief has been that people are constantly in a process of change as they experience the world around them. I assumed this change is incremental and does not have a predetermined direction. To derive a sense of the students' meanings for research I selected a specific point in time at which to frame those meanings, the completion of their proposals. Based on my previous experience with students in this project, I had considered that prior to engaging in field work there would be little change in their ideas about research. It seemed plausible that during the proposal development phase of the project students would naturally be operating with their existing beliefs of what research would be. Certainly events may have occurred during the development of a proposal which may have altered personally held meanings for research. The proposal was developed from the students' current understandings of research. I believed that the experience of data collection and field work might provide sufficient discrepant events to challenge the meanings that students held. As a result I used the orientation and proposal week to provide the temporal boundary upon which to examine conceptions which may have been evident in the students' communications with me. The definitions and stories the students provided prior to being introduced to the project, the responses to question sheet #2, and conversations I had with students during the week of proposal development were used to define the early emergent themes. From these data sources it appeared that six themes could be found in the students' understanding of research.

Research Occurs in a Real World

For students there was a material world existing independent from ourselves. We existed within that world, we related to that world and acted within it. It was an ontological position described by Rutherford and Ahlgren (1990) as realism. The students' view was consistent with a common sense notion of the world. It appears that the world exists separate from us in a material form which we can verify through use of our senses. This view ran contrary to philosophical arguments suggesting there is no external world, only the world of human experiences. Such a position idealizes the external world.

Science is conducted with reference to an external world. Any theory constructed by humans is verified in its ability to explain or predict events in the world. Acceptance of an existing world has generally been required in science as we assume basic rules to exist which apply over the entire universe. Students recognized the universality of science when they described science as "the study of the universe" (Rymer, 1995). Students' acceptance of a separate real world is consistent with the understanding necessary to rationalize the study of science.

Research is a Methodical Study

The second theme followed directly from the first. As the world existed independent of us we were able to study it. Running throughout the students' responses was the theme that research was an active process of studying. Time and effort were expended to study something in the world around us. Studying appeared to have a method to it, and this method was universally applicable. Scientists acknowledged that there was not a single scientific method. There were however, from the students' sense of research, recognizable components of a method. Although the responses given did not list all components of the method, several were identified.

The method associated with scientific research included the presence of a question or a problem. Presumably we had a question about something relative to the world around us about which we may have been curious. Alternatively, our experience in the world had allowed us to perceive a problem for which a solution was desired. It appeared that research was conducted out of personal interest in the question or problem studied. such as Michelle's concern regarding cancer or Mindy's verification of heat capacity. The other element of the problem or question was its specificity. Students identified research as limiting the scope of the investigation to a specific issue or concept. Even so, research was universally applicable to any worldly issue.

A second component of the method involved a hypothesis. It seems that the question or problem posed had through some rational process a possible answer which was speculative. Although the source of the hypothesis appeared to be logical in origin many students indicated that part of the research process required consultation with existing knowledge located in books. In previous years some students have claimed they were not doing science because they did not have a hypothesis.

The hypothesis and possibly the background reading were potentially instrumental in developing another component of the method, the experiment. Scientists did experiments and it was these experiments which provided the answers to the problem or question posed. Intrinsic to this method was logical thought, a rational approach which seemed to suggest that the methodology may be somewhat rigid in application to the task at hand.

Also included in the method was observation. For some students, like Jaimie, observation was the dominant component of research. The location of observation in the process was for the most part undefined. It may have occurred prior to the question formation, within the experiment, or it might have been the primary focus of research.

Students indicated that there was a conclusion to the process. Pam, for example, reached a conclusion about her horse's diet. Conclusions answered the question or solved the problem. Research was not described as ongoing. Instead, research appeared to be described as composed of discrete steps which proceeded in a somewhat linear manner, even if the precise order was somehow muddled by observation.

By and large, the method evident in the students' stories and comments was consistent with basic knowledge of the scientific method as portrayed in school science texts. Their understanding was also fairly consistent with the process-product model of research presented in the curriculum support document, Focus on Research (1990b). This document referred to a "comprehensive research process" that was described as proceeding through "steps" and "stages."

Research is Purposeful

The third theme that was apparent was that research was purposeful. The product of research was knowledge. At the end of the process one would know more than was known before, learning would have occurred. The type of knowledge provided by scientific research was essentially cause-effect and fundamentally logical. Knowledge was tangible, something which could be possessed, recorded and transmitted to others. Scientific research answered the questions posed by Erin's earlier comment, "how do things work and why do they work that way."

Causal relations are a form of worldly understanding which humans achieve at an early age (Wolpert, 1992) and are intimately related to our common sense. The capacity to form a causal relation between events does not require repeated observation or experience. We may quite easily do so on the basis of a single encounter. People, especially children, prefer to see change in terms of linear steps which causality nicely provides. Wolpert stated that causal knowledge was not scientific knowledge as it was more closely aligned with common sense. Interestingly, this causal knowledge was seen by some students as sufficiently explanatory to provide us technological and social benefits.

There was not a common agreement among students as to the beneficial nature of scientific research. Everyone agreed that a large part of our current quality of life was due to use of scientific knowledge. As Marc had stated, it also benefits society by increasing our awareness of situations. By this he meant that knowing scientific knowledge allowed us to be more aware of what was going on around us, through science's ability to explain. It was interesting to note that science became an independent entity in student descriptions. Science explained the world rather than humans explaining it through the use of scientific thought.

Research is Discovery

Many students' comments referred to discovery, finding the answers as a result of the study. I believed that discovery was synonymous with research in the students' estimation. Research was an activity of discovery. It seemed as if students perceived pre-formed answers existing in the world just awaiting the right question or the proper research technique to uncover them. It appeared, as in Chris', Michelle's or Mindy's examples, that the students believed that they could find the knowledge they sought. There was a sense that research was easy, which was undefinable, and that the answer would "jump out at you." Once again this theme was consistent with Focus on Research. In that document the "organized whole" could be understood by finding the discrete units which comprised it. The dominant theme of research as discovery was consistent with Blackwood-Malayko' s (1992) findings for Grade 11 students in public schools.

Research is Personal

The fifth theme that emerged was the personal nature of research. Each story related the personal connection that the student had with the research process. Research was engaged in due to the researcher's interest. The task selected met a personal goal (Pam), fulfilled a curiosity (Alicia), or completed an assigned task (Chris). The solution that was achieved contributed to a personal sense of learning (Christina). Even in the instances of communal involvement in the research process (Mindy and/or Mandy) each member appeared to have a vested personal interest or at the very least a shared purpose. Researchers appeared personally active in the processes described earlier as studying.

<u>Research is "High Tech"</u>

Scientific research was conducted in a mystical place filled with computers and very elaborate machinery. Scientists were the masters of that domain. They clearly understood those machines and used them a great deal. Science was equated with a large capital outlay. The students had only contacted scientific research in very limited ways. Photographs, stories and television, be they documentary or fantasy, portrayed the highly technical aspects of science. Even the textbook portrayed scientists using high tech equipment.

Changing Ideas

The early emergent themes were interpreted from data collected prior to the presentation of the students' proposals. After that point in time they became engaged in two weeks of field research. I engaged students in conversations which provided data from which I interpreted themes salient during that period of time.

It was intended in implementing this field project that the students' ideas about science and research would change. I felt that there was little control I could personally exert on the precise learning outcomes. In part it was a matter of trusting the experiential process. Constructivist thought held that concepts were viable, persistent and functional. Given that only a short time had elapsed in this project it was questionable whether students' ideas would change. In conversations that I had with students during their field work the salient meanings for research became apparent and the possibility of a few changes was acknowledged. The following sections of this chapter examine the students' ideas as they emerged through conversations during their field work.

<u>Research is not as Easy as It Looks</u>

Students unanimously believed that research was a lot harder than it looked. Jill and Erin were in the same class but engaged in different projects. They commented on it this way after five days of field work:

JR: How have your ideas about research changed?
Jill: I really couldn't say. It's not as easy as it looks.. It looks easy but it ain't. I guess it would be interesting if I knew more about it.

JR: Getting back to your sense of frustration, what had you hoped to find in this project?
Erin: I just figured it would be easier than it is. I thought it (the answer) would jump right out at you. I don't have patience.

Research was hard. Believing that the answers were located out in the world and they would suddenly "jump right out" when using the right methods seemed to be the basis for students' frustrations. They had observed different aspects of the world, hypothesized the reason for the differences in a cause-effect line of reasoning, then sought the cause. When the data collected did not support the existence of the hypothesized cause they were frustrated. Research was hard because it was frustrating and the answers did not leap out. The example which recurred frequently was mentioned, in part, earlier. Students could see a distinct visible difference between the spruce and poplar forests. Given the visible difference, it was a logical common sense move to believe that there would be qualities of the soil that were equally different. The obvious choice was soil pH because it was easy to determine and the students held a basic knowledge of pH relations. Frustrations and disappointments arose when the differences found were not "drastic" or impressive. The simplicity of cause-effect thinking was challenged by the students' involvement in scientific processes. Their experience provided a sense of complexity which had not been apparent before.

The failure of real life experience to achieve the desired ends may have been disheartening. A group of three seventeen year old students were investigating forest fires. In their research proposal they indicated that they had chosen this topic for the following reasons:

> it is an everyday issue,
> we are worried about our forests,
> we wanted to do a different topic than the other groups,
> it was something we could relate to, it was not abstract,
> we thought it would be easier to study than some of the other ideas we came up with.

The students had selected three areas for study involving two burned sites, one old, the other recent, and an unburned area. They had proposed and conducted numerous physical tests to determine if differences existed between the sites. At the time the following conversation took place they had been working in the field for seven days and were investigating pH. I had been present as they conducted their pH tests, participating in the process with them. They had hypothesized that there would be differences but could find none. The following exchange took place:

> JR: So basically they look as if their pH is the same.
> Ann: Yeah
> Beth: That's disappointing.
> Ann: Yeah

I was surprised by the response expressing disappointment and chose to pursue this more.

JR: You say it's disappointing but what were you expecting?

Ann: Something drastic.

Beth: We were hoping for something drastic.

JR: So you were hoping for something drastic.

Ann: You always want something interesting.

Beth: You want something that looks really important to impress your teachers so it looks like you did something.

Ann: But that's the basis of everything though. Whenever you do something that is for your own personal benefit it's so hard to answer because you want to make it look like the best answer, you want to have the best answer.

JR: So you want it to stand out as if more work was put into it?

Ann: Yeah

I was curious if this desire held for the outcome of the research act might influence how the students were viewing science. By this point in time I was seriously questioning the possibilities of science education achieving the desired authentic context.

JR: So how does that affect the way we look at science?

Beth: We want to be different.

JR: You're looking for something?

Ann: Yeah like even if it's not what you're looking for, something that is just to make it stand out more.

JR: So in that regard we would be doing it more for ourselves to feel good than to do science. Hmm that's interesting.

Ann: Yes.

JR: Now you actually have found something quite startling.

Ann: Really?

JR: Really...

It seemed to me that the research was being conducted to meet a more personal goal related to recognition. This recognition was possibly expected to be in the form of better grades. It seemed evident in the conversation that the students believed a "best answer" existed and this would "impress the teacher." The students had a clear sense that they needed to please the teacher, to provide the teacher with something the teacher wanted. The major task may have been, "What was it that the teacher wanted in this new context?" This may have contributed to making research hard.

The World Becomes More Complex

In the last two days of the field work I chatted with several of the groups in greater detail about their experiences. In each case students commented on how much more complex the world seemed. Jill and Alyssa had studied the mosses found in the park. Initially moss was just a plant in the forest that may or may not be noticed as one walked through:

> JR: Have your ideas about research changed since we started the project?
>
> Jill: Well there's a lot more to it and we didn't have the interest in it that we have now. It's a lot more than just looking at moss and saying cool.
>
> Alyssa: You have to pay attention to every little detail, there's so much more than meets the eye. When you actually start studying it - its overpowering. You start looking at one aspect of something and discover different aspects but there is not enough time to fit it all in.

Through research students gained an awareness of complexity which I did not believe could be developed as effectively in the classroom. In the case of Alyssa and Jill, their understandings of moss ranged from a macroperspective to a microperspective. In researching moss these students examined the plants in relation to other plants in the forest. They started to notice that moss was more common than they had believed. They discovered different types and the different stages of moss development. In microscopic investigation they discovered that a community of micro-organisms existed within the moss plants. Alyssa summed up her learnings in the following manner:

> Before we did this we would walk through the park and say oh that's moss. Moss is just moss. I had no clue that moss has been around for millions of years, how it was sexual and asexual. It was amazing what I discovered in researching it. There's more to it than meets the eye."

As a biology teacher, the students' realizations of the complexity of nature on a variety of levels was a sufficiently important learning to justify the project's use.

<u>Structures from School Science</u>

The students' most direct connection to scientific research had been the science classroom. Other connections included the media and popular culture. They may have conducted what they described as research out of the school but it seemed that school science was the measurement device against which to judge scientific activities. The following examples highlight the persistence of students' conceptions held for science and research. They also illuminate some hope for changing those ideas.

School science focused on re-presenting what was already known about the world. Students would effectively re-produce what was known for examinations and assignments.

Even the common research report was little more than collecting the known from books in a library and then hopefully converting that information into the student's own words. School science activities which may be best described as "doing science" were limited to the laboratories. These laboratory activities then became the standard against which an activity was deemed to be scientific.

Laboratory activities were planned well in advance of the students' arrival in class. These activities had been selected as resources because ostensibly they illustrated curricular concepts. The criteria for an activity included its relevance to the curriculum, its safety for the students, and most important, whether it provides the desired results. Availability of equipment and chemicals might be a further consideration. For each laboratory detailed instructions were available and commonly teachers would add further instructions if experience had proven them necessary. Students engaged in a variety of experiments through their schooling. Common to all experiments would have been manipulation of equipment, observation of results and measurements. These experiences then became the defining aspects for students in judging scientific actions such as research.

Mandy, Theresa and Erin had started the project intent on studying birds in the park. This became problematic in the first five days of the project. As fortune would have it they were lucky to stumble across a pair of squirrels with infants. This was a relatively rare event for urban dwellers and it captivated their interest. They switched research topics the day before I chatted with them in the following conversation:

JR: Do you think your ideas about research have changed this week?

Mandy: Yeah a little. The process you have to go through to actually gather your data is tough. Before all of the stuff we ever had done was in the lab. It's been very controlled and you're set out with your four petri dishes, your four siphons and you've got to do this, this and this. Here there is no structure. You have to be a lot more careful in what you do. You have to be a lot more careful in what you write down. If you don't take it down you're going to forget it.

JR: And if your tape recorder doesn't get turned on you miss it. (Laughing)

Mandy: (laughing) Exactly, which you have to do. (Turning to her partners) We should get a tape recorder and record the squirrel.

JR: You might find a video recorder works better.

Mandy: Yeah good idea.

I was curious if this uncontrollable aspect of field work may have contributed to a change in thinking about research.

JR: So research is not as controllable once you move away from school. How does that change the way you think about research?

Erin: It makes it more interesting.

Mandy: In the lab sometimes the things you do are neat. You see that turn purple, that turn brown, that turn blue to see if it has iron in it. But out here there's nothing turning colors, and you don't know what to expect. There aren't twenty-four other kids to turn to and ask, "Did it turn blue?" "Okay, good." Out here when you ask did you see the squirrel, it's gone. (they all laugh)

Theresa: It's more interesting like that.

They were criticizing the traditional science laboratory as disinteresting and I wondered what made field science more interesting.

JR: Why is it more interesting?

Mandy: The freedom to do what you want to do. Everybody likes what they're doing. If somebody is doing soils it's because they want to know what's in the soil. When you are in the lab sometimes you really don't care if there is iron present. We are doing squirrels because it interests us.

Research outside the school context must be organized to a greater degree by the researchers. The organization fundamental to the classroom experience was necessary for timely completion of an activity within a limited period of time. This reduced the learning experience available to students to merely going through the motions and checking that they have achieved the common desired result. The organizational skills of science were lacking for students in the lab activities. These skills, although time consuming in the classroom are beneficial for students. They may aid in the development of transferable organizational skills. They also increase the personal relevance of the activity. In the lab it didn't matter if they were observant, someone else had the same event occurring nearby. Results would be verified immediately and students would know they were "right." Laboratories of this nature may have given students the impression that a right answer or at the very least an expected answer existed.

As an aside, this interaction also highlighted one of the types of interactions a teacher researcher may have with students. Being engaged in research at the same time as the students created a common experience of researching. I could relate to their recording difficulties due to an instance I had a week prior when my tape recorder quit during a conversation and I had to reconstruct it from memory. They immediately acknowledged this as a problem I would face but it stimulated the idea of using recordings in their work. As I believe the teacher or researcher may suggest other alternatives, I suggested the video camera. Students did not have to engage in an experience in which they were left totally alone to grow as they might without mentorship or guidance. I, as teacher and researcher, was an integral member of the classroom community so I was permitted to make suggestions. They did not need to be heeded.

The strongest perception that students held about research was that to be scientific, research must be quantifiable. They associated the tests that were done as lab activities with science. Their evaluation of their own scientific actions was determined by the presence or absence of "weird experiments" as Kirsty termed it on the sixth day of field work:

JR: Do you believe you did this project scientifically?
Kirsty: We looked at them (water invertebrates). More scientific is like them. (pointing at another group conducting measurements of O_2 concentrations in stream water) They're doing all those weird tests but there were no tests we could do on ours.
JR: You couldn't do experiments but was your study not scientific because of that?
Kirsty: That's how I feel. But it probably still was scientific. You have to do weird experiments.
I had assumed from her physical reference to the other group that she was referring to conducting measurements.
JR: So a scientific study has more measurements in it?
Kirsty: Yeah that's what I think.

Kirsty and Kelly had been sampling and observing the aquatic invertebrates in a swamp within the park. They had designed collection devices to effectively sample the populations. Together they had attempted to identify the invertebrates, a daunting task for an experienced biologist. Even though they had conducted and documented the sampling and collection activities in a careful manner Kirsty found it nearly impossible to see herself as acting scientifically. There was only a distant possibility for her that she had been scientific. To be scientific required the use of measurements.

Terri and Crystal had conducted a series of "tests" on the creek's water quality in three areas of the park. They, too, judged their actions as scientific because of the similarities to school labs:

JR: What is your perception of how scientific you were in your project?
Terri: Very scientific. We did all those tests. We took every little, itty bitty thing into account. We tried to anyway. We had to find out the levels of things. You only do labs like that in science (class) so it makes sense that it was scientific.
JR: So because the things you did, like the titration for oxygen content, were only done in a lab, a science classroom situation then what you did had to be scientific?

Terri: Yeah.
JR: Crystal would you agree with that?
Crystal: I guess I'd agree because of the labs and stuff. But it doesn't seem like science because we're not in the classroom...
JR: So has science changed for you then?
Crystal: It's not so boring. We get to actually see it instead of reading a book.
Terri: And figure it out for ourselves.
JR: It's no longer just in class.
Terri: There's a whole world out there.

Crystal and Terri had a very successful project. They did not want the activity to end because it posed more questions which they wished to continue to pursue. This was a common occurrence for others as well. Students often indicated that they did not want the project to end. In so doing the activity raised the recursive nature of scientific research as a possibility. Where the initial meanings held that a conclusion was reached making research terminal, research became an ongoing process.

Scott, Chad and Justin studied the impact of mountain bikes on trails in the park. When I approached them on the last day of the field work Scott maintained that science was directly related to typical classroom activities, "measurements, weights and stuff like that."

JR: Would you describe your study as being very scientific?
Scott: I don't know. What do you mean? Did we use science?
JR: Okay. Sure. Did you use science to design your project?
Scott: To design it no. For figuring it out yeah.
JR: How did you use science for figuring it out?
Scott: The density tests and stuff like that.
JR: What was it about those tests that made it scientific?
Scott: Just using measurements, weights and stuff like that. We didn't learn that until science (class).
JR: In designing your project you said you didn't use science, could you explain that?
Justin: We made a hypothesis, that was science.
JR: OK. So do you think you were quite scientific in how you approached things?
Scott: I don't know.
Justin: I'm not sure what a scientific approach would be.
JR: What do you think a scientific approach might be?
Scott: $E = mc^2$ or something like that, some theory.

Given the pace of our conversation I had focused on the formula he gave.

JR: So using some formula?

Scott: Yeah. We saw some kind of physical effects and we wanted to learn why it was like that.
JR: You observed some things, the ground where the bikes traveled was bare. You went out and examined that.
Scott: We took some samples.
JR: OK so the tests you did were scientific and the samples were scientific, the hypothesis was scientific.
Scott: The field work, I don't know if you'd call it scientific though.
JR: Would you call it scientific?
Scott: No.
JR: What would you call scientific?
Scott: Me trying to figure out the atomic bomb. Just sitting in a lab all day doing tests. That's what I would call science.
JR: So science happens in a lab and involves measurements.
Scott: Yeah. All it is is measurements.
JR: Do you agree with him?
Justin: Ah there must be some kind of field work too. Like some of the stuff we did, collecting samples.

So again the ideas associated with the science classroom predominated in the meaning of science and research for these students. As our conversation proceeded Scott developed a dichotomous definition of science, characterized as physical and theoretical:

Scott: I don't know what the definition of science is. Do you mean physical science and theoretical science? We were doing physical science, we weren't thinking we were doing.
JR: Which part of your doing was science?
Scott: Everything. The theoretical was when we were in here measuring and examining. That was trying to prove the physical science.
JR: OK, the theoretical was proving the physical. What was the physical science?
Scott: The collecting samples, doing the experiments on the trails.
Chad: Science is difficult, 'cause you are trying to prove something that you don't know the answer to.

For Scott there was a distinction between thought and action. He had constructed a model of science based on school experiences. Doing experiments was doing science. Using "measurements, weights and stuff," was being scientific. In fact, all science was measurement. Science was largely restricted to "sitting in the lab all day doing tests." Whether or not field work was scientific was in Scott's mind questionable. Chad's comment reinforced a concept mentioned earlier, research was hard.

Research was the act of proving. In general it was a matter of proving something for which an answer was unknown to the researcher. Without a known answer the difficulty was related to the whole issue of knowing. How do we really know?

I had in my classes several students whose academic achievement was in excess of 90% consistently in all the sciences they had been involved in. They all had an interest in pursuing a scientific career. Two of these students, Christina and Chris, had formed one of the few co-ed groups to study the probable causes of the differences observed between spruce and poplar forests. On the last day of field study Christina presented a very different learning about research than I had expected:

Christina: I learned that the qualitative research was as important as the quantitative. Observation had a lot to do with it. Like looking at the needles and how water falls on them. Observation can be just as important as numbers.

Chris Sometimes there's a link that you can figure out. Well maybe this is higher and that would explain why these are spaced this way (referring to needle and leaf patterns), so you can sometimes link observations together.

I was quite interested in Christina's comment.

JR: So quantitative and qualitative are not separate in research?

Christina: Yeah, they're used in connection. I didn't really think that qualitative was as important as quantitative, but now I think it is. You have to make connections in which observations are really important.

Chris: It's good to have numbers to back it up. Just saying this is what I observed isn't enough. Someone else can't repeat your work. If they get a different number it might explain why they're seeing something different. They need numbers to back it up. So putting them together is best.

I had been totally taken aback by this comment from a 16 year old student (Christina). Even as I had entered graduate school for my Masters degree the research community was apologizing for the use of qualitative research. Some scientists still discount qualitative research as little more than popular journalism. Christina had an insight into science which I thought was valuable. Obviously the insights into research that students gained had very personal meanings. These meanings were closely associated with the degree of conceptual sophistication that they each had. This illuminated for me the lack of control a teacher may have in an experiential framework. Students will start with different bodies of knowledge and they will develop their concepts along directions which relate to those starting points. I seriously doubt that I could achieve a common understanding about the interdependence of qualitative and quantitative research with all of the students. Each had gained personal learnings. Each may have modified his or her ideas about research.

Metaphors as Meaning Giving

After the research had concluded, the students presented their findings to each other and approximately ten days later submitted their completed projects. At that time a final request was made of them, complete the simile, "scientific research is like..." This metaphoric device provided a description from which to interpret further meanings students held.

Metaphor is fundamental to human understanding of the world (Ricoeur, 1977). Metaphor has been central to our understanding of science (Kuhn, 1979). It has formed the basic tool scientists use to communicate their understandings of the world to each other and non-scientists. For example, the term, wave, has been adopted in the physical sciences to describe our understanding of electromagnetic and sound energy movement. Our understanding of waves in water has simply been transferred as an image to represent the scientific findings in these areas of study. In biology we commonly use the term, cell, which had been used by Robert Hooke to describe what he observed under a microscope. The term was reputed to have been applied to the structures he observed because of their similarity to the thick-walled cells of monks or criminals.

Although simile has been distinguished from metaphor (Geiger, 1981), I adopted the broader Aristotelian position consistent with Ricoeur (1977) and Pugh and others (1992) which included simile as a subset of metaphor. Metaphor has generally been the more appealing largely due to its poetic qualities often requiring greater thought to be understood. I find the distinction between simile and metaphor limited to literary dissection as both provide non-literal comparisons for descriptions. I elected to use simile as a metaphoric device for two of the five reasons Williams (1983) believed metaphor would be useful in education:

1. simile presented students' concepts in terms of their experiences, and
2. teachers could assess students' understandings through their choice of simile.

A more pragmatic reason for the choice of simile over metaphor was that I believed simile was a straight forward literary device which students could readily use without me providing leading examples as I may have had to in the case of metaphor.

A list of the completed similes is found in Appendix E and is worth examining. Students had completed the simile, scientific research is like, on the last written response I had required of them (see Appendix C#4). The simile was requested after the written research report had been handed in (June 17). In completing it they also wrote the salient points which connected their similes to the concept of research. When I was provided this additional information the similes appeared linked to events in the students' experiences of research. Jaimie's responses best illustrated the connection of the simile to experiences. She stated:

> Scientific research is like a crumpled piece of paper in the park. At first you don't have a clue as to what it is, and then, once you pick it up and examine it, open it up and lay it out flat so it's a simple shape, you can see what it is. And learn so many things about so many more things than just what kind of gum it was.

Jaimie described her experience leading to the simile:

> For my project I worked with garbage and the gum wrapper was the most predominant of the items I found. We had to draw many conclusions from what we found and we learned a lot from this.

From the data provided, meanings were evident for research. These meanings were different than those evident prior to the research project. This did not necessarily mean that these were new meanings but they were the more salient meanings after the experience. The similes cannot account for tacit meanings which may have arisen through indwelling. The similes contained within them corresponding features which formed the basis for the themes I identified.

Research is Dealing With Novelty

> Scientific research is like going into high school for the first time because you have all these expectations and ideas about what it's going to be like but you end up being surprised and finding that it's very different from what you thought it would be. (Rob)

The first theme identified in the similes dealt with novelty. Most students had not experienced a research project of this nature in their schooling. Entering into research for the first time in a "serious" manner would result in a series of expectations to exist based on held meanings and understandings of research. One's expectations are rarely the reality of the experience.

As a result of never having conducted research in the school context in the manner I desired, students were uncertain as to how to proceed. This uncertainty was in itself anxiety provoking and thrilling. Crystal chose a particularly anxiety laden simile:

> Scientific research is like jumping out of an airplane unsure if your parachute will open. It can be a thrilling experience. You won't know what will happen until you do it.

Uncertainty existed about the process, how to proceed and how it might turn out. Uncertainty may have contributed to the sense that research was "harder than it looked." Pete wrote:

> Scientific research is like an orange. It is hard to get into at first but once you've started and got something to study, all you get is good stuff.

Research was hard to get into because most students had not done this sort of thing before in school. It required organizational skills, collaboration and negotiation. Being engaged in a novel experience, difficulty was enhanced due to uncertainty about how best to proceed. Any anxiety created would undoubtedly be increased by the impending evaluation. This uncertainty was interesting in light of the students' earlier ideas Research seemed to be understood as a method which could be applied to solve almost any problem or answer any question. The students had difficulty in applying this method and indeed could not truly be seen to have a single defined method.

Terri portrayed her uncertainty in the following manner:

> Scientific research is like driving a car with no brakes. You are unsure what to do when you realize what is happening. There are times when you think you are close to a solution, something falls in the way. The adventure is exciting and thrilling and you wonder if it will ever stop.

She was indicating that the method used to conduct research was determined by the interaction of the researcher with the question in a specific context. It was an intimate act, like driving a car, in which one must be alert and prepared to modify one's actions. Situations might occur during research or data might be gathered which make it impossible to develop an answer.

A recurrent simile I have encountered over the years that this project has been running involved a movement from darkness into light. This is a culturally derived simile which equates knowledge with illumination. It sums up the uncertainty students felt and the resolution of that uncertainty as they dwelt within the world of research. Marc phrased it in this manner:

> Scientific research is like looking through sunglasses. It seems dark at first but soon your eyes adjust to the change and you begin to see more and more and get more insights!!

I liked Marc's simile because of the possibilities I could see in its interpretation. There was for me a beautiful, if unintentional, symbolism provided. He put on sunglasses to see the world as we had put on research to investigate the world. He also suggested nicely that research was a process he became accustomed to as he engaged with it. As a result of this engagement he found a new way to see the world.

Research is Dynamic

Leading from the first theme was a second; research was a dynamic process. It was for the most part uncontrollable. The intimate interactions of the researcher, question, and context created multiple possibilities. These possibilities arose frequently as twists. Arizona characterized research as a bumpy, twisted road:

> Scientific research is like a road with many bumps and turns. It was hard to start, and there were a lot of things that needed to be considered. Once the project was going things needed to be slightly altered because it didn't go right at first. Then the project just about took a wild turn to become something else but went back slightly changed.

Her simile revealed the difficulties she had getting started and how the research needed to be altered. She almost entirely changed her research topic in the middle of the allotted time. She definitely indicated the intimate interaction she had with her research context in the impending "wild turn" she almost took.

Mandy characterized the changing demands of research in a slightly different manner:

> Scientific research is like a spiral stairway. Each step you take introduces you to a new level with new meanings and even though each level is more beautiful than the last it also has many more challenges and problems to figure out.

Once again research was dynamic, shifting as the researcher engaged through time with the context. She had elected to use the idea of spiraling, just as curriculum developers had used that simile, to suggest that we engage with more difficult and "beautiful" concepts as we gain knowledge through experiences.

Research changed because students were engaged in the process. It was not something trapped in a book or the words of a teacher. Research was a world they could dwell within albeit briefly. Kirsty described research in terms of examining another person's room:

> Scientific research is like a room. The more you look the more you see. A room reveals the personality of the inhabitant. There is a lot more to the room than first appears.

Research required close attention to detail. Observation could be seen in this simile to be variable from microscopic to macroscopic perspectives. The "more you look" indicated to me that the researcher controlled the levels or depths of observation. Certainly Kirsty's simile also revealed the role of curiosity in research, for when we are in the unfamiliar setting of an Other's home or room we are struck by curiosity about the Other.

The students' earlier ideas provided no sense that research was dynamic. Instead, a method was applied which led to the desired result. There was no indication in the students' earlier ideas that the researcher was intimate with the process of studying. There was neither a sense of engagement with the context nor realization of the shifting approaches to accommodate changes dictated by the situations encountered. I believe that Chris, one of the top academic students, summed this up in a lovely simile which carried research beyond the project into a global perspective:

> Scientific research is like a wind, because it moves forward but changes directions depending on the conditions in which it exists. It can be destructive or constructive depending on how it is used. It can be relentless at times.

Research is Never Ending

A third theme derived in part from the second was the theme that research never ends. Most commonly this has been captured in the circle simile like Lori's:

> Scientific research is like a circle. Once you start on the path to answering questions the journey never ends.

Occasionally this simile was captured by the pop culture icon, the energizer bunny, as Chad described it:

> Scientific research is like the energizer bunny, it goes on and on and on. It is never finished in any subject, there is always something new to be discovered.

Research became never ending due to the twists and turns of the process. As the students proceeded deeper into the topic they researched they had numerous new questions arise for which there was not enough time to follow up on. Terri and Crystal did not want to return to regular classes. These "Biogirls" had intended donning their "Bioboots" climbing into their "Biomobile" nightly to continue researching their topic. Terri's earlier example of simile had her wondering "if it will ever stop."

This understanding of research was different from the earlier themes had indicated. In those themes research had a terminal point, a conclusion was reached. There was no indication that research was recursive or ongoing. It had appeared as a terminal linear event. Research was now filled with greater possibilities leading to further research.

Research Provides Unexpected Treasures

Initially research had appeared to be purposeful, to solve a problem or answer a question. The simile which arose instead portrayed research as culminating in a treasure. The implication, of course, was one of discovery, possibly nuggets of knowledge. Alyssa described it in a common simile, the pot of gold:

> Scientific research is like a pot of gold at the end of the rainbow. It is an amazing thing that holds many treasures at the end of a beautiful discovery. You must follow a path to it requiring patience and careful observation before you reach what you're looking for.

Research required the use of a method or path to attain what was sought. The path was no longer predetermined but emerged as the students walked. The pot of gold simile was a nice way to suggest that the product of research was valuable but not quantifiable until one reached the point at which the discovery was made. The final determination of research's value was only determined after the fact.

Conclusion

I could not say with any degree of confidence that the meanings students held for research were totally new meanings; they may very well have existed before in a tacit form or were merely not expressed earlier. I could however say that the research experience they had contributed to raising these meanings to the forefront. Clearly indwelling as students had for a short period of time provided an aesthetic appreciation of research. As a teacher I had to examine what gains had been made in this experience to assess its pedagogic value. The insights students seemed to have gained into research were a tentative beginning. They were sufficiently important in my estimation to warrant continuing the project in the future.

CHAPTER 7
REFLECTING ON THE SELF AS TEACHER / RESEARCHER

Introduction

Rebecca Luce-Kapler (in press) asked the provocative question: "can research be anything more than a not so subtle form of writing the self?" The researcher is intimately interwoven into the fabric of the research. The researcher is woven even deeper into the words which describe the research. The researcher has lived the experiences which provided the focus for the written word. Repeatedly the researcher returns to tapes or transcripts, re-constructing the images, voices and thoughts which have become disembodied by time. The voices had been intermingled with smiles, gestures, movements, and the broader environmental stimuli. These images, incompletely captured in memory, fade with time. Researchers dance intimately with words, spinning, changing direction, finally settling into a pattern. The understandings of research are most vivid and meaningful for researchers because of their physical, emotional and intellectual involvement in the process. Research is personal, a process which redefines researchers, altering them slightly.

After teaching for twenty years, there were some answers I had come to expect in relation to science and research. I expected that students would portray scientists as very smart, using high tech equipment to discover new things. This is a classical stereotype. I expected students to describe research in the context of their school experiences. The science classroom is the only experience for most students which has been formally defined as being scientific. My attention was attracted by the words spoken. They seemed to describe broader concepts and I formed my interpretations. These interpretations formed the boundaries I defined for students' meanings for research. During our conversations students responded to my questions or shared ideas which at the time seemed complete within the context of our conversation. Certainly there were times I could have pried deeper into a statement, but often these moments were lost by the nature or pace of the dialogue. At times I had not realized the importance of what students had said until I listened to tape; the moment to further investigate lost.

Chapter 6 examined the students' meanings for research as I had interpreted them from their spoken and written words. I engaged with them in person through the course of our class time together. I reflected on my experiences as I bicycled from group to group, as I drove home, and in the evenings. These activities are typical of the daily life of a teacher. The activities I conducted as a researcher were atypical of teaching life. Tapes were listened to repeatedly and logged into my field notebook. Written responses were read, reread, and categorized. My understanding developed as I observed specific responses and focused my attention on them. Returning to students I sought to clarify if I had interpreted their words appropriately.

Meanings were a wavering of presence and absence. Occasionally, while I listened to the transcripts, engaged with the words, I was disturbed. I wondered about what students had left unsaid. Imagine listening to a conversation, recognizing the discrete comments or patterns of words which appear to indicate a particular understanding, but almost simultaneously being aware that something expected was lacking. My engagement created the possibility for me to examine that which was left unsaid by students. Although the unsaid suggests a little about the students' meanings for research, it also highlights my expectations and biases. These reflections as researcher provided insights into issues and topics which may be considered when I next teach science. It is these aspects of the research which this chapter seeks to address.

The Unspoken

Truth

In initially describing their meanings for research through stories and definitions many students spoke of the role of research in providing facts. These facts were generally seen to be immutable. Once science had discovered something it was then a fact and, as such, unchanging. I found it interesting that during the research project no students referred to truth in relation to research. Over the past several centuries science had "uncovered" and articulated numerous facts. These have been popularly accepted as unquestioned truths. For scientists these facts are tentative at best. Scientists acknowledge that the possibility exists for a fact to change. Questions still exist and the definitive truth is illusory. Certainly the knowledge that has been provided through scientific thought and research is useful within much of our known context.

For students it may simply have been that facts subsumed the truth within them. I interpreted facts, as used by students in conversation, to be knowledge of an unchanging nature. Facts removed the necessity to question. If something was defined as a fact it was unquestionable because the question was already answered. Why reopen the question? This raised for me the epistemological question: "How do you know?"

I was concerned how students knew that something they believed was a fact. In most cases it was because they had been told by an assumed authority. Textbooks and teachers were authorities. Scientists were authorities. Contact for most students with scientists was via television; it too was an authority. Television programs, including the news, provided facts. Knowledge was transmittable.

It was little wonder that the passive acceptance by students of authoritative knowledge has been disturbing to Apple (1993) and Freire (1970). Often facts tend to remove uncertainty and made life a little less discomforting. I have noticed through my science teaching experience that students are very uncomfortable with uncertainty. They prefer the definite to the tentative. To provide a tentative answer as must be done in the sciences, particularly biology, is disquieting for most students. I believe part of the answer for this disquieting effect on students is found in the structural nature of schools, which is dealt with in Chapter 8. Students are evaluated, commonly by examinations, and facts make examination preparation and writing much simpler. Commonly, facts are the answer. When presented with uncertain or tentative information in class it was not uncommon to be asked, "But what do I write on an exam?" If a fact is indeed unchanging it is relatively easy to memorize and makes exam preparation easier. High school students are very conscious of the flow of schooling; information is presented, it is studied and examined.

One of the strengths I believe the field project has is its ability to provide opportunities for students' presumed facts to be challenged. Students may encounter discrepant events during the course of their experiences. Students studying the soil chemistry of different forest communities described their frustrations involving the failure to find a difference in pH. One of the contributing factors to this frustration was that they had been "told" soil pH was lower in coniferous forests. This frustration was compounded by the popular notion that the pH would be the same throughout a particular forest and not variable across even short distances. Although the students' experiences were frustrating, they illustrated for me the challenges the project may pose to students' beliefs. Frustrations resulting from discrepant events may initiate conceptual change. According to Kuhn (1970) and Bruner and Postman (1973) conceptual change may occur when individuals recognize their expectations have been violated by an anomaly.

Variables

I had expected more students to speak about variables; only two groups made any mention of this aspect of research. Two students, Tanelle and Sandra, discussed variables as facets of a scientist's world which were different than theirs. Without a doubt the concept of "variables" was not foreign to students as variables have been repeatedly discussed in science classes. The notions of dependent, independent and controlled variables are considered basic principles of scientific knowledge. One of the rules of Cartesian methodology was to dissect problems into their simplest parts (Borgmann, 1992). Through reductionist thinking we had been able to make sense of systems operating around us. At the root of scientific inquiry has been the attempt to limit and control the variables which may act in a situation being studied. As a result, these concepts were found in the curriculum by the time a student was in junior high school.

I believed that although these variables are "studied" in school they are often taught without a context which was meaningful to students. Few students may consider these as anything more than terms which must be memorized for an examination. Variables are a real concern for scientists. Only one student, Chris, stated concerns about variables. Chris and Christina had formed a partnership investigating the factors which may have contributed to apparent differences in vegetation communities. Chris described his concerns in the following excerpt from our conversation at the end of the project. We had been talking about what they had to do to successfully complete the project.

> Chris: You have to think about what could mess you up, like controls. Like if it is raining how is that going to effect the drying (of soil samples), if you are going to dry one (sample) for two days you have to dry them all for two days. You have got to make sure the pH scale is calibrated.
>
> JR: Did you learn that in this project?
>
> Chris: Yeah 'cause we never really did an experiment like that. Everything was done for you; it would say this is what you have to do. But this way you had to think about that and do it the same way for everything.
>
> JR: So you knew about controls but this was the first time you had to apply some rules.
>
> Chris: Yeah I had to think about it.
>
> Christina: We had to decide how we were going to set it up, what tests we were going to do. How were we going to do it. No one said these are the tests you need, we had to come up with it. It was good to do it this way.

Chris and Christina said that their prior science experience in schools had not required them to consider how to actually select, manipulate and control the variables that were interacting in classroom laboratory activities. The teacher or author of the laboratory activities had already determined those aspects of the experiment for them. If this was true for other students as well, it was little wonder that any mention of variables was missing from the conversations and field notes.

The teacher researcher approach to classroom research creates a conflict in situations like this. The researcher seeks to keep the question open and not hastily close off interpretations. As a researcher I feel that it will be important to explore the students' experiences of laboratory activities. As a science teacher I do not desire to close the question but I do reflect on how I may alter my practice. These comments spoke to me of the importance of providing students with opportunities to conduct research of their own so that the task of considering variables was undertaken. The personal connection may then provide a superior level of understanding of the concepts of variability. It seems that vocabulary lacks personal meaning in the absence of a context within which the meaning may reside.

Objectivity

Science has been striving to be objective for centuries. Objectivity has become a hallmark of science. Superior value has been afforded to objectivity over subjectivity. This struggle for objectivity found its roots in Descartes' method. To achieve proper method, the rational human must abstract the problem from its "context and our tacit understandings" (Borgmann, 1992, p.35). In attempting to be objective scientists had lost the benefit provided by context, including the historical, sociological and psychological dimensions. In the past half century there has been an increased realization on the part of scientists that it is impossible to be truly objective. Individuals were intimately intertwined with the questions they sought to answer. I found it particularly curious that these realizations appeared to arise with physicists, like Heisenberg and David Bohm, yet physics had historically been the most seemingly objective of the sciences.

Students repeatedly acknowledged that research was conducted out of personal interest for both themselves and scientists. To do otherwise was in their words "boring" and probably unproductive. Only Christina had spoken of clarity and objectivity in her initial comments on research. She had assumed the supremacy of objective, quantitative research. By the end of the project she was indicating that qualitative research, which appeared to be implicitly subjective, had equal value to the quantitative. Other students did not speak of objectivity and evidence of it was not found in their written work. It may well have been that students did not view themselves as scientists. In the section on structures from school science in Chapter 6 there definitely was, for some students like Kirsty, a doubt that they had even behaved scientifically. As students, striving for objectivity may not have been seen as important.

I was pleased that students did not verbalize or demonstrate notions of objectivity. By recognizing the personal aspects of research in this project I believe the students had for the time being avoided the acceptance of the myth of objectivity.

Imagination and Creativity

Einstein was reputed to have said that imagination was more important than knowledge. Only one student, Celena, made any mention of imagination in relation to research. From her perspective scientists had the imagination to define new research topics. She felt that this was occurring in a vacuum of sorts separate from their existing knowledge. Scientists thought up interesting topics and pursued them for the thrill of discovery.

Discovery in science or other human endeavours is an act of creation. Thinking scientifically required vivid imagination just as was required in the arts. Creativity in these two dimensions of human creation was however fundamentally different (Wolpert, 1992). Artistic creations were intensely personal and remain so throughout time. Commonly the artist was remembered in reference to specific pieces of art. Scientific creations have tended to become public knowledge, thus ultimately becoming anonymous. Originality was critical to the artist, as was the nature of the creation. Usually works of art had multiple meanings and this was prized by the art community, for art could speak to everyone. In artistic communities value was assessed subjectively with varying criteria. Scientific creations had tended to have very discrete meanings often limited to members of specific scientific communities. The value of scientific creations was judged by criteria thought to be objective and shared. Where art sought moral value, science sought to be value-free.

I found no recognition of imagination or creativity as a property of research or a characteristic of scientists. Only Celena made a few comments about scientists' use of imagination in defining problems to study. Originality was prized to a degree by some, but originality appeared to be unconnected to imagination. I suspected that this originality was linked in some way to a desire for recognition. In a class with thirty others where evaluation occurred, originality may have increased the likelihood of being recognized individually.

Maybe students just did not see themselves as being creative by the time they had reached high school. Certainly every project that had been initiated had been the result of a creative process. In many instances students were not cognizant of the events leading to their development of the central idea for their project. Others, like Terri and Crystal, could identify the exact moment that their question was triggered. For these students there had been a prior interest in some biological aspect of nature, birds, water, trees and at a precise moment they had perceived something which had caused them to wonder. It was the sense of wonder that they had about what had been perceived which became the core of the question they developed. The following section from their proposal illustrated this well:

> While walking through the park, we came across a source of water which had a disgusting film on it. We were wondering if it was caused by pollution, light deprivation, the different trees surrounding the area or a sewage problem. All of the other sources of water were clear and possibly this other source could have been affected by a lack of oxygen. We would like to research the difference in contents in each of the different water sources and find out what might cause these differences.
>
> The difference in the water interests us because we are concerned about the safety of our waters. We are also interested in the looks of the water. We would like all the water to look clean and healthy.
>
> We are not very well informed about this issue. This is one reason we are interested in these differences in the two sources of water. We hope to gain more knowledge through this project.
>
> All our lives we have been curious about the Earth's future, including the bodies of water in the world. We are not close to an ocean or a large lake therefore we are researching with the two sources of water available to us. Also when we discussed with Mr. Rymer he asked us some intriguing questions which helped us shape the nature of our study.

Research is historical. This excerpt demonstrated that the students had prior interests and curiosity. Their sense of wonder was captured by the sight of "a disgusting film." Once caught in wonder students began hypothesizing causal relations (pollution, light, trees, sewage) which they thought possible as explanations for the observed conditions. Recognizing their lack of knowledge ("we are not very well informed about this") they set out to design their study with casual relations in mind.

Research is intimately related to the researcher. There is a sense of wonder that develops for each of us as researchers which we heed and allow to dwell within us. I believe that we as humans have an immense sense of wonder about the world in which we live. This, in part, was a driving force behind science. To conduct an investigation required imagination and creativity. There were so many possibilities for different lines of inquiry that a very creative process was undertaken.

Science as a Human Activity

Research was the vehicle through which students made personal discoveries. I suspected that the relationship of discovery to research was reinforced. The idea of discovery has been intrinsic to the meaning of research for centuries and has been popularized to a greater degree in the past century through impressions of science provided in the media and increases in the public's general knowledge. Even so the thought processes involved in scientific discoveries have remained mysterious (Root-Bernstein, 1989). Root-Bernstein maintained that scientists, in pursuit of objectivity, tended to strip away the historical, sociological or psychological aspects of their research as irrelevant. Students as well appeared to have missed the contributions made to their discoveries by others and themselves.

For me the most disturbing unspoken aspect of the students' understandings of research was the human connection. I had mentioned earlier that science was portrayed in student language as an entity separate from the human beings who conducted it. "Science did this or science did that." Science seemed to be acting on its own divorced from the human minds which developed scientific thoughts. Certainly we have used the word "science" in our language in a manner which permitted us to quickly and effectively allow others to understand what we intended them to understand. In conversation science took on a virtual identity without a body. In written definitions science was a thing as opposed to an action.

The curriculum intended that students hold positive attitudes toward science. This needs to be considered more carefully given the manner in which science is referred to in common vernacular. The desire of curriculum writers was probably to have students develop positive attitudes toward the nature, value and limitations of scientific thinking. In essence, students would be able to celebrate the human mind and its ability to use thought in a manner which allowed us to investigate our world through the use of scientific thinking. We are not celebrating the existence of an actual entity separate from humans.

In speaking of science as an entity separate from people students have also effectively separated science from themselves. Science was elsewhere, a mystical, mythical world populated by very intelligent analytical beings, probably with glasses, frizzy hair, white lab coats and computers. Science was not seen as a construction made by human beings determined to understand the world they lived within. By not seeing science in a manner which required the presence of human beings the students had not acknowledged one of the most important learnings school may offer them about science. Science does not dwell in textbooks, library books, videos or teachers' words. If human beings no longer existed science would also cease to exist.

Conclusion

Each of the concepts I have presented in this chapter is contained within one realization. Science is a uniquely human act. It has been interpreted by many as the human search for truth. In conducting science human beings have attempted to limit variables because the very nature of our sensory system and biological body precludes us from comprehending the shifts of more than one variable in a situation. Human beings decided that objectivity was valuable and desirable, it was not a condition set upon us by science. It is the inherent imaginative and creative nature of human beings in concert with our sense of wonder which made all that we now see as science possible. For students to not recognize that humans, including themselves, are intimately related to science is for me a disappointment. It has demonstrated to me a theme that I will seek to consciously address in my future teaching.

CHAPTER 8
QUESTIONING THE IDEA OF AUTHENTIC SCIENCE

The biology field project developed in response to the call for the incorporation of authentic science within school science. In interpreting the curriculum and developing the field project as a means to achieving several of the objectives I had not adequately considered the students' understandings of schooling. I had not been critically aware of my own connections to the discourse of schooling. This chapter examines the reflections I experienced in reconsidering authentic science as it may be applied to schools. Experiencing scientific research was my pedagogic intent. As I interpreted the data collected and developed the analysis, concerns became apparent to me relative to attempts to implement authentic science in schools. Students responded to the learning situation in manners which suggested that the situation was not authentic to the degree I anticipated. As a result the meanings they derived might very well have been influenced by the school situation and my anticipation.

Revisiting Authentic Science

The suggestions for revisions to science education in Alberta (Alberta Education, 1987;1989), in Canada in the 1980's (Science Council of Canada, 1984) and in the U.S.A. (A.A.A.S., 1989) included the notion of authentic science. The basic intent of this notion was to increase students' exposure to actual scientific processes related to knowledge construction. As a result of being involved in the practice of science the students would obtain a greater understanding of science. Michael Roth (1992a, 1992b) had investigated authentic practice in science classes and suggested the merits of such practices for science education. Roth (1991) also suggested that science education should operate as a form of cognitive apprenticeship. As mentioned earlier in the literature review the term authentic science may be viewed in three ways: first hand experience with science, an experience in accord with commonly agreed upon understandings of science, or an experience which reliably represents science.

I found the arguments for the use of authentic science intuitively compelling and as a result defined authentic science as an actual scientific experience. The field project was designed as an activity which would provide the experience of scientific processes. I desired that students would see themselves as scientists in the process. In developing the project with this perspective I had not fully comprehended the inherent difficulties. In retrospect there appear to be other considerations which needed to be understood to better develop this as a scientific experience. Social structural elements of schooling and their discursive practices needed to be considered.

Students' actions suggested to me that they did not perceive themselves as scientists during the activity. They were just students. Cohen and Harper (1991) identified the greatest impediment to students being scientists as a conceptual lack. They identified conceptual issues which were apparent in some of my students' responses. The first conceptual issue was that our culture holds a stereotypical, generally unflattering, view of scientists. Scientists are thought to be very intelligent, not so attractive, wild-haired men surrounded by computers and bizarre lab equipment, possibly like Christopher Lloyd's portrayal of Doc Brown in *Back to the Future.* What chance was there that students would see themselves as scientists if those images are gendered and "nerdy?"

Students correctly identified another issue related to being scientists. They could not be scientists for they had not gone to university, nor had they been trained as scientists. Naturally, being a scientist was the culmination of a process of becoming. They were students, still in school, planning to become something (not necessarily scientists).

The third issue identified by Cohen and Harper was that some students are from social groups commonly underrepresented among scientists. Being female, physically or mentally less able, an ethnic minority or poor reduced the likelihood a student may see themselves as a scientist or scientific. The majority of my students were female and may by this point in schooling have rejected science as a career choice. My earlier research in this school had indicated that students expected to use science in their future careers but they did not expect to be scientists (Rymer, 1995; Rymer and McLennan, 1996).

After examining the data and reflecting on my experience with students I had doubts that authentic science could be developed in schools. There is no doubt that my sociological orientation biased my interpretations and focused my attention during conversations. I believe that my understanding of sociological theory was merely one tool which I used to interpret the data I had collected. Social structuring of schools and its discourse are not discrete. Although my analysis was structured as discrete units, these units interacted and were interdependent.

Structures of Schooling - Is Authentic Science Possible?

During the field biology research project it appeared to me that many of the students ideas and actions were predicated on their understanding of school rather than science. I had intended and expected that students would see this as a scientific inquiry thereby gaining insights into science and research. Like so many of the students, I too was presented with a discrepant event. I had not recognized at the outset the attachment to school structures students had. I had not recognized that I, too, was trapped within those same structures and their underlying discourse.

Initially I examined the expectations students held for this project. After students had been informed about the nature of their science project and had been taken on an orientation walk through the study area I asked students to express their expectations for the research experience on question sheet 2 (see Appendix C#2). All expectations related to the context of students, school (see Table 2). Although this context did not define the meaning of scientific research it may have set boundaries upon what research could mean.

Category	Males	Females	Total
Get good information	0	1	1
No idea	0	1	1
Unsure - both "good and bad"	0	2	2
Have a good project	1	1	2
Get a good grade	3	0	3
Be outside in nature - not in class	2	1	3
An interesting way to learn	1	3	4
Hard work	4	7	11
Learn something new	10	21	31

Table 2. Students' expectations for field project

(total respondents = 54)

Learning

Learning is implicit within the connotation held for school. "I go to school to learn" is a concept socialized into children at an early age, well prior to entry into the school itself. It is commonly expected that learning goes on in school. We constantly inquire of children, "What did you learn in school today?" No other human social activity is questioned in this manner. The majority of students indicated that they expected the project and research to be a learning experience.

Students' expectations were consistent with the meanings described in their initial stories of research. This earlier data (Chapter 6) suggested scientific research was purposeful, learning occurred and new knowledge was found. Some expectations expressed by students included the following:

Erin: I expect that I'll learn many things. I'll learn how to look at my surroundings through new, more knowledgeable, eyes.

Jill: Hopefully I will learn more about our forest and, by having a hands-on experience, I will be able to decide whether this is something I want to do for a career.

Matt: I will learn more about nature's mysteries.

Sherry: Hopefully I will learn about something I knew little about before. This will be my first real research experience.

Arizona: I hope to find something interesting and new in this experience.

These expectations clearly state that students expected a learning experience. Comments like Erin's, Sherry's and Arizona's indicated that students acknowledged they already possessed a body of knowledge but this was lacking. They appeared to desire to address this lack through learning something novel.

On the basis of a few comments, like Matt's, nature took on the vestiges of a mysterious entity which kept secrets hidden from us. Scientific research appeared to be the means we used to unlock mysteries, to discover secrets or find facts.

Learning in schools and in science is not similar. In schools, learning is orchestrated under the leadership of teachers. Teacher commonly act as managers of, or technicians for, the learning process. Knowledge is commonly presented as pre-existing forms. The congruence of students' knowledge with the presented knowledge is quantitatively measured and reported. Teachers are likely to be seen as experts and have questions or problems presented to them by students. Teachers are expected to be able to provide answers or solutions for these problems.

In scientific communities learning is not managed or controlled by a single supervising authority figure. Knowledge is not presented to them in research but constructed or emergent. It is not seen therefore to pre-exist. The knowledge is not measured quantitatively but comparatively. Knowledge is compared to both the existing knowledge base and to the world. The degree to which knowledge explains the world is taken as an indication of its value. The knowledge scientists derive from their endeavours must be presented as claims to other scientists for their consideration and critique. The claims made by scientists are socially constructed into facts through consensus formation.

The myth of teachers as experts provides an opportunity to compare research relationships perceived by students. Tanelle and Sandra in the "Contrasting Student Research with Scientists" section of Chapter 6 stated that scientists encountering research problems could approach colleagues but expect no answers to their problems. Since research is the exploring of new areas scientists could only expect helpful ideas and suggestions from other scientists. Other scientists could not know the answer to a problem because research was novel. Students expected that any problem could be taken to teachers for a solution. It appears to be a popular myth that teachers always know the answers. There is little doubt in my mind that the historic nature of students' contacts with teachers dating back to elementary school and possibly preschool has influenced this myth. Parents may play a role with comments as simple as "Listen to your teacher." It may have been socialization, the relationships that develop between students and teachers, teachers' behaviors or a combination of factors which contributed to this myth. The result of this perception of teachers as teachers as experts framed a distinction between being students and being scientists. Students are rarely experts in school and rely on teacher-experts. Scientists are experts in their field. This distinction may also have contributed to the difficulty students had in seeing themselves being scientists or scientific.

The learning situation is therefore quite different. It differs in the degree of personal control and involvement. Students and scientists may both be presented ideas. For students the presentation is from an authority who will evaluate their assimilation of the knowledge. The ideas presented are already considered to be "true." Scientists may be presented ideas by a person recognized as an authority in a field of endeavour but their assimilation of that knowledge is not required nor measured by that authority. Their critique is expected and the ideas are considered to be tentatively true only after considerable discussion involving consensus.

Timetabling

Eleven students referred to expectations of difficulty or hard work on question sheet #2. They did not suggest that they believed research was hard or difficult. Students spoke of the demands schooling placed on them and that this project added to these demands. Certainly the weighting factor of this assignment contributed to this stress but the students generally referred to expectations of other teachers and extracurricular activities. A good description was given by Alyssa, one of the grade 10 students taking a full course load, striving for an honors standing and having a major extracurricular commitment involving a theatrical production that was just opening:

> For me personally, I have a feeling I am to become very stressed out. I have so much going for me right now, that it's almost impossible to find time for it all. Not only that, finals are approaching and teachers are trying to jampack everything in during this last month, which raises the stress levels even higher. I think that's why I'll enjoy this project, it will be work but at the same time, relaxing.

Another student from Grade 11, Jaimie, echoed this sentiment:

> This coming month I am going to be very busy trying to balance my subjects. But it will be an interesting project that I'm sure I will enjoy.

Students had incredible demands upon them, especially as this field project occurred in May and June. They had three to five other teachers expecting their time, effort and attention. To please every teacher and meet the expectations set by teachers and themselves the students were no doubt stressed. The timetabling pattern we have been using in this school is commonly practiced around the province. It locks students into defined time periods with subject area specialists. Assuming that students had a full timetable, as most did, they were in contact with several disciplines and teachers daily. It must also be realized that I am not considering the demands of students' extracurricular lives.

In striving to provide a scientific experiences in schools I am faced with an irreconcilable problem under our current timetabling constraints. As long as students have their days compartmentalized into eighty minute blocks the situation in which they work can never be truly authentic. At class change, the ideas and thoughts they have been grappling with cannot continue but have to be replaced by an entirely different discourse. Students are constantly required to "balance" their activities to meet the demands of various teachers.

For most adult activities time is not so carefully controlled as it is in schools. Time has been central to the determination of credits and compliance with the mandated curriculum at all levels of schooling. Scientists are not operating in such a situation. Scientists do not normally switch discursive communities on a time regulated basis. Students engage with scientific discourse for eighty minutes, take a brief break and then engage social studies discourse for another eighty minutes. The time to focus one's attention on research is managed by scientists. It is not stipulated by an external authority making a rigid timetable extending over a ten month period. Scientists are not normally required to shift their thinking and discursive community on a fixed schedule.

This criticism of schooling is being considered in our school to a degree. Recent faculty discussions about Copernican timetabling suggested we might possibly reduce these problems posed by the current four courses per day timetable. Such a timetable would provide half day long lessons which may better provide the time I desired for indwelling the scientific experience. The discourse in secondary schools has only recently, due to funding changes, begun to be focused on less rigid scheduling. In the past a timetable was an inflexible structure which constrained the school's operation. To meet the new economic challenges schools are now seeking innovative means to expand their "market share" and effectively use resources.

Power Relationships

Students are confined during their schooling years within a particular social structure. This structure may be seen inherently unequal and hierarchical. Jackson (1968) described school as a place where children were required to act as individuals while in a group for the purposes of evaluation. It would seem that issues of control and power would arise. From a structuralist perspective power is located in the social structure.

Alternatively power may be viewed as complex strategic relations between people (Foucault, 1977). Unlike sociologists, Foucault was not directly concerned with locating power. Instead he examined its expression and the effects of that expression. One of his concerns was the relations of power which constitute human beings as subjects. An effect of power being exercised in a social body is the definition of human beings.

The discourse of schooling includes the concept of teacher control. Classroom control is considered a teacher's responsibility. Acting in isolation, with many students, teachers' control may be exercised in numerous ways. Control is made possible by the individual students' entrapment in and acceptance of social discourse. Control is also maintained through techniques of discipline and surveillance. The failure to comply with reasonable teachers' requests can lead to varying degrees of punishment, from ridicule to expulsion.

Students are well aware that teachers exercise power and the need for compliance. The following conversation illustrates students' awareness:

JR: Why do you think students put up with teachers designing the labs you do?

Mandy: It's a respect thing.

Erin: You have to.

Mandy: It's told to you since you were in first grade. You respect your teacher. You do what your teacher tells you. You're an exception, you're a very, very, good teacher, for if something has to be changed or different, you are very good to accommodate students' needs. But at least once in school you get a teacher for whom its their way or the highway. If you don't do exactly what they say you not only fail the course, but they hate you as a person. You always know, just do what the teacher says. Do this because its told to you to do it.

Erin: Yeah.

Theresa Marks too.

Mandy: Marks are the other reason.
JR: Why do people do it for the marks? What's so special about the mark?
Erin: They don't want their parents to kill them!
Theresa: I don't.
Mandy: When it comes to this age, grade 11, you start to think about university or college. Hopefully you have specified more, I'm taking bio because I need it for ecology. I don't need physics. But for a lot of us we don't know where we want to go so it's for marks. We don't want parents to kill us, and we need a broad spectrum like chem and bio so we can get into all of these programs instead of I just took bio and can only get into this program...
JR: Do marks do anything for you as a person?
Theresa: I don't want to go down.
Mandy: Not only that but if you have a good mark it makes you feel better, 'cause you're not stupid... it makes you feel better, you know you can do it. You're not stupid.

The students' comments indicated that they had been exposed to a discourse which stated that teachers should be respected. These students indicated that they were told to respect and obey teachers at an early age, presumably by their parents. Respect for teachers and teachers' right to express power has a discursive source. Schooling experiences these students had seem to suggest that this obedience and respect are not always deserved by individual teachers.

Mandy, Theresa and Erin indicated that students complied with teacher designed activities for two additional reasons. They had a fear that teachers would exercise power through grading. There were several ramifications of a poor grade. Two ramifications were course failure and shifts in self-concept. By the latter half of secondary schooling, considerations for post-secondary schooling and career preparation becomes increasingly important as Mandy indicated. Teachers are perceived to have the potential to influence the nature of this transition through evaluation. The second fear students held was that parents would exercise power in response to students' grades. Parents recognize that grades are important for students because entrance requirements are frequently linked to grades. Their parents would "kill" them metaphorically if their grades were low. Teachers play important structural and relational roles in evaluation and control of classroom activities.

Evaluation

By high school, students have been conditioned to patterns of schooling. Evaluation has been a critical and indeed central element of schooling for students. It is derived from the social structures of schooling. The hard work of schooling is to understand all of the ideas teachers try to "jampack" into their courses so that these can be studied for the upcoming finals. Ultimately students have to produce a product. Something has to be handed in or a test has to be written. To prepare for evaluation students need to understand what is expected of them. Their basic task is to determine what teachers wanted.

Parents, teachers and students recognize the importance of grades. Many still believe that grades are a reflection of merit. All these people know that grades are important for gaining entrance into post-secondary institutions. Grades are used to select students for limited openings in these institutions, and in that regard play a political role. The concern students had about grades was reasonable within the context of school they had lived within. Students took a pragmatic approach to their schooling which optimized their opportunities.

Students expressed their concerns regarding evaluation in relation to grades, the key element of evaluation for them. Indeed three students directly indicated good grades were their expectation for the project. The value attached to grades has always varied between individuals. During the orientation walk Alicia had just described her project ideas to me and then shared the following concerns with me as we walked through the forest:

Alicia: This project intimidates me 'cause it's worth so many marks.
JR: Ah, yeah. So what's the intimidation?
Alicia: It's just that I've done so good so far I'm scared that if I get a bad mark on this project that everything I've done for the whole semester is going to be gone.
JR: So there's a degree of pressure to do a really good job?
Alicia: Yeah.
JR: So why are the marks so important?
Alicia: I'm just proud of myself. I've never gotten that high of marks before.
JR: And you have about an 85% average.
Alicia: 86.
JR: 86, yeah, not wanting to lose that is pretty reasonable.
Alicia: I always do bad on my final exams. It's like exam is such an intimidating word for me. I always freak out. So I'm hoping I'll do really well on this project. 'Cause if I do well my exam is not that big a deal.

The concern for grades was stressful. A degree of fear existed for Alicia and others, they could see their marks fall if they did poorly on this project and then had to face a final examination. As indicated in Appendix B there were pedagogical reasons for attaching a large weighting factor to the field project. Even though no single aspect of the grading scheme could by itself influence a grade substantially, together they could and this was realized by students.

Scientists having their work evaluated by peers has been a central component of the communal nature of science. Evaluation of students in school has been different. Where a scientist's work has been judged by a community of peers, sharing a reasonably common background of knowledge in a discipline and enculturated into a professional manner of critique, students have been evaluated by an adult designated as an authority. Scientists must persuasively argue their ideas to convince their peers. Scientific critique is expected. It challenges or supports the assumptions made, the quality of analysis conducted, the conclusions drawn. Scientists have a chance of converting others to their ideas should their research and presentation be sufficiently persuasive.

Students are evaluated predominantly by their teachers. The standards for evaluation are interpreted or created by teachers. Before students have presented their ideas the "correct" answer is usually known to the teacher. Critique is expected but it may be in the form of red check marks or crosses on a page. The congruence of students' ideas with the pre-determined is measured. The evaluation culminates in a grade. Unlike scientists it is unlikely that students may change teachers' ideas of what is correct.

The outcomes of evaluation for students and scientists are similar. Evaluation results in a social ranking with comparisons being made between individuals. In both cases reputations are established. Some reputations may haunt the unfortunate for a long time. Tangible benefits may accrue to those identified as most deserving. Recognition and awards are reserved for the best. Students and scientists both must know what is expected of them to present their best performance for evaluation.

From the outset of the field project students repeatedly inquired about what my expectations were for them. "What has to be in a proposal?" "What has to be in the field notes?" I had recognized this concern in preparing the outline of expected questions for the research report (Appendix B). I knew students wanted to know what they would be marked on, and they preferred to have fairly specific guidelines. Once again this was not what I had intended in creating a scientific experience.

The selection of a project topic was influenced by grading. It appears that grading was a serious topic within students groups preparing for the field project. According to the responses of 23 of 37 students responding to the third questionnaire, given when the proposal was due (see Appendix C#3), they had seriously considered the grading prior to defining their project. This concern influenced students' thinking in several ways. Angie, who had developed a study of frog populations in the park, presented the following points which represented the ideas of several students:

> I wanted a topic that was big enough so that I would have enough to do to get marks for it. It had to be something that isn't so hard that you can't understand how it would work or what the effects would be. If it was too hard my marks could fall.

Kent, developing a project on the age of park trees, took another common position:

> Marks made us decide on something that we knew the most about, because we already have a step up if we know partially what we are doing. Then we could get higher marks hopefully.

Pam stated the third position taken by students:

> We wanted to choose a question that was wide enough to find a lot of information and yet not so wide that we couldn't complete it properly.

Students indicated that they had considered strategies to deal with the grading system. The grading system limited the possibilities they saw for research topics. The strategies they employed were reasonable responses to maximize the grades they sought. These attitudes toward evaluation led students to consider that research topics had to be a certain size (big) and that there were optimum amounts of data that should be collected.

I had hoped to develop a scientific community within which to experience the development of scientific knowledge. In this community grades were not supposed to be a driving force. How could students obtain a realistic understanding of scientific research if their primary goal was to obtain a good grade? It seemed possible at the time that students may be just "going through the motions" they thought I would want for research such that they could get a good grade. For some the principle was simple, get lots of data and make a big report. This was not the anticipated outcome for this activity. Does authentic science include science in which the research question is governed by the evaluation of an authority figure?

Ideally research questions are not determined by evaluation. The pursuit of research funding may however encourage the selection of research topics which best attract cash. The situation for scientists may not be all that different from that of students.

My reflection on evaluation provided useful teaching insights. As evaluation of students and scientists appears somewhat similar, an interesting pedagogic challenge may be created. Consider the debriefing process necessary to make students aware that their selection of topics, according to their perceptions of what is acceptable, is similar to that of scientists. This shared experience students have with scientists may be an important insight in terms of exposing students to authentic science. Recognizing that a similarity exists between student and scientist in regards to the effect of evaluation in problem definition has provided an interesting potential link to the world of scientists for me to draw on in the future.

I obtained a clear sense of the time frame in which concern for evaluation influenced students. Students were concerned about grades from the time the project was introduced until they started to obtain data, usually on the third day in the field. There was then a period of about five days in which evaluation really did not matter. The students were totally enraptured by their activities. Two days before the end of the field work concerns about grades returned as students evaluated the merits of their data and began to plan their final report. As a result there was a very limited time span, by my estimation five days, in which students were free of concerns for grades.

Another aspect of evaluation became apparent from this study. I became aware as a result of sharing my findings with another researcher that evaluation may have been made more important as a result of my stance on evaluation. When we referred to the evaluation framework (see Appendix B) it was obvious that it took the form of a typical school evaluation. It became apparent to me that I was trapped in the same discourse of assessment that was influencing students' choices. The evaluation framework had determined the structure of the scientific experience students could have. It had effectively limited the range of possibilities. This is not to suggest that it constrained the possibilities to a greater degree then their past experiences in science classrooms. I believe that this experience expanded the possibilities students may have to understand science and research. I had not initially recognized the limits that were created.

Recognizing this situation, I considered how might the project evaluation be modified. What if the evaluative criteria would have been more in line with those of a scientific community? Based on twenty years of classroom experience the answer appears simple; students would have panicked, especially the more successful ones. I realized that my evaluative framework and the guide I had provided for the final report were intended to minimize student discomfort. An intuitive understanding of classrooms made me aware of difficulties I could anticipate with students presented with novel tasks. By making a novel experience as familiar as possible the fear factor is diminished. Students have an understanding of what is expected. For me the question becomes how far may one modify evaluation practices away from the perceived norm without overly distressing students yet remaining true to my intentions. At the very least, this recognition for me is sufficient to lead to further reflection and modification of evaluative processes.

Controlled Learning

Teachers have been given the legitimate authority to teach. Given this authority within the school context, including requirements for evaluation and accountability, this authority may be manifest as control over learning. The "processes (used by the teacher) necessary for public production of authority are hidden from the student" (Gergen, 1994, p.31) thus further contributing to the myth of teachers' authority. Teachers exercise "authority in agenda" through determining the manner of instruction, the pace of instruction, and the subject matter to be taught even though this may be governed in part by a larger social unit (department of education). Decisions are made about personal needs, social needs, the relative merits of domains of knowledge and political ideology when teachers exercise authority (Matthews, 1994).

Curricula tend to spiral through the years of schooling. Teachers must make decisions about how to best teach these curricula. Hopefully these decisions include the consideration of how the curricula may best be learned. Historically, in the science classroom the most common activity tends to be lecturing. Laboratories are the only activity which students had termed "doing science."

Students' responses to teachers' control seem to be manifest in desires to be free of control. Many students sought to have a research project which had never been studied before. One interpretation I developed in regard to the choice of an unstudied project was as a response to traditional schooling. Traditionally curricula have spiraled. Curriculum developers have broken down valued knowledge into units. These have been placed into the mandated curricula in age appropriate places. As a result topics are often repeated throughout students' experiences in schooling. Although the concept may be investigated at greater depth or from a different perspective, students may consider it a repeat of past teaching and learning. Schooling may then become viewed as boring or unchallenging. When given control over defining an inquiry the topic may become more interesting and challenging. Kelly and Kirsty described their reasoning:

> JR: You're working on waterboatmen, right? You didn't do waterstriders, why didn't you do something somebody else has studied?

Kelly: We wanted to look at something that hasn't been done, something that somebody else hasn't discovered.
JR: Why?
Kelly: It's interesting. It's something I don't know about already. I've heard about water striders and I've seen them all over the place, but water boatmen you have to look for a little bit more and they're more vicious.

Regular classroom activities were boring, discovery was not. Discovery was equated with being scientists by students. It was important to discover something for oneself even if it may have been discovered before by another. This may have been democratization of research (Makedon, 1989), allowing anyone to test the truth of claims. It also was a form of ownership of knowledge, directly associating knowledge with the self. Furthermore, it wasn't boring. The common science labs conducted in schools were criticized on the basis of discovery as Kelly and Kirsty did:

JR: You have discovery written in quotes here. (*I had noticed it written in their field notebook on the counter.*) Is that important in science?
Kelly: Well Yeah.
JR: Why?
Kelly: Cause if we were all looking at the same thing it would be boring.
Kirsty: Like a lab.
I quickly decided to follow up on their comment regarding labs as boring. This choice was made in part due to my personal questioning of the use of labs in science education.
JR: You find labs boring?
Kirsty: In labs everyone does the exact same thing, like in chemistry.
JR: You find that boring?
Kelly: Well yeah, 'cause you all get the same results.
Kirsty: You know you're going to end up with some pink solute and you're like wow that was easy.
Kelly: This way we figure out things for ourselves, so it's better.
JR: What makes it better?
Kelly: Because you don't already know what you're supposed to expect. Like she said in chem if you expect a pink solute well wow. If you don't get it obviously you did something wrong but you know what was supposed to happen, so you just fudge the results anyway.
Having been provided with a critique of labs I was interested how these students would contrast this open inquiry activity.
JR: So what happens in a situation like this where you don't know what will happen?

Kirsty: You just hope something good happens and if something goes wrong you write it up that way, but...you can go to the books and say it didn't work for us but according to books this should have happened.
Kelly: We still discovered what we could about it.
JR: So is discovery a really important part of science?
Kelly: Yeah, if you're not making discoveries, it's boring.
JR: So doing science equals making discoveries?
Kirsty: Yeah, even if someone else has discovered them before, it's a discovery for yourself.

These two students had a serious criticism of standard science laboratory activities which was consistent with academic critiques (Cohen and Harper, 1991). The power of inquiry was lost and having a known outcome was boring for the students. For students, teachers were in control of the agenda and students did not feel a sense of ownership and control. They were learning what they were told to learn, the value had been determined by others. Discovery involved the self and even if it had been discovered by others before them they could enjoy the control of the learning process and ascribe value to it as they saw fit.

Students referred to this as "hands-on" learning or as being "real." There was the sense that school was not in the real world. Activities in school lacked relevance and did not involve them personally, one could remain detached. They felt they were adept at coping with the expectations for passive learning and wanted a different experience. Being told information by teachers was unreal because of the perceived lack of relevance to their lives.

I had exercised authority in agenda as I believed was required by my teaching role. The students had been presented with a project format which I had believed would be scientifically authentic. They had not been instrumental in designing the concept from the outset however. The learning situation I had designed may have been positively perceived as an attractive alternative to regular classroom environments. The situation may have had a negative facet. It may have been interpreted by some as a means to be out of school, not as a scientific experience. Certainly a few students had indicated in their expectations it was going to be nice to be "out of class." A few students described the entire project as being on a "spare." Crystal and Terri offered their opinions:

Crystal: ...but it doesn't seem like science because we're not in the classroom.
JR: Oh really?
Crystal: Yeah. 'Cause all our school life science has been in the classroom and no where else.
Terri: Seems like a spare.

JR: So before you did this you had never done anything scientific anywhere but a classroom?

Terri: It's like a spare. It doesn't even feel like we were in school. It was like let's go down and see what's different today. We were just taking a walk. It's a lot more fun than school. It's just a blast.

JR: So has science changed for you?

Crystal: Yeah it's not so boring.

Crystal and Terri had thoroughly enjoyed their project and had not wanted it to end. It had become an increasing challenge as their questions had increased in number. They had even developed a vocabulary associated with their experience. The vocabulary included the prefix "bio" with almost any noun of importance to them. As a result they were "Biogirls." These two students had enjoyed the project but viewed it as being "not school" and "not science."

Conclusion

Socialization in schools is a powerful force. The discourse of schooling is varied and includes the discourses of control, discipline, authority, evaluation, curriculum, professionalism and others. Discourse defines students and teachers in particular manners. I believe students and teachers become ensnared in this discourse. Discourse is characterized by the unity of its member propositions, ideas and sentences be they written or spoken. This unity exists because of the order, correlations and linkages developed between the elements of the discourse. Individuals enter into discursive communities gaining acceptance as they master the language. The unity of the discourse is compelling and makes sense. Teachers and students are embedded in many discursive communities as diagrammed simply in Figure 3. The school structures to which I have referred in this chapter are the product of the dominant discourse in schooling. Students and teachers are unable to shift easily from the demands for conformity to the expectations of this discourse for within the discourse are established means to discipline or punish. By questioning the discourse the individual becomes marginal to it and may no longer be regarded as a member of that particular community.

Figure 3 illustrates in a simple manner the relationships held between students, science teachers and discursive communities. The discourses of science and schooling are embedded within the broader social discourse. There is a portion of both which I have suggested overlap. Both teachers and students are embedded within the schooling, science and social discourse. Their involvement in each is variable. Both teachers and students may share aspects of the discursive communities as represented by the portions of their circles which overlap. The shared portions of the discourse allow teachers and students to have similar perspectives on aspects of their lives. As teachers and students are caught in the discourse of schooling they each have a fairly good understanding of what is expected of each other within that social institution. They are also not equally involved in the discourse occurring about them. Those aspects of the discourse in which they do not share equally in the discourse like classroom control, may be sites for conflict. Some students may accept teachers' attempts to possess control while others may resist it.

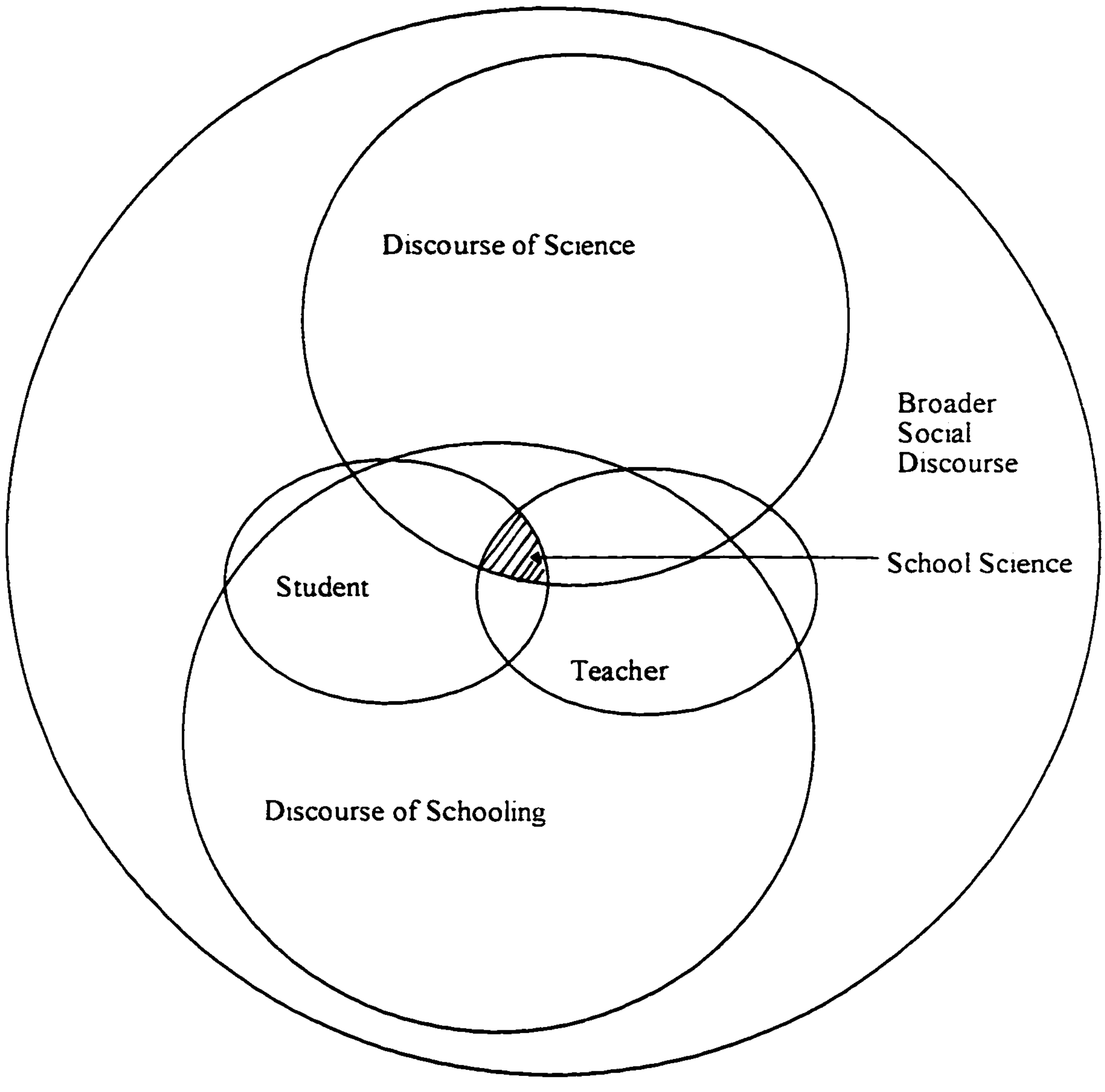

Figure 4. **Discourses of Science Education**

School science is located at the intersection of the student and teacher in the overlap of the discourses of schooling and science. This point was selected because although the discourses of schooling and science overlap in many ways as they are each subsets derived from the larger social discourse, school science exists only in the presence of both the students and the teacher.

There is a sameness that students in high school seem to feel about school possibly due to their long engagement with schooling. They seem to expect the same routine write notes, listen to teachers, write exams. Students do not reside in a social position which affords them the agency to facilitate changes they may desire in schooling. Prolonged exposure and conformity to the social practices of schooling may have made it difficult to view this field project as anything more than another school activity. As a teacher I had not considered these elements of schooling sufficiently to create and allow students opportunities to view this activity differently.

Will science education benefit from authentic scientific experiences. I no longer believe it is as straight forward as I once did. I believe that critical socio-structural elements of schooling, resulting from the discursive practices in schools, interact such that authentic science in schools is probably impossible unless these elements are addressed. Students' conditioning to the social structures is so strong at this point in their schooling that they are bound to follow long standing patterns of behavior. High school students and teachers, entrapped by the discourse of schooling, have been very adept at interacting with social structures. Each are well aware of their respective social roles and the associated agency. Even though these roles may not be enjoyed, they are generally accepted.

I still believe that the use of authentic science requires the creation of a scientific community. Scientific communities are formed through discourse. I believe the community is required to be able to expose students to scientific knowledge building processes and the consensual processes that modify scientific claims into facts. Unfortunately, scientific communities cannot easily exist within the social structures of school. The social conventions of schooling have a normative effect over time. Schools, as well as the teachers and students within them, are expected to behave in certain manners as the current drive for accountability has demonstrated. A wholesale shift to the social discourse of science in a school or classroom would cause the social structure to become anomic (Durkheim , 1947, 1951; Merton, 1968). It would cause a disruption in the currently prevalent social order of school or classroom. It may lead to a breakdown in social control and a state of "normlessness." This would certainly be resisted because there is an accepted conception of what school is and what it should be. Instead scientific discourse needs to be developed as an element of school science.

If teachers are to develop authentic scientific in schools as has been desired by the Science Council of Canada (1984), then the discourse and structures of schooling must be modified. As Gaskell (1992) correctly pointed out teachers are influenced by educational, curricular and social policies in their construction of the school science offered in their classrooms. They are directly influenced by discourse. Changes to school science need to begin in the early years of schooling. To attempt major changes at the high school level alone would be largely unproductive. If the norm for science classes was different from the elementary grades on, then gradually a scientific community may be accomplished by high school.

Such a change would require a shift in teachers' relationships to knowledge and students. Understanding teachers' relationships to knowledge would include an examination of the nature of power, its expression and the effects of that expression. Science classrooms would have to be environments for inquiry, not merely information transfer. Teachers would need to take on a mentorship role and as the sophistication of students increased in relation to the scientific tasks, a more equitable relationship would be required. Drawing on the ideas of John Dewey (1938), I would advocate that student designed research projects begin in elementary school. Each research project would be communally discussed and the learning derived from the successful completion of research would be used to enter into the next more difficult research experience. The knowledge needed would develop in concert with the research activities. Given the curricular shift to a thematic approach, specific content may be downplayed thereby reducing the need to lecture in science.

The activity I required of students appeared to aid in the development of their meaning for research. It appeared that the salient meanings held for research shifted to be more in line with the generally accepted practice of science. I do not believe that students saw themselves as scientists or in many cases as having been scientific. Instead, they were students doing an unusual form of school science. This experience may have altered their understanding of what school science might be. I believe it is reasonable to question whether their meanings for research are transferable to science including the situation scientists work within or are merely associated with school science.

Based on my experiences with this activity and my desire to have my students conduct their own research I would no longer use the term "authentic." It is far too problematic. It is essentially undefined and as such little more than another education buzz word. Rather, I would continue seek experiential situations from which students would derive altered, possibly new meanings for science and research. The intent is not to make all students into scientists but to give them the experientially based meanings from which to understand science in their world.

CHAPTER 9
CONCLUSION

This study will continue in some manner with future classes I teach but there comes a time to report the findings to others. Others, too, may find something in this study which may help create the sense of wonder that results in research or alters their teaching practices. I will position the research within its context and re-evaluate it with respect to curriculum. I believe that it is also important for me to recognize the changes this study has led to in my thinking.

Summary of the Study

I maintained that curricular changes had occurred as a response to perceived international technological threats to our economic security and reaction to inappropriate applications of technology which had social impacts. To meet the demands of competition in a global market place businesses and governments had to be more competitive. Part of the strategies employed included alterations to the science curriculum. School curricula have been generally slow to respond to rapid changes in technology, knowledge and society. It appeared logical to critics of school science that by creating situations in schools, which were like those of scientists, students would gain a better understanding of science. I attempted to create such a situation for the senior high school students I taught. Given that the curriculum and the activity implemented had the goal of altering students' conceptions, it was prudent to determine if changes indeed occurred. Accordingly this study addressed my attempts to interpret *the meanings for scientific research as it was understood by senior high school students engaged in a self-directed investigation*.

The theoretical approach adopted in this study was an interpretive orientation to social inquiry. The philosophical underpinnings were influenced by hermeneutics. This hermeneutic perspective informed my attempt to describe and interpret the meanings held by students based on the particular experience they had. Students and I provided the narrative from which these interpretations could be made. Drawing on my background in the sociology of schools and using elements of grounded theory I sought to gain a sense of the essence of the meanings held before and after the classes' activity. I recognized that the interpretations were mine alone and did not seek to develop a general theory from the interpretations. Instead I gained a sense of the shift in salient meanings emerging from the students' engagement with their self-directed investigations.

The methodology that emerged was a systematic, intentional inquiry which capitalized on my dual roles as teacher and researcher. As any teacher may have been, my curiosity and a sense of wonder had been aroused. My approach differed from the spontaneous, largely intuitive inquiries common to teaching practice in that it gathered information in an ordered manner with considerable prior planning. I drew upon existing literature, personal knowledge and intuition to develop my interpretations. Rather than being committed to a single theoretical framework I was open to any framework which could enable me to gain a better sense of the students' meanings.

It appeared from the narratives and dialogue I had with students that they had entered the field project activity with diverse connotations for research from which emerged common themes. They believed that an *external independent world* existed which could be *methodologically studied*. A scientific study was fundamentally linear with a clear beginning and end. It proceeded in a logical manner through a variety of steps or phases much as textbooks had indicated. Research was *purposeful*. It was conducted to *discover knowledge* about the causal relations which existed in our world. These relationships were of *personal interest* to researchers because the knowledge gained about them solved problems we had encountered or answered questions we were curious about. Research was also *high tech* using a myriad of instruments and equipment, including computers, to solve questions.

Although I could not claim that new meanings emerged from the students' engagement with the situations they encountered, I recognized that alternative meanings had become the more salient. Research involved *novelty*. Students were uncertain how to proceed and what to expect. This was in direct contrast to their prior experience with classroom science activities. Students did succeed in laying down a research pathway as they conducted research. They believed that research was *dynamic*. Their interaction with the world involved altering their approaches to deal with what appeared to be sudden changes or confounding data. The situations they were in provided more questions than answers, leading them to believe that research had *never ending* possibilities. There was a consensus that each had gained an *unexpected treasure* as a result of their involvement in a research activity. It appeared to me that what had been largely paradigmatic knowledge had become increasingly aesthetic. Students had a more personal meaning for research than had previously been held.

The thrust of science education reform was to provide students with a more "realistic" view of the nature of science. I believe, based on the latter salient themes that this activity contributed to an altered view of science for students. They certainly appeared to gain a sense of the tentative nature of science than they might have gained through didactic teaching methods. I believe that they experienced the subjective, value-laden and socially constructed aspects of science but were not cognizant of the experience.

This suggested to me a greater focus needed to be added in examining these aspects of science in a debriefing process.

Personal Reflections

Reflections are curious. At times reflections may lead to greater understandings which alter the way one thinks or acts. At other times reflections raise more questions. My reflections on this research experience have done both of these things.

As a teacher I initially reflected on practical elements of my experience. I had to ask myself whether or not this activity had value and should be continued. The activity did appear to be involved in fostering a shift in the salient meanings students held for research. It also had other important aspects. Students were actively involved in recognizing and defining a question which could be researched. They also had to determine and manage the organizational aspects of research. These were both general learner expectations stated in the curriculum which could not be achieved through lecture or traditional laboratory activities.

I was a resource and mentor; I did not control the learning experience. Students determined which knowledge was valuable to them; ultimately many saw themselves as teachers. If teaching literally meant that teachers were to lead students out of their current worlds into a broader understanding of the adult world, then I could not subscribe entirely to the sense of control that leadership could mean. Students live in a concrete and somewhat limited world. This activity had contributed to making that world a little broader and maybe slightly more abstract, as such it was an educative activity. There was more however, the world into which I was supposed to lead students would not be improved by followers. Instead the world of the next century, which these students would be entering as young adults, needed thoughtful, caring, autonomous individuals capable of working together. This activity fostered those qualities. I firmly believe that we all learned from each other. Leadership in teaching may be exemplified by teachers determining the need for a pedagogic activity and providing students with the resources and incentives to take on their own leadership roles within the pedagogic framework. The leadership teachers may provide is based in the teachers' abilities to develop relationships and create possibilities with students.

In defining action research as emancipatory and collaborative I limited the possibilities of my own research. As both teacher and researcher, I was intimately associated with the research I was conducting. From this I derived benefits but also suffered from being to close to my own practice. Action research provided the concept of the critical friend which could have assisted in my questioning my own pre-conceptions. I have engaged in action research with others and we mutually benefited from our interrogation of each other's ideas. In not identifying a person whom I believed could adequately fill the role of critical friend I realized too late the shortfalls of this study. For the teacher collaborative research ventures may be the more appropriate because of the enhanced opportunity to create dialogue between professionals.

The beauty of teacher research is that it provides insights from which teaching practice may be improved and understandings of theories may develop. There is a conflict however. Research seeks to keep the question open, to deepen the interpretation. The teacher on the other hand tends to focus on "practicality." A new understanding is quickly associated with possible alterations to classroom practices. The teacher's question is, "how can I use this?" The difference between teaching and research is not irreconcilable. However, there are continuing tensions inherent in the idea of teacher research. Specifically, it does create difficulties in communicating research interpretations to different audiences. Teachers and academics will appreciate different aspects of the research communicated by a teacher researcher. Each will judge it by different criteria.

Through reflection I recognize that my definition of what was authentic in science was limited. I focused predominantly on inquiry. This limited the possibilities for students to a degree, yet at the same time it provided an experience which broadened their experience beyond the science classroom. The research experience led to a need for me to reexamine my thoughts on what constitutes authentic science. Indeed, what is authentic about authentic science as it has been discussed in the literature? Is everything a scientist does authentic? To what degree am I and other science teachers influenced by romantic illusions of science? These questions need to be examined further by teachers when considering the call for authentic science in the literature.

I seriously questioned the possible existence of an authentic context for science education as a result of this investigation and now believe that to be an illusion unless there are major discursive and structural changes to schooling. Modern public schooling has a firm two hundred year history in which only the most minor changes have occurred in its social structures. The discourse which informed the development of these structures is firmly established. Even so, it may be countered although it will not be easy. Had I not engaged in the research process I may not have seriously considered the problems inherent in buzz words like authentic science. I also may not have realized how students' attachment to the structures and practices of schooling influenced their participation in classroom activities. The normal daily life of a teacher tends to use intuitive understandings of the classroom. Teacher research allows these understandings to be called into question and re-examined albeit to a lesser depth than an academic researcher might.

When Schön (1987) advocated reflection for practitioners he had not focused on educators. Missing from discussions of reflection are ideas which educators might reflect upon. Teacher research may provide teachers important focal points for personal reflection and professional dialogue. Theses foci may include ontological and epistemological questions like:

What do we know about teaching?

What do we know about learning?

How do we know these things?

In considering these questions and their relationship to teaching teachers may have a valuable source of new information about teaching. This may contribute to the connoisseurship Eisner believed necessary in teaching (1982, 1985). Although reflection and connoisseurship would be of value for all teachers, exploration of these conceptions may be of interest for teacher educators concerned with identity formation in student teachers (Britzman, 1991).

Teaching has been characterized in very mechanistic ways by some educational critics (Harris, 1979; Apple, 1986; Fenstermacher and Soltis, 1986). Certainly teachers were portrayed as technicians or managers of students' learning experiences in schools Teaching may also be described as an art or a technical act but it is fundamentally a human relationship. It was overly simplistic and naive to characterize teaching as production Teaching is very much the development of human relationships to encourage and foster the physical, emotional, intellectual and spiritual growth of young people in a manner which allows them to create possibilities for the future.

I have been exploring the possibilities of teachers as researchers for six years I admit being captivated by the possibilities I believe it provides teachers to not only improve their practice but to be empowered. Teacher professional development has often been reduced to an endless parade of motivational speakers or specialists with novel ideas coming into schools, school divisions or regional conventions to present their ideas to teachers. As such valued knowledge rested outside the individual teacher. Teachers working individually or collaboratively as researchers provides the possibility for teachers to reflect. This reflection may help define the pedagogic knowledge which was most valued to teachers in the context they dwelled within. The result would be improved practice but also empowerment. It may provide the means by which they could see themselves as master teachers. One of the actions and responsibilities of researchers is to communicate their findings. Through sharing teacher researchers could make contributions to other practitioner professionals and academic discourse.

The teacher researcher model also provided students with a unique learning experience. Researchers may tend to ask questions not normally discussed in the student-teacher relationship. Students said they had learned a lot from the questions I had posed because it caused them to think about ideas which they might not normally consider. I believe that the teacher in behaving as a researcher enhances the learning experience for students as a result of the questioning nature of research. Through wonder and action teachers communicate their interest in students and the teaching process. Students recognize and value a person who cares for them and the quality of their education.

The researcher mode brings teachers into closer dialogic relationships with students. Students had a greater incentive to share their thoughts about schooling and as a result I gained insights into the students' worlds. Their challenges, hardships and joys were concrete, not mere abstractions I might reconstruct in reference to my own schooling. It provided a greater awareness to me of their experiences in schooling and an increased sensitivity to my role in making the schooling experience valuable for them.

There was an unfortunate downside to such dialogue and the novelty of the field project. I found that students confided in me their frustrations with some of my colleagues. Certainly the students' perceptions of these professionals were highly subjective. In general the criticisms contrasted the nature of the field project with what occurred in another's classroom. Students were sharing their views of my colleagues and I was ethically bound not to comment on the professionalism of those same people. Teachers frequently are told about other teachers but the nature of the teacher researcher process may encourage students to share more about one's colleagues than one may wish to know.

Possibilities

Numerous studies have dealt with students' conceptions of and attitudes toward science (Ledbetter, 1983, Blackwood-Malayko, 1992, Gardiner, 1975; Aikenhead et al., 1989). To the best of my knowledge this is the first time research has focused on the meanings for scientific research held by high school students. This research opens new possibilities for examination.

How do personal meanings develop? Are they constructed by the individual (von Glasersfeld, 1995) or do they co-emerge through the interaction of the individual with the total environment (Maturana and Varela, 1980, 1992; Varela et al., 1991)? We do not clearly understand the processes inherent in meaning-making. Activities like this may provide insights into the process. I suspect that there is a storied nature to meaning making. The similes students developed generally could be related to specific aspects of their experiences. Recollections of those experiences were narrative in nature.

I am curious as well about the dynamics of student group work. How did students negotiate their topics. To this point it seems that a single individual expresses an idea which may be improved upon by others. Even so some students merely accept the ideas of others and follow along. Why are they content to do so? How does passive acceptance change the nature of the experience they have? Does this influence the meanings they derive?

Although I focused on simile, this study has opened up for me a greater curiosity of the role of metaphor in science and science education. I am curious as to how to involve students in the generation of scientific metaphors. Kuhn (1979) discussed the role of metaphor in science and recently Sutton (1996) has condemned science education for misrepresenting science to students because it failed to examine metaphors in science. Metaphor is noted for its subtlety and metaphors in science have slipped into our popular notions about the world. For example, the term cell was coined by Robert Hooke in an attempt to describe the structures he had observed in cork microscopically. The term has slipped into common usage but was apparently generated out of the similarity Hooke generated between cork tissues and the rooms of monks or prisoners termed a cell. The derived adjective "cellular" commonplace now in biology has been adopted into communications technology vocabulary. Metaphor also places a human role into science. I had found the human dimension to be lacking in the meanings generated by students and metaphor may be the means to give new meaning to this aspect of science. Currently suggestions on teaching with metaphor have been limited largely to teaching English (Pugh et al., 1992). The possibilities in science education are yet to be explored

The classroom offers boundless opportunities for further research. Recurrent curriculum changes and examination of the nature of classroom life provide many possibilities. As STS education is being replaced by STSE (science-technology-society-environment) education further opportunities are created. If I am correct in interpreting the "writing on the wall" I would not be surprised to see a further shift in science education to include a second E (STSEE) in reference to economy. This further shift would be consistent with the root cause for curriculum changes since 1950. It would finally focus science education on the very perceptions of international competition which have been instrumental in altering curricula.

It may be that the lag time between concern for the science curriculum's ability to produce the desired results and the subsequent changes may narrow. The changes instituted by responses to the Sputnik launch lasted almost three decades. The STS curriculum is only four years old and is being reconsidered as STSE. Will the ink dry before STSEE is implemented?

I would suggest that teachers may effectively research some dimensions of these inquiries alone or in collaboration with academic researchers. I would advocate continued examination of the lived experiences of teachers and students as reasonable research activities. Examination of the spoken and unspoken elements of these experiences may provide insights into the nature of schooling and its relationship to the broader social and environmental contexts.

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Appendix A

1. Students' ages in years as of Feb. 1, 1996

	Block 1		Block 2		Total Both C		Total
	Males	Females	Males	Females	Males	Female	Group
Age (range)	15-17	15-16	16	15-17			15-17
Age (mean)	16.2	15.8	16	16	16	16	16

2. Numbers of students by grade

	Block 1		Block 2		Total Both Classes		Total
	Males	Females	Males	Females	Males	Females	Group
Grade 10	1	2	0	5	1	7	8
Grade 11	12	15	4	16	16	31	47
Grade 12			2	2	2	2	4
							59

3. Withdrawals and Non-attendance

	Block 1		Block 2		Total Both Classes		Total
	Males	Females	Males	Females	Males	Females	Group
Withdrawals			2	2	2	2	4
Not attending				1		1	1

4. Class totals during field project

	Block 1		Block 2		Total Both Classes		Total
	Males	Females	Males	Females	Males	Females	Group
	13	17	4	20	17	37	54

5. Reasons given for taking biology (number of students for each reason given)

	Block 1		Block 2		Total Both Classes		Total
	Males	Females	Males	Females	Males	Females	Group
Its easy	1	1	1	3	2	4	6
Needed credits	4	4	3	4	7	8	15
For post-secondary entrance	2	10	1	12	3	22	25
Interest	10	8	1	10	11	18	29
Career plans	4	4	0	6	4	10	14

6. Other science courses taken

	Block 1		Block 2		Total Both Classes		Total
	Males	Females	Males	Females	Males	Females	Group
Chem 20	6	7	2	9	8	16	24
Phys 20	3	3	0	0	3	3	6

	Block 1 Total	Block 2 Total
7. Class size	30	24
8. Attendance (% of total instructional time)	90.4 %	80.7 %
9. Class average	69.7 %	63.2 %

Appendix B

The Biology 20 Ecology Project

Projects comprised 30% of the final grade in my biology classes (see Figure A1). During the course of the semester the students were engaged in five projects. The final project, the situation studied in this text, was valued at 300 marks out of a total 700 marks for all projects. This was a significant portion of the final grade attached to one activity. I believed that as approximately 30 hours of instructional time were involved as well as substantial additional hours students would invest of their own accord it deserved the greater weighting. It was also a terminal activity for the semester. Although it was not intended, the greater weighting appeared to create a seriousness that aided the students in completing their tasks. Colleagues had attempted the field project without the benefit of an on-going project framework throughout the term and with a lesser weighting value. They had tended to find that the students were not "productive" and management problems arose. I had reconsidered my evaluation scheme a year ago and actually raised the project weighting from 25% to 30% to offset the final exam mark. I have had misgivings about the quality of the final examination.

Due to the shift in curricular emphasis from a predominantly knowledge content base to the broader base described in the new curriculum (Alberta Education, 1994), the ecology field project was developed. It addressed a large portion of these expectations through the use of an authentic context. This project incorporated the attitudes, knowledge, skills and STS connections desired in the new curriculum.

This project was designed by me originally to effectively use the final weeks of course time after the required components of the course had been taught. It provided by its timing in the second semester (mid-May to mid-June) a means to achieve several goals. It offered the students an opportunity to practice and extend their competencies on the expected course outcomes in a context which freed the student from the confines of the classroom.

The project unfolded over a four week time with eighty minute daily classes (approximately 30 instructional hours) (see Figure A2). The intent of the field project was described on May 11, 1996 in detail to the students, including an assignment sheet (Figures A3 and A4) . It was framed as an activity to practice and extend their skills and knowledge about science and field ecology. It was also described as an activity which shed light on the career of a field biologist. The assessment requirements were outlined at the same time the intent and parameters were explained. The class was then taken on a ninety minute walk through the research area just west of the school. On this walk the four obvious forest types (poplar, white spruce, black spruce and tamarack), as well as the transitions between them, were described briefly.

Students had one week to develop their proposals for a research topic, as individuals or in groups. Ideas for the project had begun at the initial explanation of the project for many students. Others had their ideas gel during the orientation walk. A typical proposal included a statement of their "question," an outline of the reason this was selected, and an outline of their planned methodology. The intent of the proposal was two-fold. The proposal caused students to become quickly focused on the task at hand as time was at a premium when a 10 day field season was being used. The proposal also aided me in obtaining and organizing field equipment for the projects, particularly if materials had to be shared due to shortages and high demand, for example electronic pH meters.

Students then had a two week data collection period. During this time they were in charge of their activities and were expected to be working on their research projects. They could be anywhere in the forested area or doing laboratory work. It was a stressful period for me as teacher for I continued to be haunted about concerns for student safety. I could not leave students working in the lab and leave the school to check on others without some degree of fear and loss of control. Fortunately colleagues and our lab aide assisted in keeping the lab safe. In actual fact the students were <u>extremely</u> responsible and other than playing the radio too loud one day were perfectly behaved. The fear I had was probably more related to legal responsibility should anything unforeseen occur. The students were responsible for their time management and the organization of their data collection process. In general, I served as a reference for them to verify the methods they had selected as appropriate. I also offered suggestions which students could accept or reject as they chose. Students did not automatically adopt my suggestions. They considered them and chose accordingly.

The data collection was followed by a final week of interpretation and analysis including an oral presentation of their findings. The oral reports were conducted for several reasons. They allowed other students to hear about their classmates experiences. Students could question the presenters and as a result encourage the development of further ideas about the project. The students had a forum in which to test their ideas and develop their plan for the finished report. The final report was then due about one week later. Being the end of the semester with finals approaching time was devoted to review while the reports were being developed out of class.

Biology 20 Course Outline

Welcome to Biology 20. This is a great course, my personal favourite. This course focuses on 4 major units in biology:

The Biosphere Cellular Matter and Energy

Matter and Energy Exchange in Ecosystems

Matter and Energy Exchange in the Human Organism

I believe you will find this an interesting and challenging course. It requires a great deal of reading and mastery of the vocabulary common to biology. Your active participation and discussion is necessary for success. If you are absent, whether it is excused or not, we all suffer. You miss out on what I and your classmates have talked about or done. We miss out on your ideas and contributions. If you are absent please find out what went on. If you have any questions about biology or issues related to biology please raise them in class or if you prefer in private. It is my intent to make this an active and interesting class, you can play an important role in making it great for everyone.

Evaluation:

Projects:	30%
Labs and Assignments	20%
Chapter Examinations	20%
Common Final Examination	30%

A special note on projects:

Projects will be related to social issues involving biology and personal research topics pursuing areas of personal interest. Projects may be presented in a variety of forms of communication. It is your responsibility to select the media which you believe best suits your topic, your skills and the information you choose to present. Your **creativity is encouraged** and some suggested formats include: video, audiotape, written, works of art, music (including lyrics), dramatic productions and poetry. You will also be involved in the evaluation process of your projects. These projects are interesting, fun, great for developing skills and knowledge and very time consuming.

Figure A1. Introductory page of course outline

Orientation phase	May 9 - 13	Explanation May 9-13
		Orientation walk May 13
		Question sheet 2 given on May 14
Proposal phase	May 13 - 17	Question sheet 3 given on May 17
Field work phase	May 20 - 31	
Reporting phase	June 3 - June 17	Oral reports June 5 - 7
		Written report June 17
		Question sheet 4 given on June 17

Figure A2. Phases of the research project

Final Project

Your task:

1. Determine a question related to biology and appropriate to the site selected which may be studied within a period of approximately 10 to 15 days.
2. Draft a proposal outlining the question you wish to study. The proposal should indicate the question, your reason for selecting it, your proposed means of study and who will be involved. Please list the resources you need. **Due May 14**
3. Investigate your question. You must keep a field diary. The purpose of this is to record your data, to keep track of your methods, and provide a place to record interpretations as they are made. The field diary will be handed in with your report and then returned.
4. Analyze the data you have collected, interpret it , and draw out the insights that are possible.
5. Make a presentation to the class on or about **June 5**.
6. Write a research report . **Due June 17**.
7. Complete a self-evaluation.
8. Submit the field notes, report and self-evaluation for grading.

Evaluation:

1. The report =

Introduction	= 10
Methodology	= 20
Findings	= 40
Conclusion	= 20
Quality of writing	= 10
	100

2. The presentation =

Organization	= 10
Information	= 30
Quality of speech	= 10
	50

3. The field notes = 50
4. Self-evaluation = 50

You decide your mark, justify it, you might consider:

Degree of effort   Amount of time devoted
What you felt you have learned
Quality of your scientific actions

5. Teacher evaluation of behaviors = 50

My Expectations:

Punctuality and regular attendance
Respect for private property and the rights of others
Take personal responsibility for your learning.

Figure A3. Sample of the Project Explanation Sheet

The research report

The expectations of this report are similar to those for any project this semester (see course outline). You are conducting scientific research and are expected to do your very best. The quality of your effort benefits you primarily but also will benefit those who may work with you. To help guide your final report here are a few questions which may be helpful. These are the minimum requirements I have for this project. Feel free to go beyond the questions I have outlined.

1. Introduction:
   - what was your question?
   - why did you select it?
   - what made it worthy of your time studying it?
2. Methodology:
   - how did you do your study ?
   - why did you do it that way?
3. Findings:
   - what did you find? - explain your findings
   - present your data appropriately - graphs, charts, photos
4. Conclusion:
   - what did you learn from this project?
   - what directions are there for future studies in this area?
   - what benefit is there to you or the community from this experience?

Figure A4. The research report guide

Appendix C

This appendix includes samples of the data collection tools. Using samples of the responses of two students this appendix contains the 4 question sheets used, sample recorded conversations, and samples from the field journals.

Sample #1a

Biology 20 Introductory Questions

Name: Terri________

Underline one response in each of the following:

1. Your grade: 10 **11** 12
2. Your age: 14 15 16 **17** 18 18+
3. Other sciences you've taken: **Chemistry 20** 30 Physics 20 30
4. Why are you taking Bio 20:

   easiest science

   just for science credits

   post-secondary entrance requirements

   personal interest

   career hopes

   other (specify ________________________)

5 What does science mean to you?

   The study of everyday life.

6. Research is commonly associated with science. What does scientific research mean to you?

   When you go out into the environment and look at all the different effects or different things that could answer the question you are asking.

7. Very carefully describe a situation or time in which you believe you were researching something scientifically. Take your time and be clear in the story you present. Use the back of the sheet if necessary.

   In Science 10 last year we spent the last part of May and the first few weeks of June down in Participark researching something of our choice. The whole time we were down there I was having the time of my life, until it started raining really hard. I fell into the water while taking samples. I guess to achieve your goals and finding the results, things like that are going to happen. After the six weeks or so I handed in a research project on my topic. I felt that I was part of nature and learned a lot.

Sample #1b

Biology 20 Introductory Questions

Name: Christina________

Underline one response in each of the following:

1. Your grade: 10 **11** 12
2. Your age: 14 15 **16** 17 18 18+
3. Other sciences you've taken: **Chemistry 20** 30 Physics 20 30
4. Why are you taking Bio 20:

   easiest science

   just for science credits

   post-secondary entrance requirements

   personal interest

   career hopes

   other (specify ________________________)

5. What does science mean to you?

   Science has come to mean more than just a technical knowledge of how things in the universe "works." It can also mean specific ways of learning and understanding.

6. Research is commonly associated with science. What does scientific research mean to you?

   Scientific research generally means investigating all areas of an issue (ie. the greenhouse effect) and presenting the facts in a clear, objective manner (not swayed by the media, etc.).

7. Very carefully describe a situation or time in which you believe you were researching something scientifically. Take your time and be clear in the story you present. Use the back of the sheet if necessary.

   One time that I was doing scientific research was in elementary. I researched DNA for a science project. It was one of my first experiences that involved looking in 'heavier' books (not as many pictures!). It gave me the opportunity to learn how to pick out material relevant to my topic, summarize material in order to condense it and understand it, and try to clearly present it in a report. It wasn't exactly university material, however I did learn a lot about DNA and research itself.

Sample #2a

Second Question Sheet

Name: Terri

After having walked through the park and hearing about your assignment what are your thoughts?

My thoughts would be that there are a hundred different things I could do for a project and I don't know what to do.

Are you looking forward to this project?

In some ways yes but I think it will be hard.

Why?

Because it will be interesting to learn the different things about the forest that's been there all my life.

What do you expect will happen in this coming month for you?

I expect that I will learn a lot and be successful in making a perfect project.

If you could fantasize for a moment, please describe what you think would be the **best**

thing to happen for you during this project. Take a moment and dream.

I fantasize that it would come naturally to me and that I'd be able to do well on this project.

Sample #2b

Second Question Sheet

Name: Christina

After having walked through the park and hearing about your assignment what are your thoughts?

The different trees in the park and how the areas (i.e. deciduous and coniferous) change gave my partner and me an idea for the project.

Are you looking forward to this project?

Generally, yes.

Why?

It will give me a chance to learn things in a different way (designing our own tests - that in itself is learning). The fresh air will be good too (as long as it doesn't rain or snow too much).

What do you expect will happen in this coming month for you?

I expect that I will learn more about doing research projects and the organization of time which is required.

If you could fantasize for a moment, please describe what you think would be the **best**
thing to happen for you during this project. Take a moment and dream.

The best thing that could happen would be for the results of our tests to provide a perfect amount of information (and varied enough) for our report. And it would be warm and sunny!

Sample #3a

Third Question Sheet

Name: Terri

Outline the factors that you believe are important to consider in developing a scientific research project.

1. Know where the site of your study is.

2. Take all considerations into effect, something small may make a difference.

3. Collect all the background data you think you need before going out.

4. Make sure you are interested in the topic, if you aren't the project will fail.

How is scientific research different from other school research projects?

We designed our own ideas and didn't use a set guideline. We get to go outside and study, rack our brains to find the answer, instead of reading information.

How is scientific research similar to other school research projects?

You still use a written report at the end to state your findings. They both take a lot of time and energy to finish.

What role did evaluation or marks have on your decisions to choose the project you are working on?

A lot. I wanted a project that I could expand on and get information from other places. For example, the city gave us drain pipe maps to see where the water came from.

What role did I have on your question development and project planning?

Not much. I knew I wanted to study water and I guess when we stopped at the first site I knew that was what I wanted to do. It looked so weird to me, I knew I had to find out why.

Sample #3b

Third Question Sheet

Name: Christina

Outline the factors that you believe are important to consider in developing a scientific research project.

The factors which are important include: time (make sure it isn't too short or too long), resources available and of course interest (to learn something).

How is scientific research different from other school research projects?

Other school research projects involve a lot more time in the library and sitting in front of a computer for hours. Although this project will involve computer time, a lot of time will be spent in the field and in the lab (hands-on approach).

How is scientific research similar to other school research projects?

Time allotment and project organizational skills are needed for both.

What role did evaluation or marks have on your decisions to choose the project you are working on?

It did play a significant part, as we needed to make sure that we would have enough material for the project. However, a lot of the project had to do with learning something new and investigating areas of the forest we had been through frequently but never examined closely.

What role did I have on your question development and project planning?

When you suggested that we take another look, we cycled through the area again, concentrating on soil differences between the areas. This resulted in us noticing color changes, animals, moisture levels and other observations in the area.

Sample #4a

Final Question Sheet

Name: Terri___

These are the last questions I have for you to fill out for my research. Please take your time and carefully work through these.

Complete this simile:

Scientific research is like... *driving a car with no brakes.*

Please explain your simile in some detail.

You are unsure what to do when you realize what is happening. There are times when you think you are close to a solution, something falls in the way. The adventure is exciting and thrilling and you wonder if it will ever stop.

Your simile may have its root in your experience. If it is possible describe the experience that may have contributed to your choice of this simile.

There were times when a solution would be close but as you know a question would appear instead. My experience was awesome. It was so exciting and thrilling in reality I would want the car to stop but not the research. Obstacles were in the way but Crystal and I swerved to avoid any accidents.

Sample #4a

Final Question Sheet

Name: Christina____

These are the last questions I have for you to fill out for my research. Please take your time and carefully work through these.

Complete this simile:

Scientific research is like... *learning how to play jazz.*

Please explain your simile in some detail.

At first playing jazz is extremely different from other music (i.e. baroque). Eighth note figures, dynamics and deleting or adding parts depending on the group is very different from regular in-class band. Similarly the research was different from regular classroom instruction, as time management, methods of experimentation and organization were quite a change.

Your simile may have its root in your experience. If it is possible describe the experience that may have contributed to your choice of this simile.

Recently I have had the opportunity to practice a couple of pieces with the stage band. There are more differences between that music and concert band music than I expected. However once I "got the hang of it" it went quite well. The research project went very close to the same way.

Sample Field Notes #1

May 23, 1996

Side A:		Side B:	
Hardness:	25 gpg	Hardness:	22 gpg
Iron:	0.7	Iron:	0.7
pH:	8	pH:	8.2
TDS:	480 ppm	TDS:	470 ppm

City water TDS 600-1200 ppm

Side A: -more green on trees

- current same

weather warmer today, slight breeze cloudy, high 16C
water levels lower than previous 2 days

Side B: - more green grass growing in mud

- water around drain gross looking (brown vomit, small light brownish scum floating on top of water)
- water clearer today however bottom looks scummy
- two Safeway bags still in place
- no gas smell

our lab didn't work out for some reason, we couldn't follow directions, worded weird
tomorrow we'll redo the experiment

Sample Field Notes #2

May 21, 1996

Chris was not here today - doing his driver's exam

My findings today:

Poplar area:

- a few feet in - light "weed-like" material appears
  - layered on top of ground
  - underneath top layer - feels warmer
- further in - soil is drier
  - trees spaced fairly close together (1 to 2 arm lengths apart)
  - moss on base of trees (most facing north)
- in further again - not as many weeds, more "twiggy" plant life
  (ie. small trees, fairly tall plants knee to waist high)
  - layer of leaves on ground fairly thin

Coniferous area:

- small white fragments in soil (fungus?) - might want to check under a microscope
- needles are about 5 cm deep - maybe because decomposition is better here?
  - maybe due to something with needles (pH, nutrients?)
- drier here
- needles on ground appear red
- not much plant life, what is here is low (moss type life, small plants)
- plant life is spaced apart quite widely
- coniferous trees (especially big) - spaced wide apart

Sample Field Notes #3 - Rymer

(three digit numbers indicate tape counter position, * indicates important to return to)

May 27, 1996

Nice day considering the past week's rain.

Checked students in park first.

Kirsty and Kelly:

000 - describing what they had found

075 - realizing complexity of problem selected

100 - describing water mite's actions

115 - comments on discoveries

132 - it's been a productive week

Alicia and Shannon:

159 - scrapped grid

198 * - contentment with change of question

- did it affect thoughts about science?
- wanted success - having dreams about it

Teacher-researcher (comments while riding)

One of the difficulties in doing research is shifting in between research questions and relational questions that are integral to teaching. I find myself inserting research questions into our conversations which works okay. Certainly the students don't seem to notice it as different and they answer them sincerely being part of the conversation. It seems that the questions sometimes arise from the interaction between the student and myself given the history we have together. Some students like the last two provide more access and have a very varied conversation which doesn't seem to have a clear start or finish tending to bounce around a lot. I have a realization that I shift from teacher to researcher as my focus shifts within the conversation. Interestingly if it was not for the questions I pose as a researcher they may never have been asked. In that sense if the students' better understanding of science is a curricular objective, being a researcher of that may have contributed to an unveiling of the student's ideas.

Pete and Amy:

300 - spiders died

Jaimie and Rob:

310 - their plan

324 - what about the garbage ideas we had discussed?

Appendix D

Students' Research Projects

This appendix contains the research questions the students chose to study. In some instances two questions may appear. The question in italics was the proposed study question which was altered during the research process. I have also indicated which of the groups were co-ed in composition.

1.Mindy and Keltie:

How do water striders stay on the surface of the water?

2. Rob, Kent and David:

What is the age of the trees in the particapark?

3. Alyssa and Jill:

What is moss?

4. Erin and Celena:

What is the difference between the soil in each part of the forest?

5. Chris and Christina: **co-ed**

What are the similarities and differences between the soil and plant life in the park?

6. Crystal and Terri:

What are the differences between two sections of the stream in the Park?

7. Marc and Arizona: **co-ed**

What causes the difference between a deciduous forest and an evergreen forest?

8. Danielle and Tracy:

How do the soils differ in two forests?

9. Matt and Chad:

What are water striders and how do they interact with their environment?

10. Tyson and Jay:

Does cattle farming affect the water quality in Dog Creek?

11. Justin, Scott and Chad:

How do mountain bikes affect nature?

12. Mandy, Erin and Theresa:

What types of birds are found in the park?

What are the characteristics, patterns and parental instincts of squirrels?

13. Erin, Pam, Beth and Dana:

How does the pH of soil affect living organisms?

14. Amy, Arnall, and Pete: **co-ed**

What will happen to spiders in captivity?

15. Tala, Michelle, Angie and Lori:

What habitats are available for frogs in the park?

16. Jaimie and Rob: **co-ed**

What effect does garbage have on the park?

17. Kirsty and Kelly:

What forms of aquatic life can be found in the swamp?

18. Alicia and Shannon:

How many different types of vegetation can be found in the park during a two week field study?

19. Suesan:

What types of pollution are evident in British waterways and what effect do they have on the environment?

20. Ivanhoe and Erin: **co-ed**

What lives in moss and the fungus it shares the forest floor with?

21. Sherry and Niki:

What is the main cause of death for trees in the park?

22. Tanelle and Sandra:

What are the differences in pH in the soil and water in different areas of the park?

23. Ann, Beth, and Marie

What are the effects of forest fires on soil chemistry?

Appendix E

Similes

This appendix contains the similes presented by the students at the end of the course. I have presented these here in detail because I believed these reflect the point to which the students meanings for research developed during the project. For practiced researchers I also believe that these metaphors will be ones to which they may relate and thereby gain a sense of the sophistication these students had in their insights and personal meanings for scientific research.

Christina: Scientific research is like learning how to play jazz. At first playing jazz is extremely different from other music (i.e. baroque). Eighth note figures, dynamics and deleting or adding parts depending on the group is very different from regular in-class band. Similarly the research was different from regular classroom instruction, as time management, methods of experimentation and organization were quite a change.

Terri: Scientific research is like driving a car with no brakes. You are unsure what to do when you realize what is happening. There are times when you think you are close to a solution, something falls in the way. The adventure is exciting and thrilling and you wonder if it will ever stop.

Rob: Scientific research is like a UFO. The answer will never be explained properly.

Lori: Scientific research is like a circle. Once you start on the path to answering questions the journey never ends.

Kirsty: Scientific research is like a room. The more you look the more you see a room reveals the personality of the inhabitant. There is a lot more to the room than appears.

Niki: Scientific research is like a field. You have some direction to where you are going but there a different things along the way. They may influence your destination, or they may not. It's up to you to determine its value.

Tyson: Scientific research is like a big wheel. It's hard to get started but once it is going it is hard to stop.

Pete: Scientific research is like an orange. It is hard to get into at first but once you've started and got something to study, all you get is good stuff.

Ben: Scientific research is like a long winding road. You spend a lot of time doing things that seem like you're not going anywhere and all of a sudden your at the end.

Matt: Scientific research is like brushing your teeth. You do it first thing in the morning as we did with the first block bio class. And by only doing a good job do you receive the benefits from your work.

Anonymous: Scientific research is like my favorite food, I could eat it all day. When you have a favorite food you crave it all day. I love bio and could do it all day long and never get sick of it.

Scott: Scientific research is like a ball. It keeps going around once you get it started. The core is hard but once you break through it's filled with invisible treasures.

Anonymous: Scientific research is like driving a car. Sometimes you may get into trouble but most of the time, if you pay attention, you'll do okay.

Anonymous: Scientific research is like chewing gum, because you do it without even knowing.

Justin: Scientific research is like the universe. The more you see, the more you know there is.

Kelly: Scientific research is like a world of discovery ready to be explored. Even if a subject has been studied I find it interesting to discover and explore for myself before looking in some textbook. I learn a lot more.

Rob: Scientific research is like going into high school for the first time because you have all these expectations and ideas about what it's going to be like but you end up being surprised and finding that it's very different from what you thought it would be.

Jaimie: Scientific research is like a crumpled piece of paper in the park. At first you don't have a clue as to what it is, and then, once you pick it up and examine it, open it up and lay it out flat so it's a simple shape, you can see what it is. And learn so many things about so many more things than just what kind of gum it was.

Marc: Scientific research is like looking through sunglasses. It seems dark at first but soon your eyes adjust to the change and you begin to see more and more and get more insights!!

Arizona: Scientific research is like a road with many bumps and turns. It was hard to start, and there was a lot of things that needed to be considered. Once the project was going things needed to be slightly altered because it didn't go right at first. Then the project just about took a wild turn to become something else but went back slightly changed.

Chris: Scientific research is like a wind, because it moves forward but changes directions depending on the conditions in which it exists. It can be destructive or constructive depending on how it is used. It can be relentless at times.

Sherry: Scientific research is like a labyrinth. Every time you turn a corner there is a new possibility and decision to make.

Mandy: Scientific research is like a spiral stairway. Each step you take introduces you to a new level with new meanings and even though each level is more beautiful than the last it also has many more challenges and problems to figure out.

Erin: Scientific research is like a bottle of clear liquid. You don't know what the clear liquid is. It could be harmless like water or harmful like $HCl_{(aq)}$. The only way to determine it is by conducting a number of experiments.

Chad: Scientific research is like the energizer bunny, it goes on and on and on. It is never finished in any subject, there is always something new to be discovered.

Tala: Scientific research is like reading a mystery book. It starts off boring and really dull but as time and chapters go by you gradually understand and get right into it. You forget about time and the suspense increases. What will happen? You look back on it and say, "That was awesome."

Michelle: Scientific research is like a room full of books where you can only take out a few at a time. There is so much to learn and only so much that can be remembered. As soon as you finish one book you start another and forget the main characters of the last book.

Kent: Scientific research is like a tree. You start off at a root then progress up. you branch off to one section and then branch off again. There are many possibilities in scientific research. It is very complex. If you find out something there is more to it.

Erin: Scientific research is like a game of tag. A person always has to be observing their prey. They have to be observing and thinking of strategies.

Beth: Scientific research is like a new playground because you go for a ride and discover new things. As time goes on there may be things you may or may not enjoy.

Anonymous: Scientific research is like a needle in a haystack. It seems so broad and general but once you focus in on something specific and study it you broaden your horizons not only in that area but in science in general.

Tanelle: Scientific research is like an X-file. It is part of the unexplained and there can be more than one answer. Sometimes governments hide information from the public.

Dana: Scientific research is like a fake ego. You think you know the answer but then you realize that you must check it out further. Every time you research you feel you are smart.

Sue: Scientific research is like a quest. you are constantly seeking and are willing to push yourself to the edge.

Crystal: Scientific research is like jumping out of unsure if your parachute will open. It can be a thrilling experience. You won't know what will happen until you do it.

Alyssa: Scientific research is like a pot of gold at the end of the rainbow. It is an amazing thing that holds many treasures at the end of a beautiful discovery. You must follow a path to it requiring patience and careful observation before you reach what you're looking for.

Angie: Scientific research is like trying to find a needle in a haystack. It's fun to try.

Erin: Scientific research is like a game.

Celena: Scientific research is like a treasure never found. You may look and look and not find an answer. It takes lots of time and effort that never ends.