UNIVERSITY OF ALBERTA

CONSTITUTING A NEIGHBORHOOD OF SCIENCE

by
Margaretha Ebbers ©

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ABSTRACT

This study is an examination of the discourse of six elementary teachers as they explored the possibilities of a metaphor for science instruction articulated by F. J. Rutherford. This metaphor suggests that the goal of elementary science education ought to be one of developing familiarity; similar to the familiarity one feels in one's neighborhood. Underpinning this research are sociocultural perspectives on the nature of science and the nature of learning.

This study took place over 15 months and involved 3 phases. In Phase 1 the teachers met regularly as a discourse group to discuss the implications of the metaphor with respect to their teaching experience. Phase 2 emerged as an astronomy project with practicing scientists once the teachers recognized a need to increase personal comfort in a neighborhood of science. Phase 3 was a return by the discourse group to the metaphor to see if new understandings of science enriched earlier interpretations.

Data were derived from all conversations and discussions which were audio taped and transcribed; as well as from the field notes, interviews, letters, journals and sketchbooks used during Phase 2. Themes emerged which indicated that as they progressed through the phases, the teachers began to increase their knowledge of the boundaries, their acquaintance with natural phenomena, their savvy (confidence and competence), their encounters with science processes and their membership in a science community. Over the 15 months the discourse of the teachers changed to include the building of communal scientific understanding, the discussion of events related to science and the sharing of science teaching ideas.

The role of metaphor figured heavily in this process. It operated at three levels by providing an entry into the discourse for the participants, as an impetus for teacher change and by situating the research within the community of researchers. Implications for the role of metaphor in preservice teacher education and the professional development of teachers are discussed.

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CHAPTER I

INTRODUCTION: *BEGINNING TO QUESTION*

"Children should come to know science as they know the neighborhood they live in."
F. James Rutherford
1987

Elementary school teachers play a unique role in Canada's education system. They often train to be *generalist specialists* rather than directing most of their preservice education to one particular field. Being a generalist specialist means that one does not view each subject as standing in isolation, but instead an attempt is made to travel in and out of each discipline, while keeping in mind the threads that weave through all of learning and teaching. Typically, preservice teachers receive only an introduction to each discipline, often through a methodology course rather than a course focusing on the ontology, epistemology or historical and philosophical underpinnings of the discipline.

In 1979, the Science Council of Canada initiated a four-year study which investigated elementary through secondary science education across the nation. Its purpose was threefold:

1. to establish a documented basis for describing the present purposes and general characteristics of science teaching in Canadian schools;
2. to conduct an historical analysis of science education in Canada;
3. to stimulate active deliberation concerning future options for science education in Canada (Orpwood & Souque, 1984, p. 24).

The research arose out of a concern that "Canadians must be literate not only in the traditional basics of language and mathematics, but also in the new basics of contemporary society: science and technology" (Science Council of Canada, n.d. p. 2). Questions guiding the research included: *How well is Canada's educational system equipped to meet the need for scientific literacy for all? Do students receive enough science education? Is it appropriate to individual needs? Are some groups—girls, for instance—neglected? What science should students be taught, and how? What indeed are the aims of science education?* (Science Council of Canada, n.d. p. 2).

The study concluded that renewal in science education at all levels was essential, and needed to be immediate. At the elementary level, concern was expressed over the fact that science was often taught with inadequate facilities and insufficient time. Elementary teachers were found to be "inadequately prepared," and in-service opportunities were either "nonexistent or of little value" (Science Council of Canada, n.d. p. 5). There appeared little to merit hope for the development of scientific literacy at this level in elementary schools.

According to Shamos (1995), the present and "active pursuit of universal scientific literacy" (p. 76) is rooted in specific concerns emerging from World War II and the development of atomic weapons. Subsequent to Hiroshima, many people believed the best way to avoid future catastrophe was to educate the public regarding the hazards of nuclear development. A number of special interest groups formed, with the express purpose of enlightening the public regarding the "precipice" to which science and technology had brought civilization. Since that time, an alarming number of equally important scientific and technological developments has increased the need for a public equipped to make informed and intelligent decisions. Concerns include acid rain, nuclear power, depletion of natural resources, animal experimentation and genetic engineering (Shamos, 1995).

The drive to develop a scientifically informed Canadian public has also been fuelled by low standings on international science assessments, a minimal percentage of women and minorities in the field and the questionable status of science education (Eisenhart, Finkel and Marion, 1996). Calls for reform across North America (American Association for the Advancement of Science [AAAS], 1993; Bybee, 1995; Council of Ministers of Education, Canada, 1997; National Research Council [NRC], 1996; Ahlgren & Rutherford, 1993) include as a priority the need to develop scientific literacy. While these documents define scientific literacy in various ways, each encompasses the mastery of substantive content that can then be used to solve problems regarding the relationship between science, technology and society.

Eisenhart, Finkel and Marion (1996) argue that simply knowing more scientific information does not guarantee people will use this knowledge in socially responsible ways. Nor does it address the problem of people considering science relevant only as long as they are engaged in its study. Someone who is scientifically literate does not stop reading *about* and purposefully engaging *in* science once schooling requirements have ceased!

Shamos argues that as long as the efforts to achieve scientific literacy "continue to focus on traditional science knowledge as the mark of the literate individual," (1995, p. 229), they are doomed to fail. He points out that science is a difficult subject due to its cumulative nature and its reliance on mathematics. For non-science majors, the effort to truly understand the discipline as well as become literate may not appear worthwhile. Shamos redefines a scientifically literate person as one who

a. has an awareness of how the science/technology enterprise works;

b. is comfortable knowing what science is about, even though he or she may not know much about science;

c. understands what can be expected from science; and

d. knows how opinions respecting science can best be heard.

Given such a definition, science education must undergo radical change in both conceptualization and curriculum.

Becoming Aware of Possibilities

Rutherford (1991) proposes that the goal of science education in the early years of school should be *familiarity* rather than *literacy, mastery* and *competency*. Mastery and competency, he suggests, are goals more suitable for the end of schooling, while literacy implies a deep understanding that is unrealistic given the depth and breadth of the scientific domain. Familiarity, on the other hand, "implies having some knowledge, but not complete or even expert knowledge" (1991, p. 23). This familiarity, Rutherford says, is similar to how one feels about one's neighborhood.

Rutherford begins with a sketch that offers demarcation: knowing the *boundaries*. Many of us live in one neighborhood, work in another, even socialize in a third. We learn to differentiate between neighborhoods early in life, when we begin to travel from our home to the grocery store, to visit relatives and family friends, to go to church, to recreate. Even very young children know when they return to their own neighborhood as they increasingly recognize familiar sights, people, sounds and smells.

Elementary children in a science neighborhood must begin to see how endeavours in that neighborhood differ from activity in the other neighborhoods they navigate as part of their educational experience. Boundaries refer not to a division of subject material, but rather to the types of questions and procedures generated in scientific investigation. Rutherford uses the example of the seashell. A seashell itself is not science. Studying the beauty of a seashell is not science, nor is sketching one necessarily science. Finding out what seashells are made of, determining how fast they grow under different circumstances or figuring out how they become embedded in mountains *is* science. This is the difference children should experience and begin to identify. *Are elementary teachers able to identify what falls within the boundaries that make up a neighborhood of science?*

Rutherford fills in the sketch with a design in which children develop a richly diverse acquaintance with neighborhood *artifacts.* These artifacts include places, stories of the people who live and work there, the de facto rules of the place; in other words, the raw material out of which more sophisticated knowledge will grow. In Rutherford's terms, this collection provides necessary information regarding "what's what and who's who." He suggests it is more valuable for children to have a somewhat superficial understanding of a large variety of things than a deep knowledge of a select few. To develop this acquaintance, elementary children must be introduced to as many different phenomena of the real world as possible. It does not matter if they cannot explain things completely "scientifically" at this point; it matters only that they recognize and know something about the behavior of lots of trees, insects, rocks, shells, falling objects, buildings and so forth (Rutherford, 1987; 1991). *Are elementary school teachers able to facilitate student experience with as many phenomena of the real world as possible?*

Colour is added as Rutherford introduces the notion of *savvy.* A person with savvy has the ability to use the practical knowledge gained through developing such acquaintances. In a neighborhood, this means being able to physically navigate as well as to maneuver socially. Children must be able to get from place to place; communicate with neighbors; deal with signals and signs, bullies and friends; determine who can be regarded as trustworthy. Rutherford suggests the elementary science program should have a dual purpose. First, to help children begin to acquire an appetite that will fuel the desire to develop skills necessary to investigate natural phenomena and scientific questions. Second, to foster confidence in students, so they feel they *can* learn. *Do elementary teachers have savvy in a science neighborhood?*

Delicately etched details take shape as Rutherford describes the need for children to have frequent *encounters* with their neighborhood. It is not enough to simply reside in or live near a particular collection of buildings; children learn about their neighborhood because they are actively engaged. They participate in the neighborhood's activities, they explore its confines, "acting on it as well as responding to it, learning by trial and error" (Rutherford, 1987, p. 9).

Children need many opportunities to be engaged in scientific activities. They need to ask, wonder, look, listen, count, measure, propose and test. It is not enough to simply read or listen to the teacher talk *about* science; children must have plenty of opportunity to *do* science. Rutherford suggests that insights and attitudes toward science must be developed, at least in part, through experience. *Do elementary school teachers regularly engage in scientific activity?*

Finally, Rutherford spreads his patina. To truly belong in a neighborhood means having a sense of membership. Familiarity nurtures a positive emotional response, and as Rutherford carefully illustrates, the opposite is also true. "Unfamiliarity breeds fear, distrust, and avoidance" (p. 9). *Do teachers of elementary school science feel a sense of membership with a science community?*

Identifying a Need to Travel

As a Member of a Teaching Neighborhood

As a practicing elementary school teacher, I have been privileged, during the past nine years, to work closely with many excellent teachers. I have observed that, while these teachers speak positively and confidently about their abilities in language arts, social studies and mathematics, they talk rather disparagingly about their teaching of science. Often, comments related to science are prefaced by such statements as:

I was never very good at science.
I hated science in school.
I never really understood it anyway.
I hate teaching science.

For a number of years, I have been curious about this reaction. I have a strong interest in science and believe that when children enter our classrooms, they have already begun to visit a neighborhood of science. When I read accounts written by scientists, I am continually struck by their passion for the discipline and their single-minded pursuit of understanding. Children share these characteristics. They come to school with a body of knowledge, are intensely curious, ask questions beyond the tolerance level of most adults in their lives and persist until they have constructed meaning. I find it curious that children come into elementary school eager to explore the world and yet, by the time many of these same children become teachers, their love of science has all but disappeared.

I can remember two kinds of science teachers in my own schooling experience. Most simply relayed data: what had been discovered, and who discovered it. But the odd teacher made me grapple with answers, encouraged questions, pushed my personal creativity in science. These were the teachers who showed me that science is part of life, that it is a way of thinking and of looking at the world rather than a battery of factual knowledge to be memorized. These latter teachers were *not* in elementary school.

As a Member of a Research Community

The hue and cry in elementary science education for the past two decades is predicated on deficit models. It bewails the limited science background knowledge of elementary teachers, deplores their methods of instruction and voices despair at the lack of improvement in spite of repeated calls for reform. Canadian teachers do not face these winds of condemnation alone. This call is echoed throughout the Western world, ringing loudly across Australia, New Zealand, the United States of America and the United Kingdom. In response, many countries are moving to national science curricula and standardized assessments. Those regulations do not appear to be the answer, however. Research shows that, despite mandated curriculum, many teachers ignore science, teach it in a limited fashion or abandon it altogether in the face of other curricular demands (Goodrum, Cousins & Kinnear, 1992; Orpwood & Souque, 1985).

The science background of elementary teachers is repeatedly found to be inadequate (Mechling, Stedman & Donnellan, 1982; Moore, 1987; Orpwood & Souque, 1985; Tilgner, 1990). It often consists of high school biology, one or two introductory science courses from the faculty of science (usually in environmental or earth sciences) and possibly one or two science methodology courses during preservice education (Ryks-Szelekowvsky, 1993). Chemical and physical sciences are seen as sadly neglected.

Research studies take great care to delineate shortcomings, discuss implications and offer tentative solutions for the problems found in elementary science education. One branch of research seeks to identify and isolate deficits in either teachers or the teaching profession that prevent entrance into the scientific neighborhood. Another branch focuses on preservice and in-service training. Out of this research come improved teaching methods, new models of instruction and a greater understanding of pedagogy (in its narrowest sense). With such extensive laundering, one would expect many problems would eventually wash away, given sufficient time. Sadly, this does not appear to be the case and a closer look at the framing of research problems is in order.

Developing a map. The words we use to frame research problems become a point of intense consideration. Participants in problem solving situations often bring different and even conflicting frames. More importantly, however, "the ways in which we set social problems determine both the kinds of purposes and values we seek to realize, and the directions in which we seek solutions" (Schon, 1993, p. 150). Herein lies the rub.

The Oxford Dictionary defines *problem* in the following ways (examples have been omitted):

1. a doubtful or difficult matter requiring a solution;
2. something hard to understand or accomplish or deal with;
3. causing problems: difficult to deal with, in which a social or other problem is treated;
4. an inquiry starting from given conditions to investigate or demonstrate a fact, result or law, a proposition in which something has to be constructed;
5. a puzzle or question for solution (Barber, 1995, p. 1153).

Most of these definitions refer to a particular difficulty or inquiry, followed by the need for a solution. In other words, a deficit has been identified for which a corresponding "fill" is required.

Much academic research, particularly in science, is framed by the description of the word *problem* in four out of the five definitions above. Hence a problem is isolated, extracted, examined and ideally addressed through the parallel development of a solution. In essence, we frame research within a deficit model. Is it possible to frame our research by the fifth definition: *something hard to understand or accomplish or deal with?*

Using a metaphor. There has been increased attention in the literature to the role of metaphor in education. Metaphors are used routinely as pedagogical tools, but more recently focus has shifted to the ways metaphors held by teachers drive the practice of teaching (Aubusson & Webb, 1992; Briscoe, 1991; Tobin, 1990). The neighborhood metaphor described by Rutherford offers a new way of looking at the past, present and future of science education in Canada.

While explicating the metaphor, I postulated five questions, set in italics above, which ground the metaphor in science teaching. These questions can be collapsed into one larger question: *Do elementary teachers feel at ease in a neighborhood of science?* It appears self evident that the answer is a resounding ***No***.

This discussion stimulates other questions: Why do students (who later become our teachers) turn off to the "hard sciences," namely chemistry and physics, dropping those subjects as soon as possible? All disciplines contain specific discourse practices; is it discourse practices in the sciences that makes people uncomfortable in its neighborhood? Are teachers comfortable with some of the discourses in science? These are some of the questions that have led me to research this particular field.

As a Member of Society at Large

The above questions connect with what I see as a trend in our society. Although we are surrounded by vast amounts of data and information regarding all facets of life, people do not appear to connect scientific inquiry with daily living. Very rarely do people discuss scientific discoveries, despite regular media coverage. Very rarely do people discuss scientists or the ethical dilemmas they face as changing technology brings new discoveries.

I would even go so far as to say that most people would be hard pressed to mention contemporary scientists, let alone discuss the nature of their work. This fact was brought home to me just recently, on two separate occasions. First, in an introductory science methods class I teach at the university, I asked the students if they knew the names of any scientists. Four names were proffered: Isaac Newton, Albert Einstein, Galileo and Copernicus. The class chuckled as I pointed out that these particular scientists were all dead, that none of them were women and that three of them were from another century! The second incident occurred at a celebration for a friend who had just completed the oral defense of her Ph.D. in pharmacology. I observed that during the evening, not once did anyone ask about her research, about her experiences or even about the department in which she earned her doctorate!

I suspect people view science with a degree of insecurity, due in part to the way science is represented in the literature and by the media. Often, we hear about scientific work only in terms of the final discovery. Little, if anything, is said of the struggles, hopes, fears, disappointments and tribulations in the life of a scientist. In effect, we isolate scientists and their work from the rest the world. If one sees a discipline only in terms of its end result, one begins to view it as out of the realm of ordinary experience, even as grandiose.

Elitism also crept into the discipline in the way that the 20th century glorified the *scientific method* of inquiry as *the* research method rather than one of several possibilities (Medawar, 1996). Clive Sutton (1996a) points out that when scientists begin describing their work, they do so in a way that is personal, figurative and tentative. Their primary goal is to persuade their audience. After years or decades of study, however, the findings are presented as an established body of knowledge, even as a labelling system.

Unfortunately, most teachers are not privy to *science in action,* but rather see *science-presented-in-journal-article* (Abrams and Wandersee, 1995). Consequently, they constitute a particular view of science, which is passed on to their students.

Focus of the Research

This research is grounded in a sociocultural approach to learning. By this I mean that all learning takes place within a specific context, which cannot be divorced from what is being learned. Rogoff (1995) suggests development occurs in three "inseparable, mutually constituting planes" (p. 139): personal, interpersonal and community. She argues that it is impossible to study individuals without referring to the community in which they are positioned and the social interaction representative of that community.

It is possible, in the interest of research, to highlight one area, but never to the exclusion of the others. Instead, Rogoff suggests we view an examination of learning or development as an opportunity to place one or more plane in the foreground, with the understanding that the remaining planes continue to operate in the background.

This need to be mindful of coexistent planes is particularly evident in our use of language. The language we choose to represent what we know—the metaphors, the frames of reference—come with "culturally laden significances" (O'Loughlin, 1992, p. 811). By implication, this means the *body of knowledge* is not a collection of objective truths that we as teachers must break down, sequence and pass on to our students.

Instead, the body of knowledge contains the ideas, beliefs and information deemed significant by the greater community in which we live. These are made manifest through the discourse processes that both constitute and give voice to ontological and epistemological issues.

As teachers of elementary science, we pass on both explicit and implicit messages regarding science through the discourse practices we employ. Elementary teachers are rarely part of a science-centred discourse community, however. Thus our discourse in and around science can reflect only a limited understanding of the nature of science and science activity. As a result, it seems doubtful that the cyclical passing down of a particular view towards science will be broken. It also seems unlikely, given the connections between thought and language, that without opportunity to participate in discourse in and about science, elementary science teachers will become any more comfortable in a neighborhood of science.

Hence my decision to establish a discourse community of elementary science teachers—a community whose primary purpose was to explore the various dimensions of Rutherford's metaphor. My research within this community was guided by the following questions:

- How will new understandings of the nature of science be generated out of repeated discourse *about* science and *in* science?
- How will the confidence levels of elementary teachers in relation to science be affected if they have opportunities to explore a neighborhood of science?
- How will a new metaphor for science teaching shape the discourse of elementary teachers?

CHAPTER II

LITERATURE REVIEW: *SITUATING THE RESEARCH*

Introduction

It is common in the literature of science education to speak of the *orientations* toward science held by the teachers under consideration. These orientations refer to combinations of *beliefs about* and *knowledge of* the nature of science. *Orientations* is a particularly fitting term for this study, for at its root lies the French word *orienter*, meaning to *determine the bearings of.* Consequently, the word evokes images of travel and of the need to plot one's navigation; perhaps even of *orienteering,* and of those participants who make their way across unknown terrain armed only with compass and topographical maps.

Rutherford's neighborhood dimensions have been explored by the research community. The knowledge teachers have of the boundaries of science and their personal savvy with respect to science, have been subsumed under issues of competence and the need for a more multidimensional view of science than the view generated through science schooling. The ability of teachers to provide students with scientific phenomena and to regularly engage in scientific inquiry has been recast as pedagogical concerns. Their feeling of membership in the community of science has been reiterated as areas of (non)confidence.

Elementary school teachers arrive at the doorsteps of their classroom equipped not with a compass, but with particular orientations toward science, toward science teaching and toward science learning. Most of these orientations are not developed through an immersion in the scientific community, nor through working in research labs, nor through contact with scientists, professional science organizations and/or science journals. Instead, teachers glean knowledge and beliefs in and about the discipline from personal experiences, primarily through schooling (Gallagher, 1991) and the media (Kyle, 1995)—particularly television (Schibeci, 1986). It is a cultural understanding of the nature of science that helps nourish individual orientations toward science. Hence, we gain a richer understanding of teachers' orientations by situating them against the backdrop of their own culture's view of science. This cultural understanding is both mediated and constituted through language—and metaphor plays a significant role.

The following literature review situates the questions guiding my research within the discourses of relevant disciplines. To that end, the questions serve as a framework for the literature review as well an inquiry tool. I have reduced those questions to key phrases that structure the three main sections:

1. Metaphors as influencing discourse;
2. Constituting neighborhoods of science; and
3. Confidence in a neighborhood of elementary science.

Metaphors as Influencing Discourse

Language as Mediating and as Constituting

Traditionally, language was seen as a tool for communicating thought and describing sensory perceptions. The relationship between language and thought could be characterized as linear, with words expressing what the mind knows. Polkinghorne (1988) calls this the "traditional empirical model of language," and suggests that this conception of language springs from belief in an external reality that can be "accurately reflected." This view attributes communication difficulties to the inability to find language that reflects external reality in a manner that is "true." Little consideration is given to the way social interaction mediates language or to the role generative metaphor plays in constituting thought.

Various writers have pricked holes in this model of language; enough in fact, to carve a new understanding of the role of language. Wittgenstein (1953) suggests that words, rather than portraying inner thoughts or an outside reality, are social constructions that allow community members to understand one another. They are part of "language games" people learn to play in specific situations. Obviously, meaning does not rest on words alone. For example, *"Fetch me some water"* can be uttered as declarative, interrogative or exclamatory, obtaining very different results. The selfsame words, used as different "illocutionary acts" (Searle, 1993; 1996), are governed by rules that determine which response is to be invoked at a particular time, —rules mediated by social mores within culture.

Vygotsky (1996) describes thought as a product of mediated activity. Rather than words simply reflecting thought, language is crucial in developing thought. He theorized that, as children acquire words, they are acquiring the tools of thinking. These tools are used to influence others and oneself.

> Thought development is determined by language, i.e., by the linguistic tools of thought and by the sociocultural experience of the child. Essentially, the development of inner speech depends on outside factors; the development of logic in the child, as Piaget's studies have shown, is a direct function of his socialized speech. The child's intellectual growth is contingent on his mastering the social means of thought, that is, language (1996, p. 94).

From a Vygotskian perspective, children learn through social interaction with people at a higher intellectual level. In other words, social interaction helps to *develop* higher mental processes, as opposed to simply reflecting them.

In a commentary on Vygotsky, Wertsch (1991) notes that research in the West assumes verbal mediation is the "means to represent and resolve a wide range of problems" (p. 30). He points out that researchers who study cultures that rely less heavily on verbal communication identify other means of problem solving (e.g. Kearins, Rogoff as cited in Wertsch, 1991). Superior performance by some nonwestern children in problem solving situations in which verbal mediation is not the only tool for resolving tasks suggests that, while Vygotsky's research into the thought/language relationship is crucial for cultures that privilege verbal mediation, we must be careful not to overgeneralize to all cultures.

Vygotsky (1996) does not spell out the relationship between mediated action and its relationship to historical, cultural and institutional settings (Wertsch, 1991). Subsequent researchers and theorists articulate another dimension to language, even more powerful than its ability to mediate thought: its *constitutive power*.

Language does far more than move an individual to new understanding or increase thinking abilities. Language constitutes thought by acting as a framework upon which concepts and understanding are built. For Bruner (1986), language has the capacity to create reality through its many functions. "We create reality by warning, by encouraging, by dubbing with titles, by naming and by the manner in which words invite us to create 'realities' in the world to correspond with them" (p. 64). It is not a matter of simply learning the appropriate vocabulary; learning a language means learning what a culture deems significant or "how to express intentions in congruence with culture" (Bruner, 1986, p. 65). Far from being neutral and reflecting an objective reality, words are selected *because* of the stance of the speaker and in turn *depict* a stance of the speaker.

Speakers never stand alone; they reflect and are reflected by their own culture. In Egan's words, "The set of sign systems one internalizes from interactions with particular cultural groups, particularly communities, will significantly inform the kind of understanding of the world that one can construct" (1997, p. 29). Gusdorf (1977) describes language as the "agent" of the creation of the world, as it situates people within their culture by defining relationships.

> It is by speaking that man comes into the world and the world comes into thought. Speaking manifests the being of the world, the being of man, and the being of thought. All spoken words, even in negative or self-deceptive speech, attest to the horizons of thought and the world (p. 49).

Maturana and Varela (1998) suggest that language can never be used as a tool for reviewing the world because it is our language that constitutes the world.

> It is by languaging that the act of knowing, in the behavioral coordination which is language, brings forth a world. We work out our lives in a mutual linguistic coupling, not because language permits us to reveal ourselves but because we are constituted in language in a continuous becoming that we bring forth with others (p. 234).

Thus the language we learn as children engenders in us ways of looking at the world, rather than the converse. Examples of this constitutive power are the pervasive function of *metaphors* and *discourse theory* as articulated by James Gee (1996).

Role of Metaphor

Tradition 1: Figurative metaphors. According to Schön (1993), one tradition uses metaphor as a kind of figurative language that needs explaining. We derive meaning through the comparison (Boyd, 1993; Duit, 1991; Searle, 1993) and interaction (Black, 1993; Richards, 1967; Sutton, 1992) of two situations. The comparison is not explicit, but rather allusion is made to their respective relational qualities. For example, when Romeo's friend Mercutio is mortally wounded, he calls out, “They have made worms’ meat of me” (Shakespeare, 1993, p. 46). Rather than the literal statement “I have been mortally wounded,” the comparison of two situations brings understanding to light.

Black’s interactive theory (1993) suggests that a metaphor has two subjects, and that the principal subject acquires new meaning through interaction with the subsidiary subject. This relationship is evident in Mercutio’s cry. Situation A (or primary subject), in this case the status of Mercutio’s health, is revealed as it is positioned alongside situation B (secondary subject), the recognition that worms feast on decaying flesh. Out of the interaction of the two situations emerges new meaning. The hearer selects some of situation B’s properties (e.g. when do worms eat, what do worms eat, where do we find worms), constructs a parallel implication-complex that fits situation A (under what conditions would Mercutio be associated with worms) and reciprocally induces parallel changes in situation B (Mercutio must be dying; therefore we are speaking of the worms [larvae, actually!] that eat flesh).

Metaphors are commonly used in the science classroom (Lemke, 1990) to make difficult and abstract concepts (e.g. the interaction of body systems, the action of orbital atoms) more concrete for the learner. Bruner (1986) artfully describes metaphors as “the crutches to help us get up the abstract mountain” (p. 48). Muscari (1988) suggests metaphors are necessary to facilitate learning as well as to increase “opportunities to create new and interesting formations of thought” (p. 424). Ogborn, Kress, Martins & McGillicuddy (1996) advocate the use of metaphor, and not simply to “decorate” scientific thought while the “real work” is “done by plain literal expression” (p. 72). Far from inessential, metaphors provide a framework from which “productive questions can be asked and answers can be sought without needing to know everything” (p. 74).

Martin and Harré (1982) assert that the language we have available, particularly its terminology, is often inadequate to express thought, and thus metaphor is vital to communication. Metaphors fill what Langer (1979) terms "poverty of language" (p. 141) by serving as a *catachresis*, that is, supplying a term in our language when one is lacking (Martin and Harré, 1982). This function gives rise to Boyd's (1993) assertion that metaphor is useful for its role in theory change.

The interplay between thought and language is an important consideration when discussing metaphors and their relationship to science. Sutton (1992) points out that commonly used expressions in science help to generate ideas about phenomena. It becomes vital to understand the source of these expressions, as the following passage illustrates:

> We claim now that "heat" is just a sort of internal agitation or tremor—an opinion which did not appeal to Joseph Black (1728-99), the Scotsman who did much to establish quantitative methods for the measurement of heat. Accounts of Black's work suggest that he was cautious of explanatory theory at all, but it seems to me that in those days there was such a growing belief in the "capacity" of different materials for heat that the language was firmly set in the direction of fluid theory. Less reticent thinkers, experimenters and writers found it very helpful to imagine heat as another of these "very subtle" fluids which could float in and out of things. They gave it various names (matter of heat, igneous fluid, caloric), which we have now dropped, but the idea is still preserved in our everyday language and our scientific language, in expressions such as heat flow, conduction, heat sink, and thermal capacity (Sutton, 1992, p. 12).

Examples abound of scientific terminology that reflects a lingering metaphor used while theory related to a principle was first teased out: *computer virus, magnetic field, harnessing energy, horsepower.*

The use of metaphor is not restricted to senior science teaching. Gallas's (1994) observation of 6 and 7 year olds in the science classroom demonstrates that children routinely develop metaphors to "make the intellectual leap toward theory" (p. 102). Some recent science teaching manuals for elementary preservice teachers suggest that teachers develop analogies and metaphors as tools for facilitating understanding (Bloom, 1998; Carré & Ovens, 1994; Ebenezer & Connor, 1999).

Tradition 2: Generative metaphors. A very different tradition treats metaphor as essential to the way we develop our perspectives on the world. In this tradition, *metaphor* refers "both to a certain kind of product - a perspective or frame, a way of looking at things - and to a certain kind of process - a process by which new perspectives on the world come into existence" (Schön, 1993, p. 137). Schön terms this metaphorical use *generative metaphor,* and demonstrates the importance of being critically aware of the pervasive generative metaphors that frame the way we discuss issues. Often these metaphors are subtle and, if left unchallenged, can contribute to a specific way of understanding, as the following story bears out:

> When I was a little girl, I liked to help my mother in her flower garden. One day in early spring, I mentioned that "the dirt felt cold." My mother looked at me briefly, then gently and quietly said, "You know, Margaret, I always think of dirt as the stuff I clean away, not the stuff I plant things in." She then proceeded to pick up a handful of soil and proffered it in my direction. "Here, this is earth; do you smell it, Margaret? It is full of life; that's why we plant things in it. It's not dirt that we try to clean and throw away."

Through a process of word archaeology, Reddy (1993) uncovers a powerful generative metaphor at the heart of how we refer to the process of communication. He demonstrates that, within the English speaking community at least, language is portrayed as a conduit, with thoughts transferred bodily from one person to another. Within this metaphor, words become containers in which meaning is deposited, and communication becomes a matter of sending. Reddy (1993) uses common phrases such as *"Try to get your thoughts across better"* and *"You still haven't given me any idea of what you mean"* (p. 166) to show how this generative metaphor has become all pervasive. As a result, what English speakers say about communication becomes framed (and thus restricted) by a canon of phraseology that subsequently lessens the chance of enacting new metaphors.

Two other examples of generative metaphors that pervade today's educational world are *school as workplace* (Marshall, 1988) and the *constructivist metaphor* (Spivey, 1997). Marshall (1988) points out that the school as workplace metaphor has been used to drive research and stimulate teaching models. He argues that while there are similarities between work settings and classrooms, there are also significant differences. Thus "conceptualizing the classroom as a workplace neglects those *unique* qualities of the classroom that create a 'learning setting' as differentiated from a work setting" (p. 9). This example points to one of the dangers of dominant metaphors: no metaphor can completely capture the essence of a situation. A metaphor's ability to illuminate aspects of experience, to creatively awaken understanding by juxtaposing two situations, also confines the understanding to this referential interaction. The very strength of a metaphor is its ultimate weakness; by focusing on certain aspects, others remain obscure and some meaning is ultimately lost. When a metaphor is called into play, it inevitably brings along companions in the form of assumptions, tacit understandings and beliefs. Sfard (1998) names these companions "metaphorical entailments," (p. 5) and cautions that they serve to "bar fresh insights, undermine the usefulness of the resulting conceptual system and—above all—perpetuate beliefs and values that have never been submitted to a critical inspection" (p.5).

To Lakoff and Johnson (1980), a discussion of metaphor is ultimately a discussion of human thought and culture, for dominant metaphors surface through everyday speech patterns. Two of their examples demonstrate how we in the West conceptualize ideas.

Ideas are commodities:

- He won't *buy* that.
- That idea just won't *sell.*
- That's a *worthless* idea.
- It's important how you *package* your ideas.

Ideas are plants:

- Mathematics has many *branches.*
- That's a *budding* theory.
- Here's an idea I'd like to *plant* in your mind.
- His ideas have finally come to *fruition* (p. 47).

The importance of Lakoff and Johnson's (1980) work lies not in the abundance of dominant metaphors they have painstakingly identified, but in the fact that these metaphors direct our speech, and thereby our thoughts. The process by which ideas are constructed, shared, debated and reformulated over time is embedded in language and, subsequently, in society. *Generative metaphors* are one of the ways in which ideas are both constituted and shaped by language. The sharing of generative metaphors in turn contributes to the creation of discourse practices.

Discourse Practices

As constituting neighborhoods. All human activity involves language, and the nature and forms in which language is used are just as diverse as the activities themselves (Bakhtin, 1986). Organized cultural communities develop particular ways of using language, yet language is but one of the semiotic systems used by humans to communicate. Art, music, written work, vocal tone, gesture and rhetoric are a few examples of texts used to create meaning. Each community has its own system of meaning, its own system of linking texts together (intertextuality) and its own preferred discourses (Lemke, 1995). Gee (1996) distinguishes between *discourses* (connected stretches of language that make sense, such as conversations, stories and reports) and *Discourses,* defined as the following:

> Discourses are ways of being in the world, or forms of life which integrate words, acts, values, beliefs, attitudes, and social identities, as well as gestures, glances, body positions, and clothes. A Discourse is a sort of identity kit which comes complete with the appropriate costume and instructions on how to act, talk, and often write, so as to take on a particular social role that others will recognize (p. 127).

For ease of reading, I shall refer to *Discourses* simply as *discourse practices* throughout the remainder of this work.

Bruffee (1986) suggests that language is used primarily to "join communities we do not yet belong to and to cement our membership in communities we already belong to" (p. 784). Discourse practices are inherently ideological, as they involve values and viewpoints regarding the relationship between people (Gee, 1996). At the same time, they are political in that they relate to the distribution of social power and hierarchical structure in society. As Gee points out: "Control over certain Discourses can lead to the acquisition of social goods (money, power, status) in a society" (1996, p.132). Acceptance into a neighborhood ultimately depends on mastering the discourse and discourse practices of that neighborhood.

In the classroom, discourse operates on different levels. First are the discourse practices surrounding much of the hidden curriculum, including issues such as power structures, gender and ethnicity (Heath, 1983; Guzzetti & Williams, 1996). These discourse practices manifest themselves in various ways, including questioning techniques, classroom rules and body language. Such discourse mediates the inclusion and exclusion of students. Cazden (1988) illustrates the difficulties felt by children in school who are not part of the dominant culture through the following poem, written by an Apache child in Arizona.

Have you ever hurt
about baskets?
I have, seeing my grandmother weaving
for a long time.
Have you ever hurt about work?
I have, because my father works too hard
and he tells how he works.
Have you ever hurt about cattle?
I have, because my grandfather has been
working
on the cattle for a long time.
Have you ever hurt about school?
I have, because I learned a lot of words
from school,
And they are not my words (p. 18).

At another level, discourse operates in the general enculturation process by which a teacher introduces students to various disciplines and their discourse practices. In science education, this means learning scientific vocabulary as well as how to use language to express things in a way that is meaningful in relation to science. Lemke (1990) says "science teachers belong to the community of people who already speak the language of science" (p. x). Note that he does not say science teachers belong to the community of scientists; they are, however, able to engage in its discourse(s). He goes on to point out that *language* refers to the system of resources, thus encapsulating discourse practices. At the same time, by using the word *community,* he embodies the belief that science happens within a group of people who share certain values and beliefs.

Kelly & Crawford (1996) point out that while individuals might have private thoughts, scientific knowledge is *communally shared.* This communal sharing goes beyond information dissemination, for it is also crucial in the construction of new understanding. Besides being a major contributor to the discourse practices that make up the discipline of science, language works—through generative metaphor as well as other means—to engender conceptions of the nature of science. Because generative metaphors and discourse practices are more often implicit than explicit, they help perpetuate beliefs that may or may not truly reflect the discipline.

<u>Institutional discourse: Neighborhoods of science teaching</u>. The picture painted regarding the nature of science in Western schools is disheartening. Duschl (1988) suggests that "the prevailing view of the nature of science in our classrooms reflects on [sic] authoritarian view; a view in which scientific knowledge is presented as absolute truth and as a final form" (p. 51). King (1991) claims that, for many teachers, science is nothing more than a body of knowledge "arrived at by the neutral, objective application of the scientific method to natural phenomenon" (p. 135). Herwitz and Guerra (1996) characterize the view of science held by elementary school teachers as a "fixed, somewhat daunting, body of knowledge. The information is often perceived as reserved for the elite few" (p. 22). In a review of the literature regarding teacher attitudes toward science across England, Northern Ireland and Wales, Osborne, Driver & Simon (1998) found that teachers see science as "a series of milestones represented by the significant discoveries over the last century" (p. 29) and fail to "communicate contemporary issues in science, or to portray the actual working practices of scientists" (p. 29).

Appleton (1997) describes a view of science perpetuated in many Western classrooms as "80 years out of date" (p. 69). This view is revealed through everyday conversation and can be characterized by the following beliefs:

- Science is a collection of laws and principles of nature that scientists have discovered by using complex equipment and a systematic, objective, scientific approach.
- The essential components of science are the laws of nature, the scientific methods used to discover them and the scientific information published about those laws.
- Truth in science is anything that has been proven scientifically—scientific information.
- Science is mainly inductive because the scientist makes lots of observations and discovers the laws of nature from relationships induced from the observations (p. 68).

Other characteristics of this view of science include the notion that laws of nature exist independently and are simply awaiting discovery, that the method used by scientists is unique and infallible, and that once the laws of nature have been proven true, they become authoritative knowledge (p. 69).

Textbooks contributing to the institutional discourse. High school science reflects and encourages a narrow view of science through the predominant use of textbooks as a vehicle for content delivery. Gallagher (1991) found that popular biology and physics texts used in the United States of America give little attention to the nature of science. Despite overwhelming focus on concepts and principles in both print and diagrams, the books pay little heed to how the knowledge of science is either formulated or validated. The texts also place little emphasis on the usefulness of science in daily life. Most science textbooks resemble large encyclopedias of scientific facts. New information is added as soon as it is accepted by the scientific community but, as

Gallagher points out (1991), rarely is content "pruned out." The world of publishing is a competitive one, and publishers try to accommodate the curricular needs of multiple states and provinces within the covers of the single text.

Myths of science. Hodson (1998) claims that nine myths about science abound today, particularly in schools. These myths, which underpin the view of science described by Appleton and others, are as follows:

1. Observation provides direct and reliable access to secure knowledge.
2. Science starts with observation.
3. Science proceeds via induction.
4. Experiments are decisive.
5. Science comprises discrete, generic processes.
6. Scientific inquiry is a simple, algorithmic procedure.
7. Science is a value-free activity.
8. The so-called "scientific attitudes" are essential to the effective practice of science.
9. All scientists possess these attitudes (p. 95).

For those of us who have graduated from Western school systems, many of these myths rebound through our memories of schooling. They bring to the forefront the following questions: *What then is "real" science, if it is not the science portrayed in schools? How did the distorted view arise? Why is school science failing to reflect the many dimensions that make up the scientific neighborhood?*

Constituting Neighborhoods of Science

The search to understand how and why beliefs that may not reflect the discipline have become part of the institutional discourse requires a tracing of science and its relationship with science education as it is reflected in recent history. Egan (1997), however, cautions against using history to ascribe blame. Bloom and Hirsch (as cited in Egan, 1997) blame Rousseau and Dewey for the condition of schools today, he notes, but "Rousseau and Dewey have enriched our conception of education in important ways. We will not make educational progress by trying to cut away their contribution" (p. 31). So it is with the nature of science and its relationship with science education. It would be tempting to blame logical positivists or various curriculum emphases (Roberts, 1982) that have arisen during the past 100 years. My intent with this brief historical overview, however, is merely to point out how science has been conceptualized and constituted over time, and how public discourse around science and around learning has enriched and reconstituted a more multidimensional view today.

Canada is positioned alongside the United States of America and consequently is influenced by educational trends south of the border. Many of our science programs and resources are American texts modified to suit Canadian students. Hence, my brief historical discussion primarily traces North American science, with the focus on Canada wherever possible.

Brief Historical Overview

According to Chalmers (1982), Francis Bacon was the first philosopher/scientist to begin articulating modern methods of science. "In the early 17th century, he proposed that the aim of science is the improvement of man's lot on earth, and for him that aim was to be achieved by collecting facts through organized observation and deriving theories from them" (p. xvii). So began positivism, which reached its heyday in the mid-18th century. Essentially, positivism was the belief that the only true knowledge was that which resulted from the verification of what the senses determined. "It took its name from the assumption that sensation gives direct experience of the physical world and we can be *positive* about it because it is 'given'" (Poole, 1995, p. 35). One of the consequences of such a view is that science becomes the arbitrator of knowledge, for only by scientific methods is new knowledge is created.

Not unsurprisingly, this was the age of the scientific and industrial revolution as well as an era of scientific popularity (Shamos, 1995)—in Europe, mainly among the upper class. Examples of this popularization include the fact that Voltaire had sufficient audience to translate Newton into French, that the electrical experiments of Galvani and Volta were favored subjects in the royal courts and that Napoleon became an avid supporter of science education, establishing the Ecole Polytechnic in 1793. America at this time was struggling toward independence and displayed less interest in science, but educated classes at least had regular opportunities to attend lectures by itinerant scientists (Shamos, 1995).

During the early 1900s, the boundaries of positivism were expanded to include logic; hence the growth of logical positivism. Now truth included not only those things that could be verified via the senses, but also statements that were analytically true; in other words, truth by definition. All moral, theological and metaphysical statements were dismissed in the name of science (Poole, 1995), and science achieved the status that comes with being unique, in this case the singular purveyor of knowledge.

It was during the late 19th century that science began to develop as an "independent intellectual force," no longer tied to "the natural theology that had fettered it since the Copernican revolution" (Shamos, 1995, p. 39). It also began to be seen as an excellent method for training the mind through the improvement of such mental skills as observation, concentration, reasoning and memorization (Shamos, 1995). During the late 1800s, science became part of schooling (natural philosophy), generally geared toward pragmatic applications: nature studies, so future farmers would produce better crops and future merchants would understand the use of new materials.

Reforms in School Science

Across North America, most students did not continue their education beyond the elementary level until well into the 20th century. Therefore, science education has been a concern for less than a hundred years. Up until the 1950s, school science focused on science in daily life: the "practical, vocational, social and humanitarian aspects of science and the inclusion of these aspects in the curriculum" (Matthews, 1994). During this time, biology focused on agriculture as well as disease prevention and hygiene. (Not surprising, given the multiple problems engendered by World War II.) Physics, too, emphasized applied questions, using the technology of everyday life to illuminate scientific principles (Roberts, 1982).

The successful launching of Sputnik on October 4, 1957 sent the American scientific world into a tailspin. Critics of science education claimed the launch as the proof needed to add rigour to science programs. The subsequent National Defense Education Act plunged $94 million into science education and pledged a further $600 million for the years 1961-1975 (Matthews, 1994). This rather significant funding stimulated conferences and meetings across the country and enabled the National Science Foundation to begin transforming school science.

The National Science Foundation was charged with improving science, mathematics and engineering education at all levels, including elementary. One of its primary goals was to produce more trained scientists and engineers (Shamos, 1995), and so it began to change school science into "proto-university science" (Matthews, 1994). With Britain carrying out simultaneous reforms, both sides of the ocean stressed the need to develop *scientists,* not just students who *learned science material.*

To that end, new programs emphasized either the structures thought to make up the disciplines of science or the processes (Gagne as cited by Millar and Driver, 1987) used by scientists. These emphases led to a host of secondary curricula and support materials, including Biological Sciences Curriculum Study (BSCS) under Joseph Schwab, Chemical Education Materials (CHEMS) and Introductory Physical Sciences (IPS).

The elementary school curriculum also underwent scrutiny, with several programs developed to assist teachers with curriculum delivery. Osborne & Simon (1996) note that the different program emphases speak to the ways science was conceptualized at that time. Science - A Process Approach (SAPA) emphasized highly structured teaching of specific processes such as observing, classifying, measuring and predicting. Elementary Science Study (ESS) emphasized independent exploration of phenomena while Science Curriculum Improvement Study (SCIS) attempted to develop understanding of some science concepts as well as inquiring minds. "The distinction in emphasis between these courses is fundamentally a reflection of disparate views about the aims of science education—some emphasising the development of scientific skills and attitudes, and others, SCIS in particular, the development of scientific knowledge" (Osborne & Simon, 1996, p. 101).

This was the time period in which *discovery learning* rose to the forefront, aimed at promoting the *skills* as well as the *nature* of scientific inquiry. Students were encouraged to learn about science by being scientists: conducting experiments and inquiries set up to demonstrate scientific principles. On the surface, discovery learning was very attractive. Science classes were modelled after laboratories and appeared to successfully engage students in the inquiry process. This form of teaching, however, relied heavily on beliefs that science is inductive, that students can "discover" the structures of scientific theories and that the senses are not guided by conceptual understanding (Matthews, 1994).

Western Science in "Crisis"

In the mid-1970s, the National Science Foundation withdrew its involvement in school curriculum development—and its concomitant funding. Within 10 years, questions regarding the effectiveness of the earlier reforms began to emerge, and a crisis was again pronounced in 1982, when the National Science Board issued *Today's Problems, Tomorrow's Crises.* This study reported a dearth of qualified science teachers at all levels, lack of interest among students in science careers and declining test scores (Shamos, 1995). Those concerns were reiterated the following year in *A Nation at Risk* (U.S. Department of Education, 1983), which voiced the rallying cry "scientific and technology literacy for all."

The United States was not alone in its concern over the future of national science education. Canada initiated the cross-country investigation outlined earlier (See pages 1-2) as did the United Kingdom (DES as cited in Osborne & Simon, 1996) and Australia (DEET, 1989). These national reports led to extensive research in an attempt to shed light on perceived deficits in elementary/primary science programs. There was cross-continent acknowledgment that a large percentage of elementary teachers were reluctant to teach science (Appleton, 1992; Manning, Esler & Baird, 1982; Yates & Goodrum, 1990). Orpwood & Souque (1985) suggest that in Canada, "not more than half of all elementary school classes receive any science at all" (p. 629). Of those who did receive science, questions began to surface regarding the way the discipline had become institutionalized.

Multidimensional Science

Mathematician Warren Weaver (1968) writes about the imperfections of science, arguing that success has earned science a "great and strange reputation" (p. 15). Public discourse emphasizing the enormous accomplishments of the worldwide scientific community has contributed to the notion that science is all-powerful. This has garnered science a great deal of prestige and respect. At the same time, Weaver argues that science needs to be given a more realistic interpretation. It is being *incorrectly* hailed as a unified, entirely logical, objective profession, able to give ultimate explanations.

While it is easy to describe what science is not, it becomes much more difficult for a non-scientist to define what science actually *is*. To that end, I turn to the work of scientists and those who study the history and philosophy of science, as well as to ethnographers and sociologists whose recent works add to the discourse surrounding the neighborhoods of science. This growing body of work adds substance to the rather meagre view as portrayed in school science. Note that it is beyond the scope of this dissertation to describe the totality of scientific enterprise.

Scientific methods. It would be impossible to make a statement that represents the whole of the scientific enterprise. One has only to look at the history of science to see the rise and fall of incompatible movements that, during their heyday, were considered *de rigueur* in their discipline. In an introductory account of the nature and history of philosophy of science, Chalmers (1982) traces the rise of inductivism, provides a critique of inductivism and introduces the growth and limitations of falsification as established by Popper. He discusses theories as structures, analyzing the works of Kuhn, Lakatos and Feyerabend. Chalmers' purpose is quite simply to show that "there is no timeless and universal conception of science or scientific method" (p. 169). Instead, science seems to be a complex interweaving of society, belief systems and scientists at work.

This point is brought home in the history of the theory of continental drift as described by Werner Israel (1996). Until society (scientific community notwithstanding) was ready to accept the notion that the earth is not stable or solid, none of the "evidence" supporting Wegener's claim was considered credible. It mattered not that Benjamin Franklin, having seen a layering of oyster shells on a mountain in Derbyshire, mused as early as 1782 that perhaps the earth's crust is nothing more than a shell floating on a liquid. Nor did it matter that in 1923 geologist Alex du Toit noted similarities in formations in South Africa and South America. Even the suggestion put forth by Arthur Holmes in 1928, that thermal convection might be the force pushing land masses apart, did not give rise to acceptance. As far as society was concerned, the earth beneath was solid and unshakable. In fact, until the late 1960s it was impossible for the scientific community, let alone the rest of society, to admit to making a mistake.

The tale of continental drift theory is reminiscent of a Kuhnian paradigm shift. Whether or not one accepts Kuhn's (1970) description of scientific enterprise as a series of "revolutions," one cannot help but be struck by the relative uncertainty of science. Historical overviews by Hawking (1988) and Chalmers (1982) show quite clearly that both observation and experiment are often molded by theory, not the reverse. At the same time, one can see that no particular method is more appropriate than others for use in scientific inquiry. The *scientific method* most people memorize is in reality a multiplicity of approaches and techniques.

While there may not be one method common to all engaged in scientific enterprise, it is incumbent upon scientists to search for and present their knowledge in a "faithful, factually sound manner" (Martin, Kass & Brouwer, 1990, p. 542). At this time, there do not seem to be any guidelines that universally embrace each field within science. Thus I interpret fidelity as fidelity to the research question, to the inquiry process and to the reporting of the findings.

Community science. All of science is conducted within specific communities. A science community is nested within culture at large, and both have impact upon scientific research. While there is no *single* method common to all scientists, methods in science reflect an interplay between questions, appropriate approaches for specific questions and processes and procedures selected from a range approved by the scientific community (Hodson, 1998). As ideas develop, they are subject to scrutiny by the rest of the scientific community.

Besides giving credence to multiple processes, procedures and methods, the scientific community is involved in developing each new idea by acting as a forum in which new models are presented (Kuhn, 1993; Newton, 1999; Sutton, 1993, 1996b). In this arena, "these ideas are articulated, questioned, clarified, defended, elaborated, and indeed often arise in the first place" (Kuhn, 1993, p. 321). Several competing theories can develop in response to a particular scientific question, for the "facts" of previous scientific endeavors act as planks in the platform upon which arguments rest. The scientific community is also significant in terms of accepting new metaphors and for developing and monitoring discourse practices.

Societal science. An authentic picture of science does not isolate science from the rest of society (Martin, Kass & Brouwer, 1990), for science occurs in the context of ethical, economic, religious, ideological and cultural values. Abrams and Wandersee (1995) make this point in their discussion of the growth of biological knowledge. They urge classroom teachers to acquaint students with the forces affecting scientific research, particularly with funding agencies, which play a major role in molding scientists' research practices. McGinn & Roth (1999) illustrate by depicting the way AIDS activists have shaped AIDS research, despite the fact that many activists have little formal education in science or medicine.

> This has prompted a shift from scientists' interest in maintaining scientific standards to produce solid, trustworthy results toward the interests of people with life-threatening illnesses (and the medical practitioners who support them) who use whatever knowledge is available to make the best treatment decisions possible. Activist engagements in science have led to changes in therapeutic care techniques and modifications to clinical trial design including broader entry criteria, more diverse subject populations, and access to concomitant medication during clinical trials (McGinn & Roth, 1999, p. 16).

The role of society pervades all aspects of scientific inquiry. Longino (1990) suggests that science is based on evidential reasoning and as such is always context dependent. She uses examples to illustrate that society shapes observation, reasoning, the research used to investigate hypotheses and the language used to communicate scientific understanding. The experience of individual scientists, she says, "is a nexus of interpretation coming into existence at the boundary of nature and culture" (Longino, 1990, p. 221). Thus as cultures change, so does science.

Personal science. A variety of motivations stimulate scientists, both in their choice of what to pursue and in how they pursue that choice. Kornberg (as cited in Abrams and Wandersee, 1995), a retired professor from the Stanford University School of Medicine, claims the discoveries that have changed medicine as we know it, namely penicillin and recombinant DNA, result from life scientists' "unbridled curiosity about nature" (p. 654). Sir Peter Medawar, 1960 Nobel Prize winner, gives the following description of the scientific mind:

> Among scientists are collectors, classifiers and compulsive tidiers-up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics (1996, p. 13).

This collage-like image of scientists is enhanced by Salk (Goldberg, 1984), who talks about the role of intuition in great discoveries. Hawking (1988) adds drama by outlining some of the divisiveness within the field, while Crick (1988) and Goodall (1988) give us stories of men and women in science who have hopes and dreams, setbacks and the occasional success. Richardson and Lee, who won the 1996 Nobel prize for physics, add to this glimpse into personal science with the somewhat humorous note that their discovery of superfluid helium-3 "just popped up, we weren't really looking for it" (Reuter, The Associated Press, 1996)!

Private science. John-Steiner (1985) points out that most published accounts of scientific work exclude the detours that are part of the development from "first ideas to finished research" (p.185). Instead, textbooks and scientific articles present science in a clean and sanitized form. Little or no mention is made of the "blind alleys and false starts" (Martin, Kass & Brouwer, 1990, p. 546). Nor, as Medawar (1996) describes, do we read of the guesswork that goes into forming hypotheses. This world of ideas, mistakes, boredom, repetition and emotion is also part of what we call science. The historical stories of idea development (not the historical hero stories, which often reinforce stereotypes, See Milne, 1998) provide opportunity to see multiple facets of scientific enterprise.

Historical science. Because science is part of our cultural heritage, it must be taught as a development of ideas within an historical framework. In fact, the history of science is crucial for showing the evolution of ideas. Sutton (1996b) suggests that science can be seen as a process of modelling, with each new insight involving a "*re-description* of the phenomenon being studied" (p. 144). Drawing convincing examples from the history of chemistry, physics and biology, he shows how scientists have re-described aspects of their field using new analogies and metaphors. In the 1600s, for example, William Harvey began to speak about the heart in terms of circular motions rather than as a spring; in 1644, Torricelli began to re-describe air as a fluid with the famous line "we are living at the bottom of an ocean of air."

In the first stage of modelling, when visualizations are fleshed out, new terminology is developed or old words take on new meanings. Words are used to interpret, rather than to label information (Sutton, 1992; 1996a). Unfortunately, this exploratory, tentative and questioning writing is not the writing science students see. Most of us first learned about Galileo in secondary school, where he is often portrayed as one of the "fathers of astronomy." We were impressed with "his" invention of the telescope and subsequent discoveries. But how many of us actually read Galileo's original letters in *Sidereus Nuncius*? Consider the following segment, written in January 1610:

> All three little stars were to the west of Jupiter and closer to each other than the previous night, and separated by equal intervals as shown in the adjoining sketch. Even though at this point I had by no means turned my thought to the mutual motions of the stars, yet I was aroused by the question of how Jupiter could be to the east of all the said fixed stars when a day before he had been to the west of two of them. I was afraid, therefore, that perhaps, contrary to the astronomical computations, his motion was direct and that, by his proper motion he had bypassed those stars. For this reason I waited eagerly for the next night. But I was disappointed in my hope, for the sky was everywhere covered with clouds (Galilei, 1989, p. 65).

What rings through the segment is not only that Galileo is "discovering" several of the moons of Jupiter, but that his explanation appears to be riddled with questions. Galileo is working out an explanatory model for one aspect of the solar system and hence his writing reflects a certain hesitancy. By ignoring history, the nature of science is cloaked in the litany of discovery.

Learning about the history of science can help balance persistent and inappropriate images of science and scientists. Russell (1981) argues that teaching the history of science helps to change student attitudes toward science as they develop positive images of scientists to counteract the negative images portrayed in the media.

Science and its relationship to technology. Much contemporary science is connected with the working of technology. Technological advances have produced sophisticated machinery and devices that contribute enormously to scientific discovery, particularly in microbiology and astronomy. Many people see little distinction between technology and science. In Alberta, the new elementary science curriculum (Alberta Education, 1996) may well add to this blurring. Rowell (1995) points out that linking each technology unit (other than Grade 1) with a science inquiry unit reinforces the erroneous assumption that technology is, in effect, applied science. Layton (1988) argues for a review of the relationship between science and technology, and predicts that this review will inexorably lead people into a field of moral questions.

The aims of science. This final attribute of science, as defined by Martin, Kass and Brouwer (1990), uncovers the need to "introduce a position regarding the fundamental aims of science" (p. 550) and address questions related to agendas: "Today science must be understood in the light of private, public, industrial, or military agendas" (p. 550). Keller (1992) points out that funding priorities help shape the profile of scientific research. As resources are diverted into specific areas, others are divested of possible funds. Hence while scientific knowledge may flourish in one area, others may suffer, depending on the funding available. One can see that a portrayal of science could be very different depending on whose agenda is being served. To that end it becomes difficult to decide which view is a more authentic portrayal of science.

These dimensions of science, while not the totality of scientific enterprise, present a view of science that is not in keeping with the view held by most elementary teachers (Robottom, 1992), nor that found in the resources, manuals and informational books usually associated with science education (Elliott & Nagel, 1987). It *is,* however, a neighborhood of science that Rutherford suggests we as elementary school teachers must introduce to our students.

Confidence in a Neighborhood of Elementary Science

Increasing Background Knowledge

The research into elementary teachers' reluctance to teach science uncovered an interplay between confidence and competence. Identified first and foremost was the lack of sufficient content knowledge among elementary teachers (Moore, 1987; Manning, Esler & Baird, 1982; Mechling, Stedman & Donnellan, 1982; Tilgner, 1990). Close on its heels arose concern about teachers' confidence level and questions about the relationship between confidence and science background (Appleton, 1992; Yates & Goodrum, 1990). A comparison between Australia and the United States (Kahle, Anderson & Damnjoanovic, 1991) demonstrates similarity in background education as well confidence among teachers of both countries. Generally, it was felt that the lack of background knowledge in science led to a lack of confidence in teaching science and therefore a willingness to forego science teaching in the face of competing demands. Dissension arose, however, in response to recommendations (DEET, 1989) that more science discipline courses be added to preservice teacher programs to improve both confidence and competence. Stepans and McCormack (1985), for example, found that students who took more traditional science courses at college did not necessarily have greater understanding of science concepts. Symington (1982) argues that certain teacher abilities can compensate for a lack of scientific knowledge when asking children to investigate by designing problems. Appleton (1995) found increasing self confidence more important than increasing background content knowledge. Once self confidence is raised, he suggests, teachers are more likely to seek out necessary scientific information.

Improving Teacher Education

A second wave of research flowing out of the confidence/competence work focused on improving teacher education. At the preservice level, findings included the improvement of student attitudes toward science and science teaching through field service programs (Strawitz and Malone, 1986) and pedagogical studies rather than *traditional* discipline studies (Appleton, 1992; Skamp,1989). Appleton (1992) found that a preservice science pedagogy class had far-reaching positive effects, extending student confidence into all science areas despite the fact that the unit covered only one area (energy)!

The Centre of Science and Mathematics Education Research at the University of Waikato (New Zealand) and the University of Canberra (Australia) engaged in long-term research projects that attempted to develop models for teacher training programs at both preservice and in-service levels. Dr. Valda Kirkwood was instrumental in both programs, termed WASTE or Women and Science Teacher Education Project and PECSTEP or Primary and Early Childhood Science and Technology Education Project. Their primary purpose was the development of gender sensitive models directed toward changing attitudes to science and science teaching among women (Bearlin, 1990; Hardy, Bearlin & Kirkwood, 1990; Rennie, Parker & Hutchinson, 1985). These models focused on women because “female teachers predominate in primary schools, and tend both to have more negative perceptions of their teaching skills in the physical sciences than males, and to expect girls to perform less well in these areas than boys” (Bearlin, 1990, p. 22). The importance of breaking the self-perpetuating cycle is apparent.

Although the PECSTEP project originally focused on preservice programs, it became apparent that preservice education was not enough, given the “dearth of primary science being taught in schools” (Hardy, Bearlin & Kirkwood, 1990, p. 142). The need to bridge the gap between preservice education and the “real world of teaching” is also evident in Alberta. Rowell and Gustafson (1993) followed beginning teachers as they moved from a university preservice program into their first year of teaching. Throughout that study, we see that the new “keen” teachers are gradually encultured by factors beyond their control. Classroom conditions and extracurricular demands, as well as more tacit factors such as little-used science equipment, minimal science curricular minutes and subtle reinforcement for a less than well developed science program permit the continuation of very limited programs in science. Brickhouse and Bodner (1992) found that classroom constraints such as the segmenting of time periods and assigned textbooks play a significant role in undercutting teacher expertise. Lederman and Zeidler (1987) suggest that these and other constraints are sufficiently powerful to influence a teacher's portrayal of the nature of science as well as pedagogy.

Increased Understanding of Pedagogy

While the "crisis" in science education was being articulated, criticism of science education was marshalled on several fronts. Millar and Driver (1987) argue that while science programs were proclaiming they modelled "scientific methods" or "the way scientists work," little was written on the history, philosophy and sociology of science to justify these stances. At the same time they suggested that science process skills are characteristics of general logical thought, not specifically related to science, and that science lessons ought to promote how the skills could be used for science in particular. The focus of observation in science, for example, is not simply noting details, but rather determining which of these details are significant for developing *scientific* understanding. This requires that children "recognize the elements of a complex situation which are scientifically worth observing, to learn the observations which are relevant to scientific classification and to conceptualise the task in a manner which reflects a scientific approach" (Osborne & Simon, 1996, p. 110).

Emphasis on what students know prior to the teaching/learning activity augmented new understandings regarding pedagogy. A body of research was growing which demonstrated that children, despite years of science teaching, often held "misconceptions (alternative frameworks, children's ideas etc.) about scientific phenomena (Driver, 1989; Driver, Guesne & Tiberghien, 1985; Osborne & Freyberg, 1985). These findings led to the development of conceptual change theory (Hewson & Thorley, 1989; Posner, Strike, Hewson & Gertzog, 1982) and constructivism (Driver & Oldham, 1986).

Constructivism has been sculpted out of several significant theorists' work, including Piaget's early work on children's explanations of natural phenomenon, Vygotsky's theories on language acquisition, von Glaserfeld's views on the nature of knowledge, Osborne and Wittrock's (1983) work on the active construction of meaning and Driver's research regarding children's alternative frameworks. Constructivism holds that children develop ideas and beliefs about the natural world long before they enter the classroom. These ideas are not random, but instead link together in a coherence that is acceptable to the holder. When presented new information, children make links between the new knowledge and their old knowledge. At times, these links result in explanations for phenomena that are contrary to those given by the scientific community. This linking has serious consequences for science schooling, as Driver and Oldham point out:

> One significant finding is that some of the ideas used by children about the natural world are firmly held and often persist despite science teaching. Thus although for some children, taught scientific ideas may be applied in stereotyped school contexts, for example in examination questions, such ideas are not applied outside the formal school setting to explain everyday phenomena (Driver & Oldham, 1986, p. 106).

Multiple Dimensions of Teacher Knowledge

As the research surrounding elementary science teaching developed, it was enriched by a renewed focus on various aspects of teacher knowledge. Schwab (1970) had insisted that educational curriculum contains "practical" as well as theoretical knowledge, implying that teachers ought to equipped with both. Various authors have explored the features of this practical knowledge (Connelly & Clandinin, 1986; Connelly & Clandinin, 1988; Duffee & Aikenhead, 1995; Grimmett & Mackinnon, 1992; Tamir, 1991).

Shulman (1986) delineates three categories of content knowledge that inform teacher practice: *subject matter content knowledge*, *pedagogical content knowledge* and *curricular knowledge*. As the educational world moved out of the process skills movements of the '60s and '70s, Shulman attempted to re-establish the place of subject matter knowledge. Barnes (1989) points out that, in doing so, Shulman may have contributed to the idea that subject matter is more important than any other form of knowledge. As many authors note, however, teacher knowledge encompasses more than understanding the subject material to be taught and having at one's fingertips pedagogical practices that encourage learning. For the elementary teacher, this knowledge requires flexibility in making connections across disciplines and to the rest of the world (McDiarmid, Ball & Anderson, 1989). It requires the ability to use language to guide knowledge construction (Mercer, 1995) and to develop what van Manen (1991) describes as "pedagogical tact" or a deep and thoughtful relationship with learners. This complexity is largely unrecognized, being invisible (Wallace & Louden, 1992), and cannot be described only as a series of attributes or skills. Instead, it can be characterized as professional knowledge, gleaned through experience and hard work, converging with knowledge and understanding of the various disciplines as well as a deep caring and understanding of children.

Teaching within intersections. As shown in Figure 1, as they teach science, elementary teachers are situated within an intersection of two neighborhoods. First, a neighborhood of science (A); second, a neighborhood of elementary teaching (B).

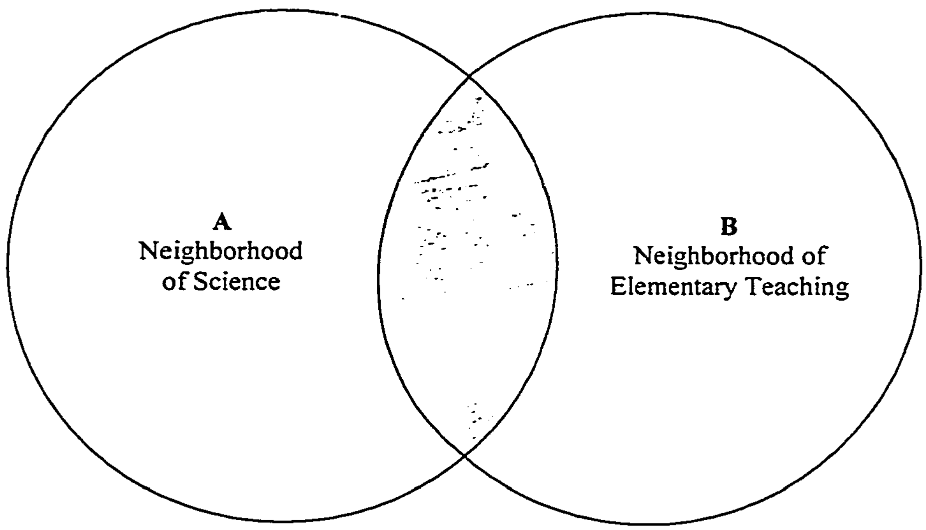

Figure 1. Positioning of Teachers in Neighborhoods of Science and Teaching.

Each community has its own rich history, community members, discourse practices, multiple fields and specific aims. From within circle A, teachers develop subject matter content knowledge and an understanding of the dimensions specific to the disciplines. From within circle B, teachers develop the various forms of curricular, pedagogical and practical knowledge related to the practice of teaching. Teachers within the intersection, however, are able to draw from both areas and thus introduce their students to a neighborhood of science rather than just the knowledge it contains. It is this intersection, currently under scrutiny in the research, which seeks to examine how classroom science might mirror science as practiced by scientists (Helms, 1998, Roth, 1995; Roth & McGinn, 1998; Woolnough, 1998; Smith & Anderson, 1999). This intersection is also receiving attention in research on "how identity is constructed by those new to the practice of science" (Richmond & Kurth, 1999, p. 678) and thus is of interest to my study.

Developing knowledge within multiple contexts. The points of intersection cradle, and are cradled within, multiple contexts. As mentioned earlier, Rogoff suggests that development occurs in "three inseparable mutually constituting planes" (1995, p. 139). This mutuality becomes clear when one examines how elementary teachers' science discourse is shaped. At the personal, interpersonal and the community level, different developmental processes occur.

On the personal level, it is through *participatory appropriation* that individuals "change and handle a later situation in ways prepared by their own participation in the previous situation" (p. 142). Through this participation, understanding is transformed. Rogoff (1995) makes it clear that appropriation is not synonymous with the concept of internalization. Rather than importing "something external," appropriation is the process by which an individual is able to transform previous understanding by linking it to a new endeavor. "It is the process of becoming rather than acquisition" (p. 142) and is both dynamic and active.

A key point is the notion of time, and hence the concept of change. The past, present and future segmentation common to a view of internalization denotes separate stages, sequentially positioned. Rogoff (1995) argues, however, that in the perspective of participatory appropriation, time is an "inherent aspect" rather than a continuum. In effect, when a person acts in the present, the previous experience (past) becomes the present. "Any event in the present is an extension of previous events and is directed toward goals that have not yet been accomplished. As such, the present extends through the past and future and cannot be separated from them" (p. 155).

At the interpersonal level, development occurs through the process of *guided participation,* in other words, the manner of involvement of people engaged in cultural activities. Guided participation can occur during face-to-face interaction or side-by-side joint participation, as well as through the choices individuals make in response to the influence of others. These influences include suggestions, commands, implications or even interpretations of the actions and words of others, both near and far. Communication is paramount, for participants “seek a common ground of understanding in order to proceed with the activities at hand” (Rogoff, 1995, p. 148). Analysis of this plane includes a focus on the communication strategies and coordination efforts of the people involved.

At the community level, development occurs through apprenticeship, a shared endeavor in which one or more individuals act as mentors for others attempting to become members of a particular community. Of importance are the institutional structures and assumptions guiding practices within various cultures.

These planes do not function independently, nor can they be examined without due consideration of how each influences the others. Development involves all three planes. By implication, an examination of participatory appropriation requires an understanding of how personal, interpersonal and cultural processes are mutually constitutive. This mutuality is evident when one considers how the discourse of elementary teachers is shaped with respect to the teaching of science.

Shaping Discourse Related to Science

Teachers never work alone. They, like all other members of society, both shape and are shaped by the culture in which they are positioned. Knowledge related to schooling has been institutionalized and is therefore no longer rooted in everyday understanding. Instead, schooling "represents a more specialized and narrow interest in furthering a particular activity" (Saljö, 1998, p. 47). While each discipline develops a particular and characteristic discourse, schooling provides a context that then reshapes this discourse. How the discourse is shaped becomes important for both pragmatic and political reasons.

Companion meanings. Östman (1994; 1996; 1998) and Roberts (1998) suggest that the language used to present science to students communicates specific messages about science. Of particular interest is the idea of *companion meanings,* the messages communicated—broadly by the science curriculum and more specifically by teachers within the classroom. Using a series of excerpts from chemistry texts, Östman (1998) demonstrates that companion meanings can socialize students into very different viewpoints regarding a view of nature, regarding the way humans relate to nature and regarding the purpose of the discipline (which he calls *subject focus*).

Companion meanings must be understood by switching "constantly between what is included and what is excluded" (p. 55). For example, Topic C of the Grade 6 Alberta elementary science program of studies is titled *Sky Science.* Its overview is as follows:

> Students learn about objects in the day and night sky. Through direct observation and research, students learn about the motions and characteristics of stars, moons and planets. Using simple materials, such as balls and beads, students create models and diagrams which they use to explore the relative position and motion of objects in space. As a result of these studies, students move from a simple view of land and sky, to one that recognizes Earth as a sphere in motion within a larger universe. With new understanding, students revisit the topics of seasonal cycles, phases of the moon and the apparent motion of stars (Alberta Education, 1996, p. B.32).

Nothing is mentioned in either the overview or the knowledge expectations listed directly below the overview to invite an understanding of science that goes beyond a series of specific processes or a collection of information. Sky science, however, is filled with a tradition of contradiction and exploration. The history of Western science and its uncovering of planetary motion, for example, is rich with drama that demonstrates the relationship between scientific discovery, technology and the interplay of research and political power. In other words, Topic C: *Sky Science* has the potential to promote a multidimensional view of science, but the opportunity lost has conveyed the companion meaning that science is nothing more than current processes and current understanding.

Companion meanings are produced not only through textual products but also by what and how teachers choose to *represent* the discipline. The numerous activities in which teachers engage each day are framed by their personal understanding and beliefs about the nature of teaching, learning and subject material (McDiarmid, Ball & Anderson, 1989). Smith and Neale (1989) offer an example of the socializing power of companion meanings through their work in teacher practice. The beliefs held by teachers regarding the nature of science are linked to the following *orientations* toward science: discovery, process, didactic/content mastery and conceptual change. Depending on the orientation held by a teacher, Smith and Neale (1989) find significant difference in the way science is taught. For example, a teacher transmitting didactic/content mastery holds that science consists of the body of facts, laws and formulae established by scientists. School science then becomes a process in which students are exposed to this content and are required to memorize and assimilate information. Typically, science lessons become relegated to reading texts, adding on new information, answering factual questions, watching demonstrations and so forth.

Contrast this orientation to that of conceptual change. Smith and Neale (1989) point out that in this orientation, science is seen as the construction and evolution of theories within a specific conceptual framework. School science provides opportunities for children to construct and reorganize the knowledge they bring in to school so it can be successfully meshed with the concepts and theories currently held by the scientific community. Science lessons become opportunities for children to articulate their own ideas, predict, explain, solve problems and make sense of discrepant events.

Companion meanings operate beyond the level of the classroom. They can be used deliberately by policy writers to socialize students into particular viewpoints regarding the rationale for studying science. One category of companion meanings is *curricular emphases* (Roberts, 1982).

Curricular emphases. "A curriculum emphasis in science education is a coherent set of messages to the student *about* science (rather than *within* science). Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself –objectives which provide answers to the student question: 'Why am I learning this?'" (p. 245). This emphasis is explicit in policy statements and instructional materials.

Roberts outlines seven *curricular emphases* that have pervaded science education at the level of curriculum development. They range from depicting science as *Everyday Coping,* in which science is seen as an important means for understanding and controlling one's environment, to *Solid Foundation,* in which science teaching at any given level is organized to facilitate *future* science teaching. Other emphases are

Structure of Science; Self as Explainer; Scientific Skill Development; Science, Technology, and Decisions; and *Correct Explanations.*

With the concept of curricular emphasis, Roberts demonstrates that differing broad curricular objectives can be found within the single discipline of school science. The importance of the fact that companion meanings guide institutional discourse at the policy level, as well as at the level of the individual teacher, cannot be overestimated. Everyone who has experienced science within a school setting has been socialized to particular viewpoints. Those continuing to work within a science community may very well develop a perspective on science that differs from their schooling experience. Most students, however, cease formal scientific activity at the end of schooling, and their orientation toward science remains shaped by their school experience (Gallagher, 1991) as well as by other experiences regarding science, predominantly via the media.

CHAPTER III

METHODOLOGY:
ASSEMBLING THE BRICOLAGE

Introduction

The questions guiding this research suit the qualitative paradigm for several reasons. First, my main purpose is to describe and explain rather than to predict or test theory (Leedy, 1997). Second, the research involves an "interpretive, naturalistic approach to its subject matter" (Denzin & Lincoln, 1998b, p. 3) in that it examines the meaning participants brought to phenomena rather than attempting to depict an objective reality. Third, the study is exploratory. The variables were unknown at the onset of research and the guidelines remained flexible to permit the design to evolve once the research group was established (Leedy, 1997). This lack of prescription was purposeful and allowed me as primary researcher, as well as my fellow companions, to pursue "new paths of discovery as they emerged" (Patton, 1990, p. 41). Thus, as various dimensions of the metaphor became articulated, we had freedom to change the format and the direction of the research, which proved invaluable on more than one occasion. Finally, this study attempted to remain holistic through a focus on *complex interdependencies* rather than on linear cause and effect relationships (Patton, 1990). To do so, it was necessary to take on the role of bricoleur—drawing from various methods, performing a variety of tasks and engaging in a process of intensive self-reflection (Denzin & Lincoln, 1998b) to maintain the essence of the research questions.

Bricolage Dismantled

Denzin and Lincoln's (1998a) description of the historical development of qualitative research demands from researchers a sensitivity to the way research is shaped and guided by the methodology and language of particular methods. Previous difficulties, such as the formalization of qualitative methods and issues of validation, are recast as the struggle emanating from modernists who tried to clothe themselves in "the language and rhetoric of positivist and postpositivist discourse" (p. 17). Shank (1995) claims that, in effect, the insistence upon triangulation (among other issues) is an attempt to bring positivism in "through the back door" (p. 4) rather than a conceptual and foundational change.

Out of various movements occurring during the history of qualitative research, present day concerns emerge. Shank (1994) suggests these are strategic concerns rather than the tactical issues typical of earlier methodology handbooks. Foremost are issues related to the dualism regarding whether one should one see written texts as *capturing* or *constructing* experience (Denzin & Lincoln, 1998a). Concerns related to this dualism include issues of *representation;* that is, how can one represent another's lived experience? Alongside these issues of representation are issues of *legitimation;* that is, how are studies to be evaluated?

As my work flows out of a sociocultural perspective, my role as a researcher is one of attempting to record how I/others construct our experience in a way that is true to the texts I/we select to use as data. My concerns lie with understanding and reconstructing experience rather than offering either a method of prediction or the restitution and emancipation offered by critical theory and action research (Guba & Lincoln, 1998). My role as participant stemmed from a desire to avoid the Self - Other dilemma (Fine, 1998) as much as possible, and focus on the understanding generated by the group—with myself as group member as well as researcher. This stance factored heavily in my decision to garner participants of similar age, gender and culture.

From the start, I was concerned with issues of representation and legitimation. Constructivism places great value on the experiences of individuals and on the meaning made by individuals within specific contexts. Each of us lives in multiple contexts and draws from various personal experiences. The interpretation of events, while governed by social interaction, is personal. Hence, the claim that each research experience is unique and must be treated accordingly has some merit. The nature of educational research, however, is a concern for the development of a "critical pedagogical competence" (van Manen, 1990, p. 8). To that end, individual studies are enriched through their links with others. In the words of Vidich and Lyman (1998), "the uniqueness of our own research experience gains significance when it is related to the theories of our predecessors and the research of our contemporaries" (p. 81).

Researchers today harvest fields plowed by various movements, furrowed by multiple disciplines and tended with a richness of technique. Denzin and Lincoln (1998a) liken the work of a researcher to that of a bricoleur. They suggest that "the product of the *bricoleur's* labor is a *bricolage*, a complex, dense, reflexive, collage-like creation that represents the researcher's images, understandings, and interpretations of the world or phenomenon under analysis" (1998a, p. 4).

While this image is emancipating to a researcher, issues of representation and legitimization become paramount. The freedom to select from a multiplicity of methods and techniques comes not without price. The commitment to a single, specific research method provides not only a preordained path but a series of safeguards to ensure *proper* *implementation*—and by implication, a certain level of trustworthiness. The onus on the researcher is thus to be true to the selected research method. Evaluation of the research is predicated on an evaluation of implementation and interpretation as outlined by the multiple manuals and training books developed for individual research methodologies. How then does one evaluate research that selects aspects of various research methods and knits them together in response to particular questions?

Gee and Green (1998) address the issue of evaluation by suggesting that researchers who combine approaches develop a *logic-of- inquiry*. This logic "influences the ways in which learning can be studied in social settings, the questions that can be asked, the research decisions and procedures used and the ways of reporting and representing findings" (p. 120). The following represents my logic-of-inquiry for the various strategies I selected to explore the research questions, and how I identified and dealt with issues of representation and legitimation.

Logic-of Inquiry

Establishing a Need for the Examination of a New Metaphor

Munby and Russell's assertion that "realities are constructed metaphorically" (1990, p. 117) is being borne out in educational research. In a study of 73 teachers, Provenzo, McCloskey, Kottkamp & Cohn (1989) found numerous metaphors used by the teachers to describe both their roles (articulated as trainer, anchor, minister, doctor, mother, etc.) and their work experience (selling, menial, mechanical, nurturing, being up against a brick wall). In another study, 40 teachers who had been selected to participate in the Primary Science Teacher Education Program based on their enthusiasm, expertise or interest in science were asked to generate metaphors describing their role (Aubusson & Webb, 1992); their metaphors were generally teacher centred (e.g. captain of the ship, architect, torch, conductor). Many of the metaphors identified in these studies appear in other studies on metaphors related to the teaching profession (e.g. Bullough & Stokes, 1994; Gurney, 1995).

Case by case, recognition is growing that the metaphors used by teachers to constitute their roles substantially impact classroom practice. Volkmann and Anderson (1998) examined extensive journals written by a chemistry teacher (and one of the researchers) during her first-year teaching. They found metaphors being used to resolve internal and external dilemmas. The neophyte teacher struggled with her perceived need to be someone who was older and tough, who could make chemistry fun to learn, while in reality she was very young, highly caring—and disliked chemistry. This dilemma was resolved as she developed personal metaphors of what it might be like to be a science teacher (role model, human being, favorite teacher). Together, the metaphors helped create a professional identity congruent with her personal identity.

Milne and Taylor (1995) investigated the relationship between the beliefs of three teachers about the nature of science, scientific knowledge and their own role as classroom teachers. Examining the everyday discourse of the participating teachers, they uncovered three global metaphors, which governed teaching and learning practices in those classrooms: *Teaching as a Journey*, *Teacher as Pathfinder*, *Knowledge as Object*. Milne and Taylor (1995) argue that the presence of these metaphors indicates a particular stance toward the nature of science, one that "supports an objectivist epistemology, a belief in the security of knowledge which has been proven, and an acceptance of the one-to-one correspondence between perceptions of physical reality and reality itself" (p.46). They go on to suggest that as long as objectivist metaphors continue in the school system, development of constructivist pedagogy for school science will be hampered.

Bullough (1994) credits industrial metaphors, which currently dominate education and teacher education, for promoting a particular view of teaching and learning. He urges preservice educators to begin developing personal metaphors that challenge these dominant metaphors.

Briscoe (1991) suggests that the metaphors teachers hold can thwart change when that change is based only on the implementation of different curriculum or the alteration of practice. She notes that, despite numerous professional development initiatives in science education, little documented, sustained change has occurred in practice. This gap is attributed to the lack of consideration as to how knowledge is conceptualized. Professional development that remains focused on exemplary teaching techniques and materials flows out of a model of learning in which knowledge is carefully delivered from the expert to the novice. Sociocultural learning theory suggests, however, that knowledge—rather than being passed from one person to another—emerges as individuals transform themselves by interpreting new ideas in light of old ideas.

To learn more about how belief systems help to constitute new information, Briscoe examined the relationship between metaphors and practice in a case study involving one teacher. Identified as exemplary teacher, he was attempting to shift the focus in his teaching, from "teacher-centred practices and emphasis on content to student-centred practices emphasizing problem solving" (p. 187). In spite of his commitment to change, Briscoe found that only the changes that supported his role metaphors were enacted. Most of the metaphors held by the teacher had been formed in "traditional teaching and learning environments" (1991, p. 198), and he was unable to create new role metaphors to guide his newfound practices.

Tobin and LaMaster (1995) investigated a teacher who experienced great difficulties with student behavior in her first year of teaching. The teacher articulated three dominant metaphors as she conceptualized her practice: facilitator, manager, assessor. After a new metaphor (social director) was formulated and introduced, effective changes in practice became apparent. The researchers suggest that metaphors serve as *referents,* providing images and sculpting language to guide action.

Out of the research linking metaphor with teacher practice has grown a branch of work focusing on how metaphors facilitate teacher change. Those studies have been used to facilitate discussion and "deliberate reflection about what it means teach" (Carter, 1990, p. 114), and to generate new ways of thinking (Munby & Russell, 1990) about teaching. Tobin (1990) uses cases from previous studies to demonstrate how specific metaphors held by teachers contribute to the way they implement science and mathematics curricula. Findings collected over a five-year period suggest that significant change in classroom practice is possible "if teachers are assisted to understand their teaching roles in terms of new metaphors" (p. 123). They also suggest that once teachers' beliefs and roles are gleaned from the metaphors they use, new metaphors can be introduced—and teacher change implemented.

Neighborhood of Science as an Appropriate Metaphor

In a symposium titled *Children, Science, and Books* (November 20, 1986), Kathleen Roth responded to the metaphor postulated by Rutherford by comparing three approaches to teaching science with respect to the neighborhood of science each represented.

Out of a series of case studies, Roth (1991) drew three very different portrayals of a science neighborhood. In a traditional textbook-based, didactic method, the study of science was depicted as memorization of "big words and lists of facts" unrelated to daily life (p. 147). Questions were considered unnecessary, and a neighborhood of science appeared as a foreign country rather than anything familiar.

In direct contrast was an activity-based, discovery oriented method. Here children were free to explore and explain to their hearts' content, and thus felt very comfortable. Little attempt was made, however, to link the children's explanations to those of the scientific world, and no attempt to facilitate conceptual change when necessary. Science activities and processes were seen as ends in themselves, with all explanations considered equally valid.

The third representation was fostered through a conceptual-change approach (spearheaded by a unit Roth had developed). In this classroom, the development of new concepts was used to engender understanding that science explanations, while personal, connect to explanations posed by the scientific community. The concepts were specifically related to everyday life experience, and as the child began to move from a *personal* explanation to a *scientific* explanation, the switch was both meaningful and relevant.

After demonstrating that a *neighborhood of science* can be interpreted in a variety of ways, Roth calls for a definition of what it means to be in a neighborhood of science. She suggests that Rutherford's approach to becoming comfortable is problematic; without guidance, children will not "figure out the language, rules, and ways of thinking in the neighborhood" (p. 159). Her critique presupposes that *teachers* know the language, rules and ways of thinking; clearly, as evident in the literature, that is not the case.

I think the concern that teachers themselves are uncomfortable in a neighborhood of science is of greater merit than the difficulties Roth sees with two out of the three approaches to teaching science. Unless teachers become comfortable exploring scientific territory, we have no hope of developing new understanding regarding how best to introduce this neighborhood to students. The intent of this research is to illuminate what Rutherford's five dimensions mean for discourses related to science and science education. While Rutherford applies the metaphor to the experiences of children, this research clarifies the metaphor with respect to teachers.

Description of the Research

The intent of my research is to explore the five dimensions of Rutherford's metaphor. I formed a discourse/interpretive group to conduct the exploration, and we met, on average, once every four weeks for 15 months. (See Appendix A for research timeline.) During the first meeting, it became apparent that the teachers had little or no experience with practicing scientists. To provide some experience, I set up a project with a group of astronomers. In short, the project involved bringing together teachers and practicing scientists, watching the scientists re-enact the trial of Giordano Bruno, reading Galileo's *Siderius Nuncius*, building a telescope with specifications similar to those used by Galileo, orienting the teachers to the sky, setting them up to do an independent moon observation over several weeks and then reconvening to share findings and observations. In this way, the teachers had the opportunity to experience some of the multidimensional aspects of science.

An overview of these meetings can be seen in Appendix A. Once the moon project was complete, the teachers met three times as a group to discuss the ramifications of the project with respect to the metaphor. To explore any remaining questions regarding the project and to allow the opportunity for each participant to reflect without the interruptions that occur when discussing as part of a group, I conducted a series of informal conversations with individual participants. We then met twice more, once to discuss the descriptions I had written on behalf of each participant and once to discuss the analysis and findings of the research. The data were then used to determine how the metaphor influenced the discourse of the research group, how new understandings regarding the nature and neighborhood of science were generated, and finally how the confidence levels of the teachers changed as they explored a neighborhood of science.

During the research I was primarily concerned with the way that the teachers constituted and re-constituted a neighborhood of science. Although the project included getting together with scientists, I did not wish to shift my research lenses onto the scientific community, but instead chose to keep them trained on the discourse community of teachers and on their interpretations of initial forays into scientific terrain. At all times I was concerned with how and why the neighborhood was being constituted, not with determining if this constitution was "properly interpreted." I chose not to analyze the discourse of the scientists in order to refrain from setting up comparisons between the scientists and the teachers. On a few occasions comments made by the scientists fuelled later discussion in our discourse group; however, the essence of this project was the discourse of elementary teachers with respect to science and not the discourse of the scientists.

Tools of Inquiry

Discourse analysis. Various authors point to the value of talk as a source of data. Edwards and Westgate (1994) suggest that, in classrooms, talk is the "main means of transmitting information" (p. 16) and that close inspection of talk reveals hidden agendas and gives clues about how experts in the field behave. Researchers concerned with language practices in the science classroom have directed attention to how neophyte members (students) develop the discourse practices of a science community (Kelly & Crawford, 1996; Kelly & Chen, 1999; Lemke, 1990). Attention is also paid to the ways teachers construct messages about discipline. Bruner (1986), for example, describes how the language teachers use reveals their stances toward subject material in a way that engenders future stances in their students.

This research focuses on the *substance* of our discourse. My examination of language aimed to "focus on what members of a social group are accomplishing through their discourse, rather than focusing solely on language form or function" (Gee & Green, 1998, p.122). In sociocultural terms, I looked at the understanding *produced* and *expressed* by a cultural tool, namely language (Cole & Wertsch, 1999; Wertsch, 1998), rather than how this tool was used to *facilitate* development of understanding. This approach is similar to the work done by Moje (1995), who used the utterances of a teacher to depict how that teacher conceptualized the nature of science and science learning.

Data used include audio recording and subsequent transcriptions of all meetings held by the teacher research group. Most of the conversations between scientists and teachers were recorded and transcribed. At times, when reading the transcripts from the previous meeting, questions arose that would be used to stimulate conversation in a subsequent meeting. Stories told by the participants regarding their experiences in science and anecdotes related to science teaching were often shared during these conversations.

Between regularly scheduled meetings, I spoke to individual participants via the telephone, or on occasion met face to face to talk about the project. These conversations were either recorded and transcribed or immediately reconstructed and added to the data collection. Selections from the transcripts are included in an effort to highlight salient points as well as to provide opportunities for the other participants to speak for themselves. Those comments are included verbatim except where ellipses indicate the deletion of non-essential speech markers (such as repeated words, um or ah) edited at the participants' requests.

Document analysis. Patton (1990) states that "a particularly rich source of information about many programs is program records and documents" (p. 233). The term *documents* in this case refers to the official paper trail that can litter institutions. Examples include company memos, correspondence, organizational rules, program documents and budget records. While this research did not target a specific institution, much of the impetus for curriculum presentation is derived from documents that flow from the government, specific school boards and publishing houses. Hence, one of the methods used in this study was document analysis.

Official documents used as data included the Alberta Science Program of Studies (Alberta Education, 1996) and articles requested by teachers in the discourse group to help illuminate various dimensions of the scientific neighborhood. A list of these articles can be found in Appendix B. Unofficial documents used in this study include my field notes, research journal, e-mails used to communicate thoughts about the research to supervisors and memos exchanged with other participants. During the independent moon study, each teacher kept a journal of sketches, notes and observations, which I received at the conclusion of the project. Memos between participants were kept and used as an added source of information. These documents were all examined for the presence of themes noted in the analysis of the transcripts. Excerpts from journals, notes, and emails have been bordered in order to distinguish them from spoken discourse.

Issues of Representation

Formation of the Discourse Community

The formation of our research group illustrates the intimate connection between thought and language as well as the role of community in the evolution of knowledge. As I began my graduate studies, long before the obligatory methods course by which graduate students typically design their research proposals, many of my friends and colleagues were curious about my schooling experience. Our frequent meetings were often prefaced by requests for description and detail as to the ideas and thoughts with which I struggled. In response to my observation that I was interested in how little real "talk" related to science we elementary teachers do, particularly in comparison to the amount we talk about reading and writing practices, three people on separate occasions expressed interest in forming a group with the distinct purpose of *talking about and getting to know science.* One person in particular mentioned that she would like the opportunity to *do science*. Another mused that she would like to belong to a *science support group.*

These comments reverberated as I happened upon Rutherford's metaphor and began to articulate the dimensions of this research. Tarule (1996) defines discourse or interpretive communities as "sites in which knowledge is produced, reproduced and contested" (p. 286). Hence, on the heels of my desire to explore the implications of a new metaphor for science teaching came the recognition that this exploration would be best situated within a discourse community. At the same time the recognition that science education is an area of insecurity for many teachers, as indicated by previous research, meant considerable care had to be taken regarding the selection of the participants and with my role as a researcher in the discourse community.

Burbules (1993) suggests that "Genuine dialogue, if it is to have a chance of success, rides on the participants' mutual feelings of concern, trust, respect, appreciation, affection and hope as well as on cognitive understanding" (pp vii). To encourage genuine dialogue, I began by inviting participants with whom a degree of relation had already been established. The first three were those who had expressed an earlier interest, described above. Two others were recruited through word of mouth; one had taught with two of the other participants, one was recommended by another colleague.

Michelle Fine (1998) writes of the need to break away from the colonizing tendencies of a tradition that reinforces the research of Self-Other. She suggests that "researchers probe how we are in relation with the contexts we study and with our informants, understanding that we are all multiple in those relations" (p. 130). My intent was not to research *others,* but to research *some*, myself included. Although I have not been a full-time elementary teacher for four years, when this research commenced I still considered myself first and foremost an elementary teacher. As my intent was to lessen the Self-Other hyphen (Fine, 1998) as much as possible, I was content with having all women approximately the same age range although with differing years of experience.

To adhere to the *University Standards for Protection of Human Research Participants* and thus ensure anonymity for the teachers involved, for their schools and for their students, pseudonyms are used in describing this research. At this time, I would like to introduce the members of the research group, including myself. The members are described in alphabetical order, according to their self-selected pseudonym.

Members of the Discourse Community

Anne. Anne has been involved in the teaching profession for 17 years and is very clear about her role as an elementary school teacher. "I guess my role is to inspire and motivate, and what I tried to teach the kids is to ask questions, that good learners ask questions and scientists are always asking questions" [T17P8]. She sees science as a valuable subject, not only for its propensity to pose questions but because various "scientific" processes can be used in other subjects. "And so it didn't work; what does that tell us? We don't just stop there; we keep going. And to me that provides such a strong foundation for even writing. No, you don't stop after one draft; you keep going and going in your problem solving; you're always asking. I just think it's—the whole process of science can be used in every subject" [T17P8].

Interest in science notwithstanding, Anne considers her strength as a teacher to be language learning. She is heavily involved in literacy programs in her community, particularly family literacy, and has begun working on her Master's degree by taking several language courses at the nearby university.

Catherine. Catherine has been involved in the teaching profession for 25 years. After graduating in 1973 with a Bachelor of Education from the University of Alberta, she began her teaching career in Lac La Biche. Catherine has subsequently spent most of her career within a large urban centre, teaching at various schools. Her vast experience spans all the elementary levels except Grade 6, in various combinations.

Catherine considers her strength as a teacher to be language learning. First, and foremost, she finds it the easiest subject to teach, the one in which she feels the "most comfortable." Second, Catherine noted that she finds evaluation a much easier process in language learning. This ease is reflected in conversations with parents, Catherine stated; it is easy in language learning to say, "this is how he's doing and the theory, and it's not as easy to do that in the other stuff" [T3P7AM].

Erica. Erica has been involved in the teaching profession for 31 years. After graduating in 1968 with a Bachelor of Arts from the University of British Columbia, she elected to go to the University of Toronto for an after-degree teaching certificate due to the perceived benefits of its practicum program. Once graduated, Erica moved back to British Colombia and spent the next few years as an elementary teacher.

Erica has a self-confessed passion for teaching and learning. Her many years of experience have afforded her the opportunity to work with each of the elementary grades in a variety of combinations: as a relief teacher, in open area schools and as an art specialist. Her expertise in art education is becoming known in her current district, and the school board's art consultant has asked her to lead several teacher in-services.

Erica considers her strength as teacher to be in language learning and art. She believes the link between art and other disciplines is important, especially in science. Erica stressed the fact that science and art are closely related because both "observe tiny things in order to see the relationship" (FNP160). This alignment was particularly evident on one occasion, when Erica referred to dissection as "carving!"

Jean. Jean is a relative neophyte in this neighborhood; the start of this study marked the beginning of her fourth year as a teacher. Jean originally graduated from university with a Bachelor of Arts and admits that she did not want to be teacher, mainly because she had a teacher for mother! After Jean's two children were born, however, other people began to comment on Jean's patience, and she realized not only that she *was* patient, but that she really did enjoy working with children.

Upon earning her Bachelor of Education degree, Jean spent a year and a half as a supply teacher for large urban public school board. It was extremely difficult to receive permanent contracts from the school board at that time, but Jean's considerable strengths as a teacher were noted and a principal agitated on her behalf. Jean was granted a permanent contract and has taught full-time since. Her experience includes teaching grades 1, 2 and 3.

When asked to describe the subject she felt most comfortable teaching, Jean quickly responded, "I don't think I've been teaching long enough to be comfortable in anything, to tell you the truth" [T3P6]. Prodded further, Jean admitted that if she had to choose, language learning would be an area of strength, mainly due to her love of books.

Margaret. I have been in the teaching profession for 15 years, but have worked with children most of my life. My desire to return to university after nine years in the elementary classroom was based on my love of learning. I had become interested in science education early in my teaching career as a result of the numerous children in my classrooms for whom science was an inroad into literacy. I've always enjoyed working with difficult children, and realized that often these children preferred reading about the natural world to reading within the various genres of fiction. Through the years, I began to spend more and more time on the science curriculum, designing new units, engaging in professional development and beginning to read in the area. When I was given the opportunity to begin my graduate studies, I selected science education with great relish.

Sarah. Sarah has been in the teaching profession for over 25 years and stated that for as long she can remember she "always wanted to be a teacher" [T18P2]. Upon graduation from high school at age 16, Sarah went to a college in the United States and graduated from the education faculty at age 20. Her wide range of experience spans all levels of elementary school, including kindergarten and resource, and encompasses both the private and public school systems.

Sarah is dedicated to both learning and the teaching profession. "I think learning is so much fun. I could be a perpetual student, I could still be going to school if I could afford it... There's so much out there that you can learn and that you can explore" [T2P25]. This dedication was manifest in her return to university three years ago to complete a master's degree in education. Since then, Sarah has been involved in a number of research projects focused on teacher practice. She's very clear on her role as an elementary school teacher: "I think my job is to help children learn. Not necessarily to learn to pass a test... . I hope that I will inspire them to learn and keep on learning" [T2P25]. Sarah intends to return to university as soon as it is feasible to obtain a Ph.D.

Sarah considers her strength as a teacher to be in language learning. She acknowledges, however, that she very much enjoys teaching mathematics, and this enjoyment translates into success for her students.

Researcher Role

As the instigator of the research project, I was in a somewhat different place than the other participants. I had already surveyed the territory for two years through my graduate classes in science education. From the beginning, therefore, I believed it critical that my role be both defined and monitored. To facilitate this process, I used some of the "rules for group discussion" as outlined by McKernan (1991) to guide my role as chairperson (see Appendix C). I also regularly reviewed the transcripts, not only in light of the data they contained, but to perform consistent and repetitive self-monitoring (see Appendix D).

Clandinin & Connelly (1998) draw attention to the issue of *voice* in the writing of research. Those who speak on behalf of others must know when "to consider the voice that is heard and the voice that is not heard" (p. 172). During the research process, I was extremely conscious of my own voice and the need to keep it in the background. At times, my opinion was not the same as that of the rest of the research group. While other members may have felt able to disagree at any point, I preferred at times to be quiet rather than possibly sway the direction of the discourse. In the analysis and interpretation section of this research, I have indicated consensus by using collective pronouns (us, we) and differences by using "the teachers," a phrase denoting occasions when I excluded myself from the group.

In our earliest meetings, I was often asked for my opinion, and for "answers." It was a difficult walk at times, balancing the need to be part of the group and thus share my thoughts with the desire to neither dominate nor direct the discussion with knowledge I had gleaned through recent university experience. Generally, I tried to redirect questions or posit scenarios that then led to discussion among the group members. On occasion however, the teachers wished a direct response. I have indicated these occasions in the analysis section by including my words, so readers are apprised of my involvement.

At the conclusion of the research, Anne mentioned that she had noticed my deliberate attempts to facilitate conversation and yet maintain "a listening ear," which I interpret to mean that I was successful in my attempts to straddle the border between researcher and researched.

Issues of Legitimation

All researchers are faced with the need to ensure that their final text authentically portrays the research journey. I used many opportunities to make sure that my interpretation of the events occurring during the research was similar to other participants' interpretation. Areas in which authenticity was monitored include the raw data, the initial coding, the analysis summary and identification of major points of the discussion. Following is a description of how I attempted to maintain the authenticity of the research in each of these areas.

Raw data. All transcriptions were checked by a second reader, and selected transcriptions were checked by a third reader. As each conversation was transcribed, it was copied and distributed to the teacher research group to be checked for authenticity, both in what was actually said, and to clarify whether the report did indeed represent the speakers' intent. Participating teachers had opportunity to refine ideas, to fill in whatever was inaudible or to further illuminate anything they felt was too limited in its final printed form. The teachers responded orally and by writing in the margins of the transcripts.

Initial coding. I had hoped that others would be interested in assisting with analysis of the data, but that proved not to be the case. To facilitate coding consistency, on two occasions another person unrelated to the research was given the article by

Rutherford and subsequently read and independently categorized utterances in a transcript. Any discrepancy in categorization was discussed until mutual agreement was reached.

Initial analysis consisted of reading each transcript several times and categorizing (Strauss and Corbin, 1990) utterances based on descriptors that fit the five dimensions articulated by Rutherford. Utterances that did not fit these particular categories were also identified, and the following categories emerged [MEJ2P5] as the utterances were grouped by content similarity:

- School science
- Metaphors for learning/teaching
- Evaluation/Assessment
- Personal feelings toward science
- Multidimensional Science
- Science talk
- Meaning/knowledge
- Differences between talk of scientists and teachers
- Changes

As the project progressed, other data became available. I examined written sources for the presence of themes represented by the categories used to code the transcripts. Once data collection was nearly complete, the categories were compared to the five descriptions outlined by Rutherford (1987). These descriptors were then modified to reflect current research in the field, particularly regarding the need to develop a view of science that is more "authentic" and representative of the real world of science as opposed to that presented through traditional textbook science [MEJ2P9] and the need to develop language practices that reflect this science. (See Appendix E for the modification of Rutherford's five descriptors.)

Once the descriptors were modified, the categories for coding were reworked into six major themes, with accompanying subthemes (See Appendix F). Having established the themes, I re-examined the data for both the presence and absence of those themes. For example, after we completed the project with the scientists, the richness of our conversation regarding science in daily life dramatically increased. Hence, during the final stage of analysis, I examined the earlier transcripts not only for the themes that were present, but for evidence that what was present in later transcripts was not present earlier, or was present only in a limited form. These themes were then used as a framework for the findings summary.

During the initial analysis, utterances were extracted from the transcripts and placed on a chart so that they could be read both collectively and in context. Once the descriptors were modified and the themes identified, the data were analyzed again, with extractions from the various sources grouped into themes and housed in separate files of a word processing program. As the data were sorted into the appropriate files, summary notes were made for each theme. These notes were printed and then a synthesizing summary was made, linking the separate themes into a unified whole. This summary is included in Chapter IV.

Analysis summary and discussion. On completion of the initial coding, the participants examined the charts to ensure that I was appropriately categorizing their utterances. Participants read the analysis summary and relayed their belief that it captured our 15 months as a discourse group, as well as their individual experiences. Before commencing writing, I outlined the main points of the discussion, and they agreed that the framework was consistent their observations. The discussion and implication sections, when completed, were also given to willing participants for confirmation before going to print.

CHAPTER IV

ANALYSIS:
ARE WE COMFORTABLE IN A SCIENCE NEIGHBORHOOD?

Introduction

While the research questions noted in Chapter 1 provided a framework for the literature review and functioned well as an inquiry tool, those questions are not equally suited for organizing the data analysis. Rutherford's metaphor figured prominently in our discussions before, during and after the project with the scientists. Hence, his five dimensions are used to present the findings, along with a brief introduction situating a neighborhood of science within the elementary curriculum. As the analysis will bear out, the metaphor stimulated our desire to explore the scientific neighborhood. This exploration and the concomitant discourse generated new understandings related to the nature and neighborhood of science as well as increased confidence levels, as articulated by the participating teachers.

Science and Other Neighborhoods

Elementary teachers frequent multiple neighborhoods in their efforts to teach prescribed curricula. In Alberta, for example, elementary teachers are responsible for teaching mathematics, language learning, science, social studies, fine arts, health and physical education. Teachers in small schools are often required to teach music as well as the seven other subjects, whereas many larger schools can afford the services of a music specialist. See Table 1 for a breakdown of percentage minutes required in each subject as outlined in the 1994 Program of Studies (Alberta Education, 1994).

Table 1
Time Allocations for Elementary School Subjects

Required Subjects	Percentage of time allocated in Grades 1 and 2	Percentage of time allocated in Grades 3 to 6
Language learning	30%	25%
Mathematics	15%	15%
Science	10%	15%
Social studies	10%	10%
Fine arts	10%	10%
Health and physical education	10%	10%
Time for other Subjects (e.g. French, drama, religious instruction) or additional allocations to the required subjects listed above.	15%	15%

Naturally, teachers experience varying degrees of comfort in these subject areas. It is well documented in the literature that elementary teachers are neither confident nor comfortable teaching science, and this research group was no exception. Statements such as the following were common:

> Science... is the area that I feel as though I need someone to hold my hand, to tell me, "Yes, you are on the right track,"...or "That is right," or "That's not right, do it this way" [T5P9S].

> It's something I force myself to be excited about and interested in [T5P10T].

> How so unfamiliar I am with anything scientific... I shy away from it most of the time [T16P8AM].

Those same teachers repeatedly expressed their comfort and confidence in the area of language learning (formerly Language Arts).. Thus our early discussions centred on how their experience teaching language learning differed from teaching science.

At Home in a Neighborhood of Language Learning

The teachers were unanimous in stating that their comfort level was highest with language learning. They attributed this ease to several factors, including a personal interest in reading, familiarity with the demands of the curriculum and comfort with language learning assessment practices. It also depended, as Catherine indicated, on confidence and their ability to motivate children to learn.

> I think that for me it would be language learning that I would feel the most comfortable with. Probably a big part of that is because there's just so many different skills and ways that you can teach language learning and the materials are just phenomenal too.... I think that's the one that I feel the most comfortable with. It's the easiest one for me to motivate children to do and I think that's 'cause I feel the most comfortable doing it [T3P6AM].

Personal interest. For five of us, motivating children to enjoy literature was not difficult because of our own love of reading. We mentioned being engaged in regular reading as part of our personal lives; some of us, in fact, were members of monthly book clubs. This interest makes it relatively simple to encourage love of reading in the classroom. As Erica commented, "I spend a lot of time with books, and so for me it's effortless; it's just, "Oh, did you hear about this story or this book" [T3P6T]. Even Anne, who was interested in science and voiced her enthusiasm for science teaching on several occasions, felt it was easier to stimulate children in language learning.

> Even though I do love science, I still find... the promotion of books and the love of reading is so easy to just sell a book and to get into wonderful discussions [T3P7L].

Personal enjoyment becomes significant when one considers the degree of institutionalization of subjects. In the core subjects of math, science and social studies, for example, concepts, skills (processes) and knowledge (understanding) are nested within prescribed topics. Those topics that may or may not be of interest, and may or may not be an area of expertise for individual teachers. Teachers have no recourse, however, as the topics have been mandated by policy writers. In contrast, topics in language learning are not prescribed, so the required concepts, skills and attitudes may be developed through topics or themes chosen by the teacher. This becomes crucial when new curriculum is introduced for, without any implementation support, many teachers must develop their personal understanding of new topics to fulfill curricular needs.

Curriculum. Within the past 15 years, elementary teachers in Alberta have faced the mandatory implementation of new curricula in each subject area except social studies. A new science curriculum was mandated in 1996. For the first time topics (rather than just general concepts and themes) became mandatory at each grade level. Where once individual schools were given the power to develop a scope and sequence based on the expertise and skills of their teachers, now each teacher is required to teach four science inquiry units and one unit in problem solving through technology (see Appendix G). Many teachers had never taught these topics before as units and implementation support was left to the discretion of individual school boards. Furthermore, the Program of Studies, in which the content of each topic was spelled out, did not include the scientific concepts upon which many of the objectives were based.

The teachers felt that learning this new curriculum was contributing to their lack of comfort in a neighborhood of science. Despite the fact that she loved teaching science, Anne found the new program of studies "overwhelming," with "too much coming at you." Jean felt the program had too many units at each grade level and wished to be able to cover "less units and just do more in-depth stuff" [T2P19]. She expressed her belief that with fewer mandatory units, process, questioning and reflection time could be honored.

Faced with a new science curriculum and a combined grade, Jean had asked for the assistance of her school district science specialist. She was told that she was legally required to teach 10 science units (five per grade); while the rest of us laughed in disbelief, Catherine confirmed the report by reiterating the same advice, given to her school when the consultant made a school visit! Catherine added that the science specialist had recommended combining units whenever possible but had given no direction as to how this could be done.

Thus began another dimension to the conversation, exploring concepts that could be used to link different units or a way to develop new units that would tie in the components of others. Developing new units containing the understandings, skills and attitudes of the Program of Studies, however, requires sufficient scientific knowledge. In Jean's words, "that's where you really need all that science background and confidence, so you can go and make a new unit yourself" [T2P20Le].

A new curriculum always brings adjustment for teachers, particularly one that contains components with which they are not familiar. The teachers acknowledged that new curricula in social studies, language arts and even mathematics do not bring the same pressures as those in science. As Erica said,

> Social studies, if it's a unit I've never taught before, it would be in many ways easier because I would be reading and just condensing and deciding how I was going to present it... same with language arts.... Math is a matter of working to solve the problem.... Except for some of the problems in *Quest 2000*, not being too bad in math, I think science... is *probably* the main area, so I didn't make myself very clear [T5P8S].

Assessment/Evaluation. All but one felt language learning was the easiest subject to assess. As Catherine commented,

> I know we don't normally talk about scope and sequence anymore but [for language learning] I have it in my head. I have it pretty well... down pat you know, but I don't for the science [T3P7AM].

The importance of having assessment criteria firmly planted in one's head goes far beyond designing units and writing report cards. Teachers must be prepared to articulate (and in some cases justify) their assessment at any given moment.

The difficulty of assessing children's understanding in science was reiterated on a number of occasions. For most subjects, particularly language learning, pen and pencil tasks form a substantial portion of the assessment practices. Sara suggested the problem with science assessment may lie in the relationship between what is tested and how it is tested.

> In science, paper and pencil evaluation may not hit on everything you need to hit, and how do you prove that a child has learned something if you don't have a paper and pencil evaluation [T3P7T]?

The teachers expressed uneasiness with an assessment of science learning that depends solely on written tests. Catherine voiced her belief that children could do poorly on written science tests despite the fact that they may very well understand the material being tested.

> And somehow it was easier to justify if the child didn't do very well on a written science exam, that if you felt that he could explain to you... that he

> understood what you had been talking about in class [murmurs of agreement], that would be... all right; whereas in language learning it wasn't good enough to do that.... You had to actually show that on this test that he was successful. But I even found myself thinking in social studies or science, well, they didn't necessarily do that well on a written exam, but if I ask them the question, and they could, they would be able to tell me the answer in their own words, I considered that to be all right. [murmurs of agreement] But I could never do that in math ...or in language arts [3P35AM].

The teachers believed that assessment of progress in science needs to include elements beyond written tests, such as participation in activities and science discussions. They acknowledged, however, that it is difficult to assess children's scientific knowledge without being comfortable themselves in a neighborhood of science. Erica mused that her ability to assess children's artwork rested on years of being in a neighborhood of art. She suggested that the lack of confidence felt by members of the group in assessing children's scientific ability might be a lack of experience in a science neighborhood. It is this familiarity that Rutherford depicts in his metaphor of science as a neighborhood. The five dimensions of this familiarity are:

1. Knowledge of the Boundaries,
2. Acquaintance,
3. Savvy,
4. Frequent Encounters, and
5. Membership.

Knowledge of Boundaries

Introduction

Those of us who have lived in the same neighborhood for a number of years have become familiar with its every dimension. We recognize each of its buildings, we notice if any changes are made in landscaping and we are aware if anyone in the community is ill or on holiday. This knowledge does not depend on the ability to read street signs or even to describe the neighborhood. Instead, it relies solely on sensory information; that is, the sights, smells, sounds, and patterns that are familiar (Rutherford, 1987, 1991).

Recent attention in the literature across disciplines has pointed to the need to make explicit the multidimensional aspects of science and scientific inquiry. At the same time, language theorists have demonstrated the necessity of becoming familiar with discourse(s) specific to each discipline. This research expands Rutherford's description of knowledge of the boundaries to include awareness of the role of language and recognition that science is multifaceted.

During our first two meetings, there was little attempt to flesh out the difference between science and other disciplines, nor to describe scientific practice or illustrate problems and questions that might be considered scientific. Other than my noting the difference between science and technology, until the third meeting the only two comments related to the boundaries of science were the following:

> Is physics science or is physics math [T2P23AM]?
>
> I took social sciences but I didn't take science sciences [T3P5Le].

Science and Technology

The idea that there might be a difference between science and technology was first initiated by me, in an offhanded comment. We had been discussing the difference between teaching a science concept in which several units reinforce the concept, versus teaching a science topic that might contain many different concepts, as is the case in the Alberta science Program of Studies. The teachers felt that each grade of the new science

Program of Studies seems to be independent of others, with little bridging material across the grades. Sara mentioned that the "building" units seem to do a better job of linking concepts from year to year, and the group immediately agreed that the concepts learned at a Grade 1 level are reinforced each successive year. My comment "and that's technology and whether that's the same thing as science is a whole other issue" [T1P25M] sparked single utterance agreement from two of the participants, but no further dialogue occurred regarding this point.

Several minutes later, in a discussion on how we might increase both our understanding of membership and knowledge of the boundaries, Anne asked if I could bring in another article, this time dealing with the nature of science. After some probing, I suggested *Passion within Reason* by Burnett Cross (1990), a collage of anecdotes about scientists and technologists whose work was furthered by intuition and accidental discovery. This article is one of a collection being used in the science methods course offered at the University of Alberta as part of the preservice teacher program. Cross suggests that as elementary teachers, we must be careful to present a realistic view of the way scientists work, one that includes error, chance discovery and the drama that accompanies all human life—scientists notwithstanding.

Although I did not differentiate between scientists and technologists at this point, and nothing had been said regarding this distinction since my earlier comment, Sara asked if we meant inventors as well as scientists when talking about a neighborhood of science. Jean responded by suggesting that technology, with its emphasis on hands-on building activities, is a way to get children interested in science.

> In terms of teaching elementary science, I think that's one of the hooks that grabs a lot of the kids who love that hands-on... They get to create, build the models. They love inventing and if that's the hook to get them

> into science, then I say to me that's worth it, it has value. And I know technically maybe it's not strictly science [T1P33Le].

The following week, after reading the Burnett Cross article, Jean reiterated her viewpoint with an added dimension, noting that design technology units provide an opportunity to experience one of the facets of science, that is, accidental discovery.

> Even though the technology units might not be considered real science, I think they have more of a chance to have those chance ...discoveries when they're ...building something and they have to alter it or they just happened to build it a certain way and they discover something that's unexpected.... I just think that there's almost more of an opportunity in those units for them to have those chance discoveries, and they love the hands-on part of it [T2P2Le].

The difference between science and technology was not articulated until the second meeting, and Sara instigated this discussion. She confided that on the drive home after the first meeting, she had wondered about my earlier comments regarding the difference and confessed that she did not know what the difference was. The other teachers nodded their agreement and asked me for some clarification regarding this distinction. Rather than giving a definitive answer, I presented possibilities for articulating the relationship:

> I can give you some things that people argue. Technology is actually the satisfaction of human needs. It's the creation of something to satisfy need, any kind of need; it could be wants as well as needs. So people argue that there's a difference between the kinds of problems that you set up, because in science it's always to try and figure out why things are working. There's something that goes against an observation and so scientists try to figure out why. Whereas in technology, a need is identified and then a group of people work on satisfying that need. And they may very well borrow from science to do that. They may need to know about pressure and heat and temperature, but they're not necessarily finding out why. They're finding out how [T2P8M].

The explanation stimulated a series of questions that indicated an example might be in order, so I continued:

> Like folding up a paper airplane; you can make a paper airplane without knowing the science. But if you're talking about how does air work to help your plane work better, that's a science question. But there are other arguments. I mean, that's just one argument that splits the two up. There are some people that argue that science comes first, you have to know science before you know technology and then there are other people who say... technology actually came first because people were fishing with fishing lines and using stone tools long before science came into being. Then there are some people who say they're two independent thought systems, of thoughts and practice and other people say well no they're interdependent. They might have differences but they also have some similarities. So it's really a question for us in terms of the elementary curriculum, because Alberta lumps technology with science; it doesn't tell you if there are any differences. But then you have to wonder "are there?" Like what are the differences in the processes you teach, or in the knowledge that you're trying to teach them or the questions that would be technological questions, or does it matter if there are differences. So it's quite an issue [T2P9M].

Sara listened intently to this explanation, and responded immediately: "Also the questions that you would ask, if you're hoping to interest kids in a scientific principle and if you're always asking 'how' questions.... you would be aiming them in one direction without even realizing it" [T2P9T].

During the second session, the teachers asked for an article that might delineate the differences between science and technology. I suggested *Technology and science: meanings and educational implications* by Gardner, Penna and Brass (1990), also from the collection of preservice teacher readings. This article became one of the focal points for our conversation in the third session. That discussion began with Erica asking for some clarification, admitting that she was still having difficulty separating the two.

> I don't understand... I mean, scientific principles like in the case of the making of a car. The scientific principle would be what? The technology is actually building the car, right? The parts of it [T3P21S]?

Throughout the ensuing discussion, various perspectives on the relationship between science and technology emerged. Although the teachers agreed that technology could precede science, as in the case of designing a paper airplane without knowing principles of flight, the predominant position was that scientific principles exist in nature, awaiting discovery via scientific pursuit, and then are used in technology. This belief is evident in the following segments of our conversation.

> It almost makes you think of all the science, the things that were learned like all the scientific things like Galileo or Isaac Newton... All those scientific concepts have all been found out and so now it's just the technology that's happening because people need things to be better and faster... The scientific principle behind a lot of the technological like cars and computers and photocopiers that those scientific principles were invented or thought of a long time ago... Now we're just improving on the technology that comes along as a result of those scientific principles [T3P21AM].

> I felt that he made a very good point, that they are related and yet that somehow they are very different. Because science to me... are these overall principles that man will never create, that man can only discover. Technology has to do with man's creativity. Does that make sense [T3P22T]?

The intent of the discussion regarding the difference between science and technology was not to come to consensus. Rather, the intent was to articulate the boundaries of science with respect to elementary science teaching. To that end, as chair, I steered conversation back to the neighborhood metaphor by asking if children need to know the difference between science and technology, and whether this difference or lack of difference would make an impact on how the units were taught.

Sara immediately saw that the types of questions asked of children would differ depending on the point of view one had regarding the difference between science and technology.

> Yes, and the questions you ask the children and, I think, the process you put them through, because if, you're just interested in science, you probably won't have any kind of product, because you're just interested in a process, in inquiry. You may not even have answers; you'd have lots of questions, wouldn't you [T3P26T]?

The distinction between science and technology appeared to linger in Sara's mind, for she reintroduced it once we began working with the scientists. During our second session, we had some time to discuss the life of Galileo as portrayed in *Sidereus Nuncius*. After some conversation regarding the impact of his work, Sara asked the scientists if they consider Galileo to be a scientist or a technician. They all felt he was a scientist, primarily because of his creativity and ability to see regularity and predictability in new areas. It was the ones who followed Galileo and copied his methods whom they considered technologists. In the words of Dr. Piper,

> Galileo recognized that if you could abstract the world, if you could put the world into special, a special set of circumstances where you could remove all the extraneous effects—air resistance, for instance—then the world's quite repeatable, quite predictable. And it was that predictability that… told him that mathematics is of some use in describing the way the world works [T4AP31X2].

Language as an Indicator of Knowing Territory

Part of developing familiarity is becoming comfortable with the language practices that constitute a discipline. In our first meeting, the teachers were questioning why they were able to facilitate their students' comfort in the neighborhoods of art and music and yet not necessarily in science. Anne mentioned that there is an emotional quality to the comfort level, that it is not necessarily related to being physically comfortable. I interpret this to mean that if students develop skills and knowledge in a discipline, it doesn't automatically mean they are comfortable in the area. Erica was the first to bring up the connection between language and familiarity, using her area of expertise as an example.

> Like when they start using the language of art... and ...they use it like second nature, it's like a young child. You go out into your little neighborhood and you don't know the street names and you don't know the directions and gradually you start to learn and then you can talk about your directions, you can talk about where you're going [T1P36S].

Anne also commented on how the use of language is an indicator of increasing familiarity as new terrain is explored.

> Like you said with your gardening, you start off and you don't have a clue about what one plant is from another and then all of a sudden before you know it, you're talking like an expert [T1P37L].

The question arises, however: Which language genres are necessarily part of a scientific neighborhood? After our first encounter with the scientists, I was struck by the various forms of language the scientists used as they communicated their understanding of contributions made by Giordano Bruno to us and to each other. The transcripts in which the scientists were present reveal several language genres at play, including *debate, description, narrative* and *explanation.* The role of *analogy* as part of explanation was also pronounced.

Debate. After meeting with the teachers to discuss our initial work with the scientists, I remarked that I had noticed the scientists' use of debate, discussion and explanation and wondered aloud if we as elementary teachers ever engaged in debate. The teachers felt debate is not a form of discourse teachers employ, perhaps because of internalized rules of etiquette.

> J: As elementary teachers we're so polite, you know. [murmurs of agreement] We don't sort of critique someone else's way of doing things or debate about—

C: And we accept our workload and pile it on and—

S: And confront; we don't confront [T4P2].

Sara noted that instruction in elementary school often focuses on finding the right answer (that is, the answer wanted by the teacher), and that we don't often open children up to the possibility that there might be more than one way of looking at a problem. I wondered if it was gender related and voiced my observation that, even in the face of disagreement, we had yet to debate an issue in our own research group.

Erica suggested, however, that the ability to debate rests on a higher level of intellectual ability, that is, the ability to see both sides of an issue. "In order to disagree with someone, don't you have to have knowledge of, of both sides in a way and have dismissed one in preference to the other" [T4P4S]? Erica added that the sheer volume of information we are required to teach as part of our curriculum means that we have little time to facilitate the learning of extra material. She recounted the following incident:

> With wetland ecosystems, when we stayed overnight and had the two-day session, the debate was one of the possible activities, if there was time, but as the instructor said to me, "The debate cannot happen until after all this has been covered simply because they, they won't have the groundwork to play a role or, you know, take a side" [T4P4S].

Sara agreed a volume of work is necessary in preparing children to participate effectively in debate. Her experience with debating social studies issues had demonstrated both the children's interest and the amount of preparation necessary. She added, "We don't teach people how to listen to other people's opinions with an open mind, where really, if somebody disagrees with us, sometimes we take it personally" [T4P5T]. This comment brought fervent agreement from all present, both then and later in the conversation, when we discussed how apt to we are to become defensive when confronted on a position.

The group also agreed that we as teachers are not adequately prepared to weigh the merits of many scientific arguments. We recalled how we were swayed from position to position during our first meeting with the scientists, when they re-enacted the trial of Giordano. Catherine commented that the experience reminded her of listening to speeches during contract negotiations and how she is convinced by the personality of the speaker.

When probed, Erica suggested that children as young as grade four would be capable of preparing and executing a debate.

> And although not in great depth, I can see and could see in the Grade 4s last year, that beginning awareness and ...gathered some information on waste in our world, and ...if we'd had time to gather more, I think that they would have been able to do a kind of debate even more successfully, 'cause some would believe ...strongly, you know, maybe for one side and some strongly for an opposing side, or different ways of doing, arriving at the same solution to a problem. Grade 5s I think with...*Wetlands* is an issue that I'd like to try that with, but I think they have to explore the unit first, become familiar [T5P2S].

Explanation and the role of analogy. One aspect of explanation that stood out in the transcripts was the scientists' regular use of analogy as a tool. Generally, the scientists brought analogies into the conversation as a way of clarifying unfamiliar concepts. Among the analogies they used in explanations: comparing the shadow of a lit candle in a lighted room to a sunspot, comparing the light entering a telescope to light entering an eye and comparing our experience of seeing the Milky Way while being inside it to our ability to see the forest before us while walking in the forest.

In preparing to meet with the scientists the second time, most of us had read at least part of *Sidereus Nuncius*. One of the things I had noticed in my reading was the interesting way in which Galileo compares what he was seeing for the very first time via a telescope to the experiences he had in his day-to-day life. I pointed this out to the group of scientists and teachers in the following way.

> I noticed in his book too, he has a way of talking—when he's trying to explain, I think it is the fact that the shadows on the moon were probably a result of the moon not being a smooth surface—but the way he does that, he parallels it to what's going on Earth. Like when the light hits the mountain tops, you first see it in one spot, and then you gradually see the—and when I was reading it I was thinking that it sounded very *un*scientific to me—as if science ... was easy to read, and it was enjoyable to read, and it made sense to me. So he doesn't just sort of isolate factors; he also says you can see it happening in your day-to-day life [T4AP32M].

Dr Piper murmured his agreement and went on to say that Galileo used analogies whenever appropriate. Dr. Smith added that people still do what Galileo does, and that "scientists still use models as much from everyday life as possible" [T4AP32X1]. In a later interview, he fleshed this out a little further:

> Science is done by sort of analogies that may work. So it's that kind of thinking that's more important than the answers to the questions [T11P12X1].

He added that analogies are mental constructs that correspond, although not in direct one-to-one correspondence, with how things behave in nature. They are important because they describe the way things *might* behave.

The role of analogy as a teaching tool went essentially unexplored in our research group, despite my attempt to bring it into the discussion when the teachers next met by themselves. At one point during our conversation, Sara suggested that perhaps enjoyment in science depends on being a particular type of learner. She added that the units in which she gets to manipulate something, such as electricity, are the units she enjoys because she is a kinesthetic learner. Other units such as sky science that are, in her words, "really technical," are ones in which she gets "really lost."

At this point, I asked Sara if it would be possible for her to turn a unit that she considered very technical into one in which there were physical models to represent theoretical concepts. I suggested that perhaps she would find building a model of the planets in which the dimensions are physically represented much more beneficial. To illustrate benefits, I recounted how my daughter in Grade 10 biology was learning about cells as little factories. This factory analogy had paved the way for my daughter's understanding of the functions of various parts of the cell and instilled in her some fascination for its inner workings. The teachers enthusiastically murmured their agreement, and the following conversation ensued:

> S: Well, the one thing that they did have in, um, one of the resource guides was, each of the planets related to a different fruit, or seed in some cases.
>
> C: Oh, yeah.
>
> S: And I liked that, because suddenly it, it put it—
>
> C: The sizes and all of this
>
> S: —the sizes, yeah, in perspective for me. [murmurs of agreement] And that would be good to actually have and show the kids. But you're right: When you're dealing with hundreds of millions of miles, somehow I get lost in that. I can't even begin to understand [murmurs of agreement] infinity, which is basically what you're dealing with in space [T5P12T].

While Sara acknowledged that the activity noted in the teacher resource book would probably benefit her students, she had not used it at this point. This was the only time we discussed the use of analogy.

In two instances, the teachers generated analogies of their own. Both occurred after the moon project, when we met with the scientists to share our findings.

- Anne compared the process of locating Jupiter to that of an "explorer on a ship" and described the motion of the moon through the sky as a "boomerang."

- Sara described the intensity of Arcturus as being like a "welding torch."

Explanation and the role of narrative. The scientists regularly used narrative as a way of explaining concepts. At times, the narrative took the form of a personal experience that related to an issue being discussed. For example, when asked why he remained in astronomy, Dr. Piper offered the following anecdote:

> I'll tell you a story. A number of years ago... we had an observing around in August. I remember we had the dome was open, it was late at night, and ...somebody had the music cranked up; it was Holst's *The Planets.* And I remember walking at night into this huge dome, hearing *The Planets* sort of echoing through this majestic dome and this real old telescope. For me that was the really—that was a moment sort of that said, "Yeah, this is why I really enjoy doing this" [T4AP9X2].

On other occasions, narrative was used to describe scientific process, as in the following description of a unique scientific discovery.

> Yes, I can certainly think of some very exciting—one moment in particular at the telescope in the old days when we used photographic emulsions on glass plates. You had to bend these glass plates on the telescope to fit the focal plane and expose it, and then you went into a little room in the dead of winter and have your hands in these cold... chemicals to expose the emulsion and so on. And I had one particular star—this was a binary star—and it turns out that sometimes you can't tell whether a stellar system has a very short period or a very long period because of the distribution of the observations. And I knew this particular night the phasing was such that I would have the observations that would distinguish between these two possibilities. And I remember exposing these films and developing them and holding the first one up, and I could see the position of certain spectral features, so that was my reference. And the second plate half an hour later I saw—I held it up to the light, and this

> was the one, and I could see without making any measurement that this thing had shifted by a large amount. And I knew at that moment that this was a very short period, an unusually short-period system [T4AP10DH].

The scientists also used narrative to illuminate historical dimensions of science and to portray little known aspects of science neighborhoods, as in the following anecdote:

> LaVoisier and Madame LaVoisier also played a critical role in the discovery of oxygen and so on. He wanted her name on the paper, but she said, "Nobody will listen to you if you put my name on it too" [T9P1X1].

Questioning. The act of questioning is of course vital, both in teaching and in a neighborhood of science. While beginning to analyze the data, I was intrigued by comments made by two of the teachers regarding their understanding of the various concepts presented by the scientists. They felt that the work with the scientists, while enjoyable, was at times reminiscent of situations when they needed to proceed without understanding. One said:

> I found the building [of the telescope]to be another, "okay you do this,...you do this, and then you have this in the end. But...I really didn't know how it works or why it works, but that's kind of how I feel about all that [T4P6AM].

Another echoed these sentiments by admitting that she had not understood the explanation regarding how telescopes essentially "collect light," but simply listened to the explanation and acted as though she did.

To shed light on the way understanding might be mediated in a pairing of scientists and teachers, I isolated the questions in the dialogue that occurred between the teachers and the scientists during the session immediately following the telescope building.

The questions are grouped on the basis of types listed in Table 2. The total questions asked were 120, and they fall into five categories: procedural, clarification, explanation or definition, information gathering or interpretive. *Procedural* questions refer to those questions regarding the format of the evening. *Clarification* questions are those attempting to clarify information gleaned from the utterance immediately preceding the question. For example, when Dr. Piper was explaining how to cast the image of the sun onto a piece of paper, I attempted to interpret his explanation by asking, "You're never going to see the sun and the sky around it?" *Explanations* and *definitions* are self explanatory, while *information gathering* questions are those seeking an answer in the form of information rather than an explanation. The question, "He wrote that to Kepler?" was thus classified as an information gathering question. The final category, *interpretive*, refers to the questions that call for an interpretation or reflection. Hence the question, "What keeps you in science?" was classified in this category.

Table 2
Number and Distribution of Questions Asked

Question type	Scientist to teacher	Scientist to scientist	Teacher to scientist	Teacher to teacher
Procedural	4	1	2	2
Clarification	4	8	19	0
Explanation or Definition	2	6	22	0
Information gathering	14	21	12	0
Interpretative	0	2	1	0

Note. Total questions =120

What is compelling about these percentages is both frequency of the questions asked and the direction of the questions. It is unsurprising that the teachers directed most of their questions to the scientists, and that most of their questions called for explanations and clarification of information given. After all, the evening was set up to provide background information for a self-confessed area of weakness. What is surprising, however, is that the scientists asked 52 percent of the questions, while the teachers asked 48 percent. It could be argued that the teachers in this case were in the role of students, while the scientists took on the role of teachers and thus used questioning as a form of pedagogy. The direction of the questions asked, however, shows that 61 percent of their questions were not directed toward the teachers, as would be the case if questions were being used as a pedagogical tool, but to each other. Of this percentage, the most frequent (34%) were classified as information gathering, while the next highest (13%) were clarification questions. Hence, it appears as though the scientists used this session to increase their own understanding in addition to acting as a resource for teachers.

Description. It can be argued that one of the roles of science is to describe the world as well as to explain its functions. It was the words of Galileo that awakened in us the recognition that descriptions in science did not need to be the dry recitations found in our dimly remembered secondary textbooks. Sara first brought this up by commenting that *Sidereus Nuncius* contains very interesting writing, "not what we're used to reading" [T5P18]. She read the following example, adding that it was very descriptive, and that one would certainly not expect to see similes in a scientific journal.

> This lunar surface, which is decorated with spots like the dark blue eyes in the tail of a peacock, is rendered similar to those small glass vessels which, plunged into cold water while still warm, crack and acquire a wavy

> surface, after which they are commonly called ice glasses (Galilei, 1989, p. 43).

The fact that we were surprised at Galileo's writing, coupled with our indecision and lack of awareness regarding the boundaries of science, can be interpreted as resulting from a limited acquaintance with a science neighborhood. Unless we have opportunity to explore the natural world and become acquainted with the people and processes of science, such a neighborhood will continue to be removed from our personal experience.

Acquaintance

Introduction

Familiarity with one's neighborhood is developed as one builds a network of information about its people and artifacts as well as the rules under which they are governed. This information is the raw material out of which more sophisticated understanding later grows. To become comfortable, one must have a rich collection of acquaintances and begin to understand various relationships that exist within the neighborhood.

Although Rutherford does not specify getting to know other members of a science neighborhood as an aspect of acquaintanceship, it is a necessary part. New members need the opportunity to see that scientists are driven by various goals, and that scientific inquiry is conducted via multiple methods. Historical stories that detail the acceptance of new ways of looking at phenomena also help shape understanding of the epistemological dimensions of the scientific neighborhood.

To develop acquaintanceship in students, teachers must be prepared to introduce children to scientists, natural phenomena and the places where scientific inquiry is conducted. Hence teachers' background science, inculcated during school or otherwise, becomes significant.

Once finished formal science education, elementary school teachers in Alberta have the opportunity to become acquainted with scientific phenomena in both their personal and professional lives. In their personal lives, exposure comes via the media or through extracurricular science activities such as bird watching clubs, hiking and astronomy. In their professional lives, exposure comes through in-service education, graduate courses, professional development, science conferences and the five units they are required to teach each year. This exposure is multiplied for teachers who regularly switch grade assignments. Most have little opportunity, however, to become acquainted with practicing scientists.

Meeting the Members

The teachers in this study were surprised by the scientists' interest in the way science is portrayed at the elementary level. They mentioned on a number of occasions their disbelief that scientists were actually interested in the thoughts of elementary teachers and so curious about methods of teaching at the elementary level. Stereotypical ideas about scientists were revealed on numerous occasions, including the belief that scientists are geniuses and unable to communicate with "mere mortals" by speaking in "plain language." The teachers were surprised that the scientists talked about beliefs, not just theories and facts. One teacher commented on her amazement that, rather than being "introverted" as she had expected, the scientists were outgoing and uninhibited.

Perhaps the biggest surprise was the way the scientists made the teachers feel that they too could be part of a science neighborhood:

> They tried to bring whatever you said for your ideas… to make you feel like "Yeah!.. You *are* part of this and… what you have to say *is* worthwhile [T16P5AM].

The scientists encouraged the belief that elementary teachers could be part of a neighborhood of science through several practices that became evident in the transcripts. In one instance, they attributed our lack of understanding from one week to the next to "poor teaching" on their part rather than a personal trait on the part of the teachers. They reinforced the act of questioning by saying our questions were both good and interesting. They encouraged us in our difficulties with the reminder that even astronomy students have difficulty with the same procedures. They reinforced our answers and other demonstrations of understanding by acknowledging their worth. Finally, the scientists often took what we articulated and extended it into new areas rather than simply shutting down learning by pointing out our misconceptions.

Previous Experience with School Science

Midway through the second meeting, as we were discussing our own comfort levels in a neighborhood of science, Sara wondered how many of us had had a good experience with science in school as we were growing up. She relayed a brief anecdote in which a speaker at the local teachers' convention expressed his belief that teachers will create either "passion or phobias" in students. Sara felt that her experiences during school science exemplified these words as she had the "worse teacher ever" for chemistry, hated it and consequently dropped it as soon as possible. Sara's experiences in biology were much more positive. She attributed her success in high school biology to interest in the subject matter, but added in a later conversation that this interest was nurtured by one teacher in particular who regularly engaged the class in hands-on activities.

Sara was not alone. Catherine confessed that, for her, science in school involved simply memorizing information that had "very little value in terms of ever using it in my life" [T2P14AM]. For example, she recalls needing to memorize "parts of the cell," "definitions" and "tables." Catherine remarked that she saw no value in memorizing, and that there was little relation between her biology classes and her daily life. Catherine says that she still "can't see the value in learning 30 parts of the cell."

One thing Jean and Erica remembered from their high school experience was the propensity of science teachers to present material as though it were *Truth,* particularly in chemistry and physics. Studying was often a matter of "digesting information" rather than "being able to understand." Biology was fascinating for Jean, Anne and me as we recalled being engaged in actual scientific work such as collecting samples and sorting fruit flies. Jean, Anne, Erica and I took biology as part of our post-secondary education, with Erica adding a course in zoology as well.

Anne, in contrast to the rest of us, has both vivid and positive cross-disciplinary memories of high school science. Various names of teachers sprang easily to her lips, and she recollected, with enthusiasm, several events that occurred during both chemistry and biology. These experiences included work with fruit flies, flaming cotton balls and a chemistry teacher who "had all these little balls that represented atoms and he threw them all over the place" [T17P3L]. Anne was emphatic about her love for biology because of its many strands, the lab work and the quantity of "hands on experiments."

Looking back to early science schooling, Sara, Catherine and I remembered absolutely nothing of elementary or junior high. Erica, on the other hand, spoke with enthusiasm about her "favorite teacher of all time," the science teacher in Grade 7. "He got the best out of me; I went from being a little above average to just excelling. I liked his style, he had a very subtle sense of humor and we did some kind of hands-on things, which were really unheard of in that time" [T15P3]. *Plants* and *Meal Worms* are two units that stand out in Erica's memory of this particular time. Anne, too, was enthusiastic about her early school science experiences. She vividly recounted celery experiments in Grade 2, science fairs and work with sugar crystals.

Catherine suggested that our comfort level when teaching science is related to the way we experienced science in school.

> Because we feel so much more comfortable teaching a language-learning lesson and less comfortable teaching a science lesson, maybe because when we were taught science, it was not something that we ever felt comfortable with, and so it's hard to be comfortable teaching it to children now [T3P34AM].

Science Experiences Beyond Schooling

Of all the teachers in the project, including me, Anne appears to have had the richest experiences in her early science schooling. In the following journal entry, she commented on a possible reason for the depth of her experience and the importance of science experiences outside school.

October 18, 1998

When I reflect over my science experiences growing up (elementary and junior high), I reflect more on my family then my school experience. We were immersed in science both indoors and outdoors! Summers on the farm, watching the weather. Family holidays, visits to the zoo, planetarium, air shows (and more air shows). Gardening, canning, freezing. Hunting trips and guns! Spending hours watching the dog dig gopher holes. Watching my dad invent the indoor buzzer that would "unlock" to allow the dog to come in from her dog run!! Watching him fix old tube type radios. Shovelling snow, making snow forts, eating icicles. I remember telling someone (after they saw his tiny work room) that my dad made ROBOTS and they believed me!

Science has always been a part of my life, and I know that's why I'm always in awe of so many things in life! Science experiments and projects were always fun in school but maybe it was because I knew I had my very own safety net of Mom and Dad!?

I also saw the "family work bees" to fix machinery, fences, etc. at the farm. That, combined with our own projects at home I always saw the trials and tribulations! *Don't Give Up!!!* [LJP2]

It is acquaintances with scientific phenomena and various members of the scientific community that provide the background out of which one interprets new information and experience. Sara suggests that, without background experience, children will not appreciate the "facts" that they learn. This appreciation includes being able to begin making connections and identifying relationships within the neighborhood. In other words, sufficient acquaintance allows for development of the third dimension of Rutherford's metaphor, namely, savvy.

Savvy

Introduction

The knowledge gleaned as people develop a wide acquaintanceship with their neighborhood translates into an understanding of how the neighborhood operates. This burgeoning expertise includes the ability to navigate both socially and physically through the territory. People at home in their own neighborhood know the fastest routes, the most enjoyable paths and the inevitable dangerous dogs. They also cultivate a network of trustworthy people who will offer support and help when needed.

An added facet to the dimension of savvy, relevant especially to the teaching of science, concerns the understanding that scientific activity is embedded in culture. Rather than existing as an unbiased discipline, science is fettered by beliefs and understandings that cloak all disciplines. The realization that science is culturally bound allows one to begin making meaningful connections between science and other areas of life.

Confidence and Competence Issues

At the beginning of the project, each teacher freely admitted a lack of confidence and capability in a neighborhood of science. They shared experiences of preparing for science teaching in which they did not fully understand the concepts underlying activities (e.g. Magnetism and Electricity, Flight, Hearing and Sound). The teachers confessed that lack of understanding had a significant impact on how they taught science. It meant they were less likely to take advantage of "those teaching moments… where you think, 'Oh hey, this would be neat'" [T16P3AM], for those times just did not surface in science as they did in others areas of the curriculum. It meant they depended much more heavily on teacher directed and controlled activities. Erica, for example, felt that her lack of knowledge in certain areas dictated her choice of activities for those units because she was afraid to risk exploration and investigation: "I thought I should know ahead of them so that I could guide them in their discoveries" [T1P3S]. It also meant that at times students were encouraged to simply memorize information because it could not be appropriately explained.

The teachers' self-described insufficient understanding was a constant source of tension, and at times instigated fear and insecurity. Erica worried, for example, that by not knowing enough she might inadvertently guide her students in the wrong direction or "say something that will lead them to discover something that they shouldn't" [T1P4S]. It also meant that she avoided "risky" activities in case they did not work out. "When the understanding is teetering... you can't have anything wrong with it" [T5P10].

At one point at the beginning of the study, Catherine shared with us the difficulties experienced as her staff began to organize a science activity day, instigated by the parents in her school. Her journal entry points out how confidence impacts science teaching.

> *March 21, 1997*
> This day is looking as if it will take much more organization and planning than initially anticipated. Teachers still seem reluctant to accept the idea. Why is this? I am sure if it was the Track and Field day or some other physical activity day, there would not be as much opposition. Do most of us feel less comfortable setting up science activities, not just because they might take time, but because we can't seem to justify children having fun, and really learning something at the same time? Could be that we are being made to feel accountable for everything we do in our classrooms and therefore if we are not very comfortable with the concepts and the kind of learning that will take place, then it is easier not to do it [JP5AM]?

The interplay between confidence and competence was evident in the way the teachers described planning a science unit. All relied heavily on published teaching units sold to the schools by their school board. Other ideas were gleaned from materials recommended as support resources by the government. None of the teachers, other than me, had ever designed science activities or units in lieu of pre-published materials.

Catherine confessed that she wished she trusted herself more when planning science lessons.

> There are times where I know what I have to teach, and if I, first of all, go to my curriculum information and look up resources that go with it, then I find that so often I'm so bogged down looking through different things that if I just told myself, "Okay, um, in science we're doing magnets. What would the kids really like to do with magnets?" But the ideas I come up with then, just thinking about what I would like to do with them, are often so much better— [T6P17AM].

In a later conversation, Sara supported Catherine by pointing out that the knowledge we have as teachers is often devalued, so we are encouraged to rely on resources to be "good teachers." She wondered if teachers were even involved when either the curriculum or supporting resources were written.

By the end of the project, each teacher felt she had increased both her appetite for science and her confidence with respect to being in a science neighborhood. All spoke of how they genuinely enjoyed the experience—although with varying degrees of passion, as illustrated by Sara's comment.

> Science for me will never be a passion probably, because when we were doing the astronomy I thought, I'd love to be completely, a hundred percent excited; but it probably will never be a passion. But I still have learned to really appreciate it [T13P20T].

We felt that our knowledge regarding the moon and other aspects of the sky had certainly increased and that it would benefit our own teaching of science. This was perhaps most telling in the case of Catherine, who at the beginning of the project confessed that she didn't feel she knew enough science to teach the curriculum at the Grade 6 level. In an interview midway through the project with the scientists, I asked Catherine how she would react, should she suddenly find out that she had to teach Grade 6 after all. Without hesitating, Catherine stated that she would feel "much *much* more able." During the project, Catherine also began to notice *scientific reactions* in her class and wrote the following journal entry.

> *March 7, 1997*
> I am wondering if I'm noticing more "scientific reactions" in my class, due to our meetings. In our "Rocks and Minerals" unit, I was more aware of perceptions that the children were making about their work. For example, Laura (Grade 3 student) excitedly came up to me with a rock in each hand. "Which rock do you think is heavier?" One was definitely bigger, and a more obvious choice. However, the smaller one is heavier. She was being a scientist.

The teachers also expressed greater self-confidence regarding their own participation in science community. Interestingly enough, this self-confidence became evident for Sara after the third meeting, just *before* meeting with the scientists for the first time. In a journal entry, she wrote the following.

> *April 28, 1998*
> I didn't attend the last meeting because I had just returned from my cruise the day before and was I tired! But on the cruise, activities I chose, people I happened to meet, topics I discussed, made me wonder if I'm feeling more at home in a neighborhood of science or at least becoming curious about it.
>
> One of the activities I chose to do was go in a submarine. We went down to a depth of 90 feet. It was absolutely incredible. We were definitely aliens visiting a world I had never really imagined. There was topography… to the ocean floor—hills, valleys, unique life forms (different kind of corals) and many fish. Some were benign, others very vicious. We saw sharks, barracudas, and many others…. No books I read, no films I had ever seen, could actually prepare me for this experience.
>
> On my way home to Edmonton, I ended up sitting beside a scientist - one of the group of 20 who were on their way to the Arctic to study effects of pollution. He was also a pilot. I knew I had to teach the Air and Flight units and so I questioned him at length. As we took off and landed, he explained what was happening to the wings, engines, etc. of the airplane. He explained the principles of flight "oh it's really very simple," he says kindly. And it is too- at least on the surface. I'm glad I shared my ignorance. He obviously made it a safe place for me to do that [JP2T].

Sara was not the only one to feel that this experience has given her confidence, at least the confidence to ask questions and to search for opportunities to satisfy understanding. Anne expressed her belief that the experience had increased confidence enough that she would now take advantage of other opportunities in science.

The teachers were aware that their confidence and appetite for science was increasing. Erica, for example, felt that even if she did not develop her *Sky Science* knowledge until it came time to teach the unit, she would now readily pick up a book or an article dealing with the moon or the planets. She compared it to a chain reaction, gathering interest from "here, there and everywhere."

Elementary Science Experts

It became apparent in our meetings that three of the teachers felt some people have a more naturally "inquiring mind," making them better at science and science teaching. Only one of the teachers expressed a wish to have science taught by a science specialist, however. The others felt that the expertise of someone in their school who was knowledgeable in science would be beneficial as an added resource or as a mentor in case something was proving difficult. We all recognized that, unlike language arts instruction, little has been done to further teacher education in science in a substantial way. We reflected on the years we had witnessed the development of local language arts support groups and the "experts" in the field from all over the world who would come in to help educate the profession. The teachers felt that, with emphasis shifting toward science, perhaps experts in the field would also begin emerging and "help us to start moving in the direction that we really need to go" [T3P32T].

In the meeting which concluded our project with the scientists, the teachers had opportunity to share some of their thoughts regarding the moon project. Along the way, most teachers had begun to speak of the value of modelling learning for their students, and the value of teaching questioning skills. In response to the scientists' probe, several expressed their relief at no longer feeling as though they had to be the "expert" in the classroom and that "it was alright to say I don't know something." To that, one of the scientists expressed his belief that, at the elementary level, it is more important for an effective science teacher to evoke a sense of wonder and excitement than to be extremely knowledgeable.

By the end of the project, most of the teachers expressed the viewpoint that specialists who took over the science class would be helpful only if the teacher was not passionate about the subject. They felt that working with someone who has expertise in a science neighborhood would be ideal because it would maintain the generalist approach to education at the elementary level, yet capitalize on the ability and passion of one with expertise.

Only one teacher continued to maintain that she did not have a "scientific bent" and that good science teachers were those more "naturally inclined" toward science. She consistently used phrases such as "it's a way of thinking," "have an aptitude," "better able." Those comments suggest that a neighborhood of science, at least for this teacher, continues to be populated by experts and not by elementary school teachers. Conversely, it may suggest that, while a neighborhood of science may indeed be populated by elementary school teachers, this teacher is not yet prepared to cross boundaries.

Scientific processes. The Burnett Cross article pointed to an aspect of science that intrigued the teachers: the process of trial and error. Jean remarked,

> It's almost like scientists do themselves a disservice I think when they make it appear as though it was just all one straight line whereas it's more interesting for people without very much scientific background to hear that "oh it wasn't like that—it was very convoluted" and more interesting for children to hear about discoveries like that as well [T2P3Le].

While *science-presented-in-journal-article* (Abrams & Wandersee, 1995) may be the prevalent view that these teachers associate with scientific practice, they also admitted that the time constraints that are part and parcel of elementary school life help perpetuate this view. As Sara pointed out, elementary teachers rarely let children learn from their mistakes, choosing instead to simply tell students what was supposed to happen rather than providing the opportunity to try something different. Likewise, published units often include recording sheets that detail final products with little emphasis given to the many successful trials experienced by students. I offered the following anecdote.

> I was observing a group of girls and ... I just jotted all the modifications they made with two words and there were 20 in about a ... 15-minute period. And before I showed them I said, "Do you think you were successful?" and they said, "No we weren't 'cause we couldn't get it to go." And I said, "Well, look at this record, I looked at all the things and each time you did that, you solved another problem"... And they were really amazed, and I said, "Now do you think you were successful?" and they said, "Well yeah!" [T2P3M]

Jean wondered why we didn't build more emphasis on learning from mistakes into the curriculum, even though it is part of the common vernacular.

> All the wrong turns that are taken as adults we always talk about it, even in our personal lives: "You learn more from your failures then you do your successes" [T2P6Le].

Anne suggested that debriefing at the end of science lessons could facilitate rethinking problems and foster attitudes such as dedication and persistence. She felt that this review is vital, not just in science but in writing repeated drafts during language learning or in other areas of the curriculum.

The group was struck by the realization that the way we as teachers conceptualize science shapes our language practices and consequently influences the way our students conceptualize science. This fact became manifest while discussing the ubiquitous science experiment. All of us, at some point during our 18 months as a research group, talked about science experiments that "didn't work." On the heels of our discussion regarding the difference between science and technology, we began to discuss the validity of asking children if an experiment "works." We recognized that the phrase is common in our classrooms, but the discussion also brought to the foreground the fact that it implies a particular view of science.

M: And, I mean...I've asked kids a million times, *"Did it work?"* [murmurs of agreement] Well, sure, it works if you've got a predetermined working [murmurs of agreement], but that's not an experiment then.

S: Yeah, because they say, "Well, what's supposed to happen?" right? [murmurs of agreement]

E: Now there's...—rings in my ears.

J: But not with the younger kids so much. They don't know that something's supposed to happen. [murmurs of agreement]

S: Although the older kids are really hooked on that, yeah. [murmurs of agreement] *"What's supposed to happen? Did I do it right?"*

J: They've been trained long enough [laughs], right. They've figured it out by now: *"Something's specific is supposed to happen."* ...

E: They're... inhibitions or whatever. They've become so, downtrodden, having an end product.

M: Of course! I mean, I just did that with Anne's class when our experiment didn't work. What was I saying? *"It didn't work. This* *wasn't supposed to happen. And I must have done something wrong."* [murmurs of agreement]

E: Oh, and I've done the same thing with classroom chemistry... *Gas in a bag*. I couldn't get it to work, and I was just— [laughter] And how many times did I try it, and I kept saying, "*It didn't work; it didn't work!*" Still didn't get it to work. [T3P26]

Later in the conversation, Sara reminded us that this emphasis on "doing it right" really gives credence to the idea that science can be characterized as content rather than inquiry. She added that, while teachers may appear to be fostering inquiry through the development of hypotheses and other components of investigation, inquiry is not really "honoured" if the outcome must be the "right" result.

Jean was quick to point out that the ability to unpack the learning that results from an experiment depends on the comfort level of the teacher. She suggested that, unless teachers are truly comfortable in a neighborhood of science, they will not be able to take an experiment that does not result in a desired outcome and ferret out understanding. This observation elicited murmurs of agreement from everyone present. Such comfort, however, cannot simply be gleaned through a plethora of acquaintances. Familiarity emerges when, through frequent encounters with scientific activity, people begin to develop an understanding of the nature of scientific inquiry and other processes in a science neighborhood. Like acquaintance, this dimension of familiarity is predicated on hands-on experience.

Frequent Encounters

Introduction

People learn about their neighborhood through active engagement with it and not simply by being in its vicinity. Continual encounters with community members foster a sense of who is trustworthy. Repeated traveling through the neighborhood helps ascertain the fastest, safest and most enjoyable routes.

Teachers have opportunity for frequent encounters through the units they teach, through daily life experience and through professional development. For the teachers in this project, professional development was a school-wide decision, relegated at the time of this research to the new math curriculum as well as to literacy skills. I was the only one who had ever taken graduate courses in science education or attended the yearly science conference sponsored by the science council of our local teachers association. Catherine had been to a science in-service conducted by the separate school board, which covered the units for which she was responsible, and which she found quite helpful.

The teachers recognized the value of frequent encounters, for learning as well as for teaching science units. In Erica's words, "the more you do it, the more comfortable you feel" [T3P37]. She relayed an anecdote that spoke to her own comfort level as well as to the type of in-service teachers find valuable. We had been speaking about the in-services put on by a local public school board and attended by all teachers shortly after a new program of studies was implemented. The in-services consisted of going through individual booklets, designed as recipe books for each unit of the new curriculum.

> The only one that worked for me was the one where the booklet wasn't out. It was *Mechanisms Using Electricity*... We had to *do* it because the booklet wasn't produced yet... I learned how to put those pieces of a car together but it wasn't until-and I went to that in-service; I went to it three times! I'm teaching at the same time, and I just had to go back because I wasn't sure. And the third time 'round it made sense and I found I was teaching some people beside me about what parallel circuits were, and series, and finally it sunk in [T3P38S].

Encounters with the Natural World

The teachers knew that background experiences played a part in the learning of science and in the development of familiarity with a science neighborhood. Anne shared the following:

> If you live on a farm where you're around machinery all the time and you're around animals, you may have a different approach to building devices that move, gears and levers, or the biology that's involved [T2P10L].

Sara pointed out that children have less opportunity to enter a neighborhood of science outside the classroom than in previous years. We are no longer an agrarian society, dependent and thus highly conscious of the weather etc. The other teachers were quick to agree, adding that children spend a lot of their time playing Nintendo or other video games rather than being outside. Sara illustrated the lack of connection with nature she observed in her students in the following anecdote.

> And it just came home to me last week when ...we were out in the river valley. I had the kids in my small group sitting down, and I gave them plastic bags, "cause it had rained the day before; it was kind of damp and I said, "You can sit on those." And we were taking the temperature and looking at the dirt and all, and they were quite happy, and then I said, "Now, here's a rotten log," and the bark was starting to peel off it, so we had some tools, and I said, "Now, let's just take this off and see what's behind the bark." So we just peeled it back, and, you know, millipedes and centipedes and bark beetles all went, and the kids all went "Ooooo!" They jumped back about six feet, boys and girls together, and they wouldn't sit on the ground after that. [laughter] And I just—and then the one boy said to me, "Like, why are you still sitting on the ground? Doesn't it bother you? You know, there's all these *things*." [laughter] And he just said, "How come teachers aren't bothered by stuff like that?" And I thought, How sad! [murmurs of agreement] What kind of children [several speak at once] aren't absolutely—I mean, they were interested, on one hand; but on the other hand, they stayed a, quite a distance away, and I thought, these kids haven't been exposed to that. They haven't been allowed to go out and play and dig in the dirt and get dirty and, you know, all the things that probably most of us did [T3P40T].

Sara added that sometime she worries accessibility to computers has made the world of children "a virtual world." "It really frightens me when I see people relying on the Internet to give the kids a zoo experience or... to give them a lot of different experiences and I think it's not good enough" [T3P42T].

During the meeting with the scientists in which we conversed about the life and works of Galileo, Dr. Piper noted that the invention of the telescope transformed human life, for our world was no longer the "world of our immediate senses" but rather one we had "access to." The accessibility to "new worlds" had a profound impact on each of us.

During one evening viewing, we marvelled at the way what we "knew" about the sky on one level was suddenly becoming real through the telescopes. For example, Catherine's reaction when first glimpsing the rings of Saturn was, "It looks just like in the planet books we study" [T10P30AM]. Later, in a journal entry, Catherine wrote the following:

> *September 4, 1998*
> I am so conscious of looking for the moon each evening. Not only does it look beautiful (romantic), but it has taken on a more *real* meaning—really part of where we are [JP9AM].

Catherine was not alone in this reaction, for my immediate response was similar: "I know! It's true that Saturn really does have rings" [T10P30M]! Surprisingly, we all confessed to feeling a little frightened at times, that it was "too big," "too unbelievable." Catherine's first viewing of the moon also inspired in her a wish for the ability to write poetry to capture the intensity of the experience.

Erica wondered how children could possibly be "really, really sold and interested" in the moon without direct experience. Dr. Piper suggested that the media have made the distinction between what is real and what isn't very blurry, and that being out under the stars allows people to see reality. Erica responded that she felt that it is knowing the moon *is real* that encourages interest in its study.

Sara's experience, however, illuminates the disappointment one can feel if expectations are not met. Sara had difficulty finding the moon and getting her telescope to work properly. When we met to view the sky with the scientists and to share our findings, she confessed being somewhat disappointed at the sightings. As the following journal entry reveals, this discomfort was related to her media experience.

> *October 19, 1998*
>
> When I read over transcript four, I am amazed by how negative I sound about viewing the moon. I wonder about that - Even when we had our own telescopes and I had trouble (perceived trouble) - I don't know what I was expecting. Perhaps I thought the telescope was going to magnify it so much that it would overwhelm me--be too close for comfort - Whatever that means.
>
> It wasn't until we were at Dr. Piper's house for the barbecue and I looked through the scientist's telescope and realized the moon was not going to come crashing down on me - like an Imax presentation where they focus in and out so quickly - that I truly relaxed and began to enjoy the sharp slopes of the craters, the hollows etc.
>
> I will definitely use my telescope again - especially when I teach *Sky Science* to the kids [JP7T].

<u>Facilitating Science Learning Through Frequent Encounters</u>

The teachers felt that teaching units containing the same concepts would encourage frequent encounters and thereby give the students opportunity to make "connections." Jean had the advantage of teaching Grade 2, where she feels similar concepts are laced through several units. The concepts learned in *Heat and Temperature* "come to bear" when the children move on to *Exploration of Liquids,* and *Buoyancy and Boats* benefits from the knowledge gleaned in both previous units. Jean commented on her experience:

> There are relationships there, even the magnets my kids discovered "hey, when I put two drops of water close together they jump up together like a magnet," and then we can talk about the positive and negative charges in the water and it's all kind of neat, they can make those kinds of connections [T2P10Le].

She added that the advantage of concepts that link units is that the children sometimes make the connections on their own and provide the basis for valuable discussion. This also means that nothing is taught "out of the blue" but instead can be linked with previous learning. Unfortunately, as each teacher recognized, the Alberta Program of Studies is not set up so that understanding builds from year to year.

The teachers admitted that their comfort increased if they were personally enthusiastic about a topic or if they had taught a unit several times. As Anne expressed with great satisfaction, "Getting out my file folder on butterflies, just a big sigh of relief. I think, 'I know what I'm doing'" [T3P15].

Teaching a unit for the second time is much easier. According to the teachers in this research group, the first time one needs to "spend hours trying to make things work," "trying to get the concepts across or the process... worked out in my own head" [T1P4S]. It isn't simply frequency that makes a unit enjoyable to teach, however; enjoyment also depends on the quality of the activities that make up the unit. The units must encourage opportunities for interaction and engagement that inspire enthusiasm in students.

Sara and Jean mentioned their recent pleasure in teaching the units *Evidence and Investigation* and *Rocks and Minerals*, respectively, despite the fact that it was their first time through. As Jean described teaching *Rocks and Minerals*, she mentioned her students' enthusiasm, particularly with finding rock specimens. All students had the opportunity to participate, for "anyone could contribute.... someone who didn't have a special rock at home could still pick up something from the alley and bring it to school and feel like they had a collection" [T3P16Le]. Erica reiterated the importance of engaging students as she told of teaching a unit called *Comparative Embryology*. Every other day, the Grade 6 students had the opportunity to open up a chicken egg to study its development. "It was so fascinating for the kids, the kids loved it" [T3P18S]. Sara noted that units that engage children provide more than content. "That's the beauty; that's the joy; that's the interest. And I think that's what really captures children"[T3P34T]. Says Anne,

> I think the reason I liked *Butterflies* is that it is hands-on, the observations, I've done it with grade 3s, I've done it with even the Grade 6s just the joy and just the sheer delight in watching them discover the process of metamorphosis. And learning things that they didn't know [T3P15L].

Not all units in the prescribed curriculum inspire similar enthusiasm or comfort in teachers. Erica attributes this reality to personal experience with science.

> I'll be honest, I have very little interest in *Rocks and Minerals* and I think "ooh." I mean, obviously I would have to get past that if I had to teach it and you know I might be very surprised and find it very exciting and I'm sure I would, but there is nothing in my past that has caused me to go "Oh yippee these are a whole bunch of different rocks," which is too bad. I've been deprived of something, but I think it does have to do with things, you're being excited about it in your youth or in your past or whatever [T3P17S].

The interplay between personal experiences, scientific phenomena and enthusiasm appeared on other occasions. Sara explained why she felt the most comfortable teaching the unit Growing Things:

> I really like the ones with the plants, you know where you put them in the dark and those kind of things. Growing Things probably would be the one I feel the most comfortable with because I've had experience with house plants and those kind of things [T3P17T].

This interest influenced the planning and preparation, which fill up a great deal of a teacher's time table, but here the teachers were not in agreement. Sara felt that preparation for a subject rested solely on her personal interest level.

> See, if I am interested in a subject area, preparation's no problem. If I'm not interested, it's a big problem. You know, and if it's just sort of a general—I love math, and I just love the *Math Quest 2000,* and I *love* the math program and stuff. Was it surprising that my kids got the highest marks in math on those achievement tests of all the four core? And I think part of that was because I was excited about it [T5P9T].

Erica disagreed. She felt that she was very interested in science, but that she became frustrated if there was a difficulty in procedure or in understanding a new concept, particularly if she had spent a great deal of time trying out activities in preparation for teaching.

Limiting Factors

Research has documented that elementary teachers are quick to drop science in the face of competing demands. These demands include special programs that are extra to the curriculum, such as abuse prevention, drug awareness, safety and career choices. The demands also include rehearsals for concerts and other school-wide special events, guest speakers, track and field days, winter carnivals and regular assemblies, all of which contribute to the rhythm of elementary life. Meanwhile, continual budget slashing has put space and materials at a premium.

Materials. "We are really hampered by a lot of things in doing science" [T1P16T], said Sara, referring to multi-day experiments that are thwarted because students cannot leave equipment such as sundials out. Catherine mentioned that science usually meant "collecting things and setting up and you have to be in the mood"

[T3P34AM]. Materials in schools can be unorganized and incomplete; if one is pressed for time, those factors add to the difficulty.

Jean's school overcame problems with materials by setting up a science room with tables for workspace and bins for organizing materials. Teachers were not obligated to use the science room, but had opportunity to reserve its use. Jean found it particularly helpful as she was teaching two classes of Grade 2, and much of the Grade 2 science curriculum involves water. The science room contained sinks, which were not available in the standard classrooms. Erica found the idea of a separate room for science most appealing, particularly with respect to the neighborhood metaphor,

> Maybe one thing that would help would be to have a science room that has everything in it that creates the neighborhood that stays there and is constantly frequented and visited and can be visited on a regular basis even though it's not science class, but have those things set up and there, not always which we are faced with. Um, you know, half an hour to bring out things and, and explore, and then you have to put them all away because you have to bring out the other subject. So maybe to have the *physical* neighborhood might be advantageous, whether it's practical, but I think it would help with that ripple effect as well [T13P15S].

Jean reminded the group that, while her school has a designated science room, it is not quite what the others imagine. At the time of this project, there were no artifacts around the room (e.g. skeletons, posters, books), nor were there any living things to study.

> J: We don't have... the meal worms in there, and maybe fish in an aquarium. It would be wonderful to have all that.
>
> E: Wouldn't it be wonderful just to have those things operating—
>
> J: Yeah.
>
> E: —like your, your meal worms crawling and your,
>
> C: Chickens hatching.
>
> E: Yeah!

M: Skeletons, skeletons there.

E: Then you would have a neighborhood of science instead of this, you know, fleeting in and out subject that gets put in the closet and—

A: And you can observe change over time. [murmurs of agreement]

E: And then it kind of would... you have an aquarium, or you have animals, and there you have biology, you have physics, you have, chemistry; you have all of the subjects there that are operating in their elementary stages. But that's not realistic, is it [T13P15ALL]?

This raises the issue of feasibility, for classrooms are generally filled to overflowing, particularly those housed in newer schools. Also, the teachers acknowledged that there appear to be more allergies in children today, so one must be careful about the wildlife to which children are exposed.

Time constraints. Time pressure is always a problem, particularly if an experiment unfolds differently than anticipated. Often teachers simply do not have the time to repeat experiments or conduct others that might get at the concept missed in the event of a "failure." The rigid scheduling that often accompanies elementary school teaching intensifies this need for time. "The moment is lost if you've done an experiment and do not have the time to discuss it because it's time to go to gym or whatever" [T1P18Le].

Erica proposed that difficulties with time are perhaps the reason why science teaching is not geared toward exploration.

> Maybe that's one of the reasons why it's taken so long for...what we would like to see in science inquiry; maybe that's why it's taking so long to happen, because we're spread thin; we don't have the time that we need to throw ourselves into the exploration like we would like to [T3P35S].

Several teachers felt students are not given enough time to reflect on their science experiences, and that such reflection is a vital part of scientific learning.

At the third meeting, Sara read an excerpt from her journal, which brought to light some of the thoughts inspired by the two articles and our conversations to date. The piece highlights some of the real difficulties faced by elementary teachers in preparing students for the future, given the multiple constraints placed on schools today.

> *Spring, 1998*
>
> Sometimes we get hung up in schools, thinking that we must prepare students; i.e., give them the knowledge they need in the future. We can't possibly do that; there is too much to know. We can foster inquiry and creativity though, two attitudes or attributes that will be necessary for survival in the next millennium. However, are we as schools organized in such a way that inquiry and creativity are possible? I would argue that indeed the opposite is true - We work more for conformity and obedience. Even in my class—Ah!!—you can see why teaching can be so frustrating.
>
> I feel like I'm in the glass house—I can see out, I recognize that change must occur and yet I'm caught in this box entitled curriculum, assessment, crowd control (management) and my own experiences. How do I smash through without being cut to shreds [JP3T]?

The other teachers, upon listening to Sara read this excerpt aloud, nodded vehemently and echoed murmurs of agreement. The constraints, which Sara described as the "box" in constituting her experience as a teacher, continued to be articulated throughout the research.

Provincial assessment. There was little doubt in the teachers' minds that the assessment practices placed on the school district by the provincial testing program have a big impact on elementary school science. The teachers sensed an increasing emphasis on standardized testing. Erica questioned others to see if we were noticing the direction education seems to be headed with assessment procedures:

> More and more into standardized testing. Tightening up on... what needs to be taught and what needs to be learned and therefore we will test it to prove that... we have high standards in our education system [T3P28S]!

She felt that the pressures placed by the need for "measurement of what the kids know so we can prove our worth and prove that the ...public education, or whatever, is sound" [T3P28S] lead teachers to avoid engaging children in open-ended investigation, which might be much more "exciting learning," but is more difficult to assess. Later, in another discussion, she added to her previous comments:

> And I think that maybe—like, if I could just teach like that and not have to worry about silly tests at the end of the year too, then I think you'd feel a lot freer to just open up the possibilities and see where the kids would take you and where your explorations would go then. It's this real pressure [murmurs of agreement], you know, that you've got to pass those tests. [murmurs of agreement] [T5P13T].

In a session on teaching combined grades given by the district science specialist, Catherine had been told that much of the test depended on students' reading abilities.

> He recommended that you teach the six and forget about trying to intertwine any because apparently if your child is a good reader and a fairly good student and has been throughout your elementary, he should be able to get 60 percent on that science test whether he has seen any of the units [TP21AM].

She added that she interpreted this to mean that 60 percent of the test is based not on content but deduction; that is, the reasoning skills learned during elementary schooling. At that point, Anne and Jean questioned why it is necessary to learn the content laid out by the Program of Studies.

Anne, Sara and I had taught Grade 6 a number of times and agreed with Anne's assessment that the Grade 6 provincial science examination is challenging, requiring sophisticated reading and problem solving skills, and does not necessarily require the children to demonstrate an understanding of scientific concepts. Rather than a cumulative exam, the questions depend heavily on the Grade 6 units. The questions are largely multiple choice, whereas the teachers felt that some of children do better with short answer. Sara found that at times the language of the tests seems an attempt to trick the children, so that it becomes more an IQ test than a "knowledge test." The teachers acknowledged that definite things had to be "absorbed" if students are to do well on the tests, things that meant they organized their teaching to provide children the opportunity for optimal test performance. Thus the frequent encounters in a science neighborhood, at the elementary level, is shaped by assessment practices.

Increasing Frequent Encounters

The teachers say this research project has influenced their students' frequent encounters with the scientific neighborhood. As an example, I share Sara's experience. Midway through the research, in October, Sara mused that she felt she was missing opportunities to encourage frequent encounters with science.

> But, I mean, kids will bring things in, and often times we kind of, "Oh, that's nice," and don't do anything with it. And maybe just taking more opportunities to—like today, we were doing Hallowe'en poems, and I said—we were talking about skeletons—and I said, "While I'm thinking about it, if any of you are eating chicken in the near future, save the bones, because I want to boil them up ...for a skeleton." So they were asking, "Well, should we bring skeletons of fish and all that?" and I said, "Well, no." And then afterwards I thought, Oh, that was stupid! Because that would have been really good, you know, to have lots of different skeletons, even though I was thinking of flight and birds and those types of things. But still, the fact that they would be interested in that, and so just kind of tying it in with frequent encounters, which would increase the knowledge, right [T13P16T]?

By February 1999, however, it appeared Sara was capitalizing on those serendipitous moments that arise in the classroom, thereby increasing her class's frequent encounters with a neighborhood of science and ultimately several other dimensions as well. I had come to visit Sara at her school to check on a few details related to her background experience and education. She spoke of a field trip that the children had just attended. The mother of one of the children in her class was a biology instructor at a nearby high school, which had graciously invited the children of the elementary school to participate in its upcoming Chinese New Year celebration. During the parent-teacher conference, Sara and the mother were discussing the class's enjoyment of science, and the mother invited Sara's class to stay after the celebration and work with Grade 11 students as they dissected the hearts of pigs. Although this field trip was easily justified based on the health curriculum (Grade 6 in Alberta studies the circulatory system), Sara felt her burgeoning awareness of science in everyday life had helped her recognize and seize science opportunities for her students.

> The fact that we thought about it, to put it with—we could have just said, "Oh yeah, we're going over for Chinese New Year," and not done anything in the biology lab [T18P1T].

At the same time, Sara felt she was much more aware and supportive of the independent encounters children were having with science. She took the time to point out science books in the monthly book order and generally encouraged "science talk" in her classroom.

> S: They were telling me about a lady who could pop her eyeballs out. [laughter] You know, like, just shoot them out and then put them back in. Oh, it was just weird. But you can see—look at the frequent encounters *they* are having with science that we're just saying, "Oooooo," or not picking up on or—
>
> M: But see, you, you already did, because for you to say, "Wait a minute! This is a perfect opportunity" means there has been a change in you in that to notice it.
>
> S: I've become *much* more aware, *much* more aware, I would say [T13P20T].

Sara also increased the minutes she used for science teaching and engaged her class in science for 40 minutes each day rather than alternating her social studies and science teaching. To garner extra time, she "borrowed" minutes from language arts instruction time, rationalizing that her science teaching was often filled with "language arts stuff" [T8P9T].

Jean too made some changes in her science program. Rather than three 60-minute periods of science per week, she blocked in two 90-minute periods. Her rationale for this move included the need to provide discussion time as well as "a really concentrated period where you can just keep going and, you know, trying out all the possibilities while trying—this way, we'll see what happens if they have more time to discover" [T5P7Le]. Several months later, the group asked if she felt the scheduling was making a difference. Jean agreed that it had, noting that the longer science period also provided an opportunity for her class to discuss what they had learned at the end of each class, discussion she now considered essential.

For these classes, more *frequent encounters* with a science neighborhood will simultaneously enrich both *acquaintance* with and *savvy* in that neighborhood. Through this increased exposure, students will also begin to recognize and define the neighborhood's *boundaries*. Furthermore, frequent encounters play a significant role in increasing feelings of *membership* in a science neighborhood. Familiarity, while augmented by the dimensions described thus far, manifests itself in the degree to which one feels a member of the scientific neighborhood. Thus *membership* is of prime importance.

Membership

Introduction

To truly belong in a neighborhood takes time. Time to develop acquaintances and savvy. Time to experience the engagement that arises out of frequent encounters.

Time to appreciate and be in relation with its members. Rutherford describes membership as developing a feeling of attachment so that, no matter what the shortcomings of the "neighborhood," one belongs. This feeling of attachment can be so strong that it remains with us a lifetime. We are part of it, and it is part of us. "And the converse is equally true: unfamiliarity breeds fear, distrust, and avoidance" (Rutherford, 1987, p 9).

Membership in the scientific community, at the elementary level, speaks directly to the purpose of science education. It is *not* the purpose of elementary science education to identify future scientists and engineers at the earliest possible moment. Instead, the purpose is to teach children that they are part of the world of science and can remain members all their lives, regardless of career choice. Rutherford says this is already understood in the neighborhoods of music, art and history. Most of us exit the school system knowing that we can participate in these areas without becoming a professional, without any need to apologize for lack of knowledge. Rather than using school science to "drive young people away from science" (p. 10), we must teach in a way that deliberately evokes a lifelong interest in the discipline.

I did not detect anything in our earliest tapes that would indicate any of us felt as though we were members of the science community. Our anecdotes spoke of the opposite. For example, one of us reiterated a daughter's first experience with high school physics as a separate course.

> It was the second day of school. My daughter was beginning the International Baccalaureate program and this was her first experience with taking biology, chemistry and physics as separate entities. I was eager to hear her opinion of physics, for up until now she had been a strong math student and loved science. I could hear the defeat in her voice as she quietly said, "I'm not sure I'm going to like it. You know what my teacher said? He said, 'Look, it's boring. I think it's boring, you're going to think

> it's boring, but it's the curriculum. You're just going to have to do it!'" [T2P23X]

While the other teachers looked in disbelief, Catherine added that her daughter had undergone a similar experience on her first day in a university science class, being told that 30 percent of the class would fail the course.

Anne pointed out that membership in a neighborhood of science could be promoted through frequent encounters; in our case, by working on a project with actual scientists. As the date for the first meeting with scientists approached, insecurities began to surface. One teacher expressed fear that she wouldn't be able to understand the concepts necessary to build a telescope. Another hoped we would be able to continue working as a "community." Another wondered if the scientists would assume we had difficulties because we were all female. These insecurities testify to the gap the teachers assumed existed between themselves and a scientific community.

Developing a Feeling of Membership

Our first meeting was set to take place in the Physics department of our local university, and as we walked en masse through the after-hour darkened hallways, I could see expressions of apprehension crossing the faces of the research group. I had reassured the group prior to this meeting that the scientists were friendly, kind, genuinely interested in us and in science education. In my discussions with the scientists, I had learned that for the first meeting they intended to re-enact the trial of Giordano Bruno, in an attempt to provide the context out of which Galileo worked as well as to provide a more informal approach to learning related information. While the teachers were aware of the format of evening ahead, they continued to be nervous.

Once the project with the scientists was completed, the teachers were enthusiastic and filled with positive comments, about both the opportunity to work with scientists and the scientists themselves. The teachers readily confessed to feeling more confident and more capable in teaching science, particularly the *Sky Science* unit. Most striking about the experience however, are the multiple indications that we had begun to appropriate some of the discourse of the members of the scientific community with whom we worked.

Finding out that our observations had scientific significance. During the project with the scientists, we each compiled a collection of observations and sketches detailing the phases of the moon. This was the first opportunity any of us had had to actually look at the surface of the moon in any detail. Other than myself, no one had used a telescope to view the moon surface. When we met to share our findings with the scientists, several of the teachers were amazed to find that their observations were indeed keen, serving as points of reference for scientists as well. This excitement was captured by the Anne's journal entry, in which she reflected on the experience with the scientists.

> *October 18, 1998*
> When I think of how last winter you brought up the idea of working with Dr. Jones and the other scientists-I needed affirmation that it was definitely "No Experience Necessary." Fast forward to your deck in August—our field trip to Dr. Piper's and look at our own desire for talk and getting to know our own way around! How delighted I was to find out that in one of my sketches I had in fact drawn the *most famous crater* [JP5L].

These keen observations include the location of Tycho and Copernicus, the lunar maria, the presence of mountains and several extraordinarily bright spots caused by past meteorites hitting the ground at such a high speed that the fused ground underneath reflects light differently than the surrounding surface.

Sharing our findings. For many of us, this was the first time we shared the results of a scientific investigation. One difficulty for nonscientists engaged in scientific activity is being in command of a language with which to communicate. During this period of observation, many of us shared our progress via telephone and e-mail. As we shared visible features, we began to commonly refer to a collection of mountain ranges and impact craters that resembled a rabbit. The following series of e-mails illustrates initial attempts at science communication.

> *Sept. 9*
> Dear Jean,
> How is your moon sketching coming along? I see a rabbit all the time… how about you?
> Anne

> *Sept. 11*
> Dear Marg,
> I'm off to Calgary for the weekend. I can believe the moon. I was looking and looking and saw Jupiter but no MOON. Then, I saw it directly to the East at about 11 p.m. How about you? Strange… I was so used to seeing it to the south right side of Jupiter.
> Anne

> *Sept. 9*
> Dear Anne,
> I see Mickey Mouse in my moon sketches!
> Jean

> *Sept 17*
> Dear Jean
> Quick question… I can't seem to find the moon these days. How about you? If you're able to see it, can you please give me some hints. Where, When, What time...etc. thanks so much, Anne

Sept 24
Dear Ann
I'm having the same problem. A couple of weeks ago I saw it while I was picking up my daughter from a high school dance at midnight. It was very low in the sky and I could see it across the school field. I don't normally stay up that late! Since then I have forgotten to look some nights and not found it on the nights I did look.
Jean

Even when the moon was clearly visible, we had difficulty sketching it and talking about what we saw. Erica and I got together on the day of her first viewing, and I recorded our conversation as we made our observations. The following is an excerpt from the transcript:

E: Oh, I see almost like—my goodness, it almost looks like craters radiating from one.

M: Where?

E: Um, just kind of up here.

M: Mm-hmm.

E: I see, like, one, and then I see ever so slightly—

M: Hm.

E: —just where the line—

M: See, now, when you said that, and I looked and I could see craters up there. I hadn't seen them before.

E: There's a crevice. I may be drawing more than there are, but they'll get the idea [T7P12S].

Note how Erica has difficulty describing the position of what she is witnessing.

Each of us commented on how difficult it was to sketch the moon at the beginning, when we had no prior reference beyond old photographs of the Apollo moon landing. Even Erica, the most artistic of us all, had trouble with her initial sketches.

> Oh, 'cause I am just trying really hard to be so precise, and it's not—'cause I can't carry the mental image from looking in here over to my paper, because it's not, it's not reminding me of any definite shapes [T7P13S].

Gradually our observational skills and our scientific understanding grew, in tandem with our ability to communicate. Note the difference in Erica's ability to communicate what she is seeing after a month of observations and observational sketching as well as conversations regarding what she has seen.

> C: Oh, but see, I never got it looking like this.
>
> E: I don't think I ever saw it quite like that.
>
> C: You know, it, the background is more solid; it almost looks like a plaster of Paris kind of object.
>
> E: It looks more pocked, doesn't it?
>
> C: Yes.
>
> E: Pockmarks, and you're right, they are more solid. And those kind of irregular, that irregular shape, but Copernicus is much more rounded and definite, looking at it like that. Would you say it's the way the light is hitting it, or the shadows [T10P16]?

<u>Building communal scientific understanding</u>. Until the work with the scientists, our conversations did not include any discussion about scientific phenomena, other than references to concepts the teachers had difficulty understanding. During and after the project linking the scientists and the teachers, there were many instances when we, as a group or as dyads and triads, either shared or constructed knowledge. This happened

with the new understanding enacted as we studied the moon, as the following excerpts bear out.

C: Now, you know how the moon, like, the—is this called the *waning* or the *waxing*? Which part is it?

E: I think it's—I think—didn't we just have a full moon?

M: No. We had a *new* moon.

E: This is now—so this is now waxing. It is growing bigger.

C: It is! Oh! Okay.

E: I think, because a new moon is when there is *no* moon practically, and that means it's waned its little self into a new moon.

C: Okay. All right [T10P2SAM].

M: Okay, does the moon… rotate?

E: It does, doesn't it?

M: Once in the whole—

C: Twenty-four days or something.

E: Okay!

M: Well, that's right, once in the whole time that it goes around the Earth.

E: The whole time it revolves.

E: Rotate—revolve

A: yeah, that was the coffee-table thing.

M: Right.

S: Yes. That's when he got up and moved the table [T13P38].

Enriched conversation also occurred regarding other science topics unrelated to the moon study, as in the following excerpt.

A: A friend of mine took it, and not this past summer, but the summer before in Kananaskis. He said it was wonderful, so we were out for a walk and spreading the knowledge: "See, this is a pine tree. Pine tree needles are in pairs. P for pine, P for pair." [laughter] How do you find—you know, how do you tell the difference on the needles? When you just look at the needles, and a fir stands single.

S: And some of them are square too.

M: Yeah.

S: And some are flat or round [T13P9].

Discussing science around us. There was a general acceptance that the teachers had begun to see science in many parts of their life rather than as simply a subject taught in school.

> I have become more aware myself that science is around me every day. Like, it is part of my life, everyday life. Like, when I cook I'm using science, right? When I am slipping on the roads I'm using science; when I'm breathing I'm using—like, I just realized more and more when we were talking about science how pervasive it is for us [T18P6T].

That the teachers had begun to see the science in their daily lives was evident in our final "official" meeting. We ranged in our discussion from time spent on science, to possible resources used in the science classroom, to possible upcoming professional development in science, to science activities that teachers had found worked well in the classroom, to our reflections about the research project, to the neighborhood metaphor.

Our next to final topic was a discussion not about the moon, or the planets, or even education. One of the teachers had read a newspaper article regarding the recent discovery of mummified Mayan children, found in a volcano. She began the conversation by asking if anyone else had read the article. We then spent a significant amount of time discussing the mummification process and possibilities. During this discussion, we asked questions, built understanding and even disagreed. More importantly, however, this was the first time the teachers' choice of topic involved a scientific phenomenon.

For Erica, who moved to another city at the conclusion of the research, the conversations around science have not stopped. I received this note from her in early November 1999 as she made comments regarding the analysis summary. This note was stuck to the section that spoke about the increased confidence articulated by the teachers.

> Dear Marg,
> You have no idea how many people I have explained the phenomenon of Northern Lights to and that is because...I now understand electrons. The Northern Lights have always fascinated me, and the magazine was personally interesting as it explained why they occur. I feel so smart when I explain why we see them!
> Erica

Sharing our ideas for teaching science. At the second meeting, we began sharing our ideas for science. Sara began, by asking for some information from anyone who had taught the unit *Trees and Forests*. I had some sources for print material, while Catherine volunteered information about a field trip. That was the extent of the dialogue. During the third meeting, we began to share projects that had worked, with cautionary suggestions for those in the group who appeared eager to try out the new ideas. Examples include how to attach a chrysalis to a container lid without damaging the butterfly and maintaining a pond so the tadpoles do not eat each other.

As the months went by, we began to use the sessions as an idea exchange as well as to work out the implications of the metaphor. Some teachers shared books they found useful, others activities that had been successful. Still others shared what they were doing at the moment and what some of the children were bringing into class. At one point, Erica and Sara wanted to switch from teacher-directed activities to activities intended to stimulate student construction of understanding and genuine inquiry. They brought their ideas to the group and asked for input as to the feasibility of such an approach.

Perhaps the most telling conversation occurred near the end of the project, when Sara described an activity she had done with her Grade 6 students to test the brightness of stars.

S Well, they just took ...kind of a cardboard, and there were five holes in it.

E: These were the kids.

S: The kids. And then over one hole you just put one layer of like Saran Wrap, and over the second hole you put two layers.

E: Oh!

S: And then the third hole three layers, and over the fourth hole four layers and then five layers. And then you'd look at the sky, look at the stars, and if you could see it through number one, but not through number five, then it had a lower magnitude, because magnitude is brightness. And so if you could see it through five layers of cellophane, obviously it was a very bright star.

E: Oh, that's neat! So was this in, uh, *Sky Science?*

S: Yeah.

E: That's neat.

S: But I mean, it was very simple. The kids could make it. [murmurs of agreement]

S: You could make it quite easily, and then you could, um, they could try it out. [murmurs of agreement]

A: And where did you get that idea?

S: Oh, it was in the book, in the guide.

A: Hm!

M: And it is a nice way to start, with an actual doing of a kind of a procedure, I guess, or an investigation, and coming up with—you don't even have to tell them that stars have brightness, different levels of brightness. You can find that all out.

A: Through the discussion and their observations. Yeah, yeah.

A: Did you have them sketch the moon last year?

S: Uh-uh, no. Well, pardon me, I think I did—it's been a whole year. But I think I sent a calendar home, and they were supposed to look and just, yeah, a very rough sketch, what it be like full moon or half or a quarter, just the last thing in the waning, so nothing more sophisticated than that.

A: Not position in the sky and—? because that's—it's certainly—

M: Positioning and—see, you wouldn't need a telescope either to do the positioning in the sky; that's really good. You could just have, okay, show a tree that you have; where is the moon in relation to that tree at nine o'clock? and do it—that would be great!

S: That *would* be good. I never thought of that.

E: Mm-hmm, because you'd—yeah, you'd have to have something to base it on, on something—

M: Yeah.

E: —that it's relative to [T13P23].

The richness of this excerpt goes beyond the sharing of a successful activity. Here we see the advantage of working comfortably within the intersection of the science and teaching neighborhoods. First, the other teachers recognize that an important concept in understanding movement in the heavens is the moon's position in the sky in relation to other celestial bodies (science neighborhood). Second, there is a recognition that hands-on activity, discussion and observation are necessary for children to construct understanding of scientific phenomenon (teaching neighborhood). Finally, we are using what we learned during the project with the scientists to design an activity that will facilitate scientific understanding in upper elementary children (intersection).

CHAPTER V

DISCUSSION:
MOVING INTO THE INTERSECTION

Introduction

Research across the Western world has led to the general acknowledgement that elementary teachers are neither confident nor comfortable teaching science. The neighborhood metaphor offered by Rutherford suggests a new way of conceptualizing the teaching of science, in which elementary teachers introduce their students not to the body of scientific knowledge, but to a particular community. As communities are defined in part by their discursive practices, the way in which language features is important, both in how teachers articulate a neighborhood of science and in how they discuss their role as teachers of science. At the same time, by shifting the focus from the personal plane to the interpersonal and cultural planes, one is able to examine the impact of institutional discourses on how science education is constituted and mediated at the elementary level. This research was guided by the following three questions.

1. How will new understandings of the nature of science be generated out of repeated discourse *about* science and *in* science?

2. How will the confidence levels of elementary teachers in relation to science be affected if they have opportunities to explore a neighborhood of science?

3. How will a new metaphor for science teaching shape the discourse of elementary teachers?

Our decision to work with the scientists reflected a desire to strengthen our acquaintanceship with natural phenomena as well as to meet members of the scientific community and thereby increase our familiarity with a science neighborhood. Analysis of our discourse yields the recognition that, prior to and during our decision making process, there was little to indicate that we felt comfortable in a neighborhood of science, let alone feeling as though we were members. By the end of the project, there were many indications that we were beginning to feel both more comfortable and more confident in our abilities to navigate terrain that appeared much richer than we had anticipated. More importantly, our discourse revealed that we were beginning to appropriate some of the language practices of the science community with which we had interacted. This shift can be attributed to the brief yet significant experiences following our welcome into a science neighborhood.

The role of metaphor was pivotal to these changes. Elementary teachers typically constitute a neighborhood of science as it was experienced through their own schooling. The metaphor initially encouraged our entry into a discourse regarding the way we had individually constituted a neighborhood of science. It also acted as an impetus for change and provided a framework upon which to situate the research.

The following sections reflect on the research by addressing the three questions. The analysis summary articulates new understandings related to the nature and neighborhood of science, generated by our discourse throughout the research, and changes in confidence levels that emerged as we explored a neighborhood of science. While it is apparent that the teachers moved into the intersection between the science and teaching neighborhoods during this project, it is difficult to disentangle newly found confidence from the ways in which a neighborhood of science was reconstituted. Hence the changing confidence levels and the new understandings of the nature and neighborhood of science (questions 1 and 2) have been braided together in the first section.

Generating New Understandings/Increasing Confidence

Re-examination of Rutherford's Metaphor

While many of our earlier discussions focused on what the teaching of elementary science might mean with respect to the five dimensions of Rutherford's metaphor, through the project with the scientists it became apparent that developing a feeling of membership in the community was by far the most critical dimension. The first four dimensions constitute a medium out of which membership has the potential to grow. Efforts to plug the perceived gaps in teachers of elementary science typically address aspects of these four dimensions. Attention has been focused on increasing content (acquaintance) at the preservice level, on developing appropriate resources for organizing and presenting curriculum (knowledge of the boundaries, savvy) and on fostering understanding of and confidence with particular science concepts through hands-on topical workshops (savvy, frequent encounters). Note that the dimensions are sufficiently entwined that development in one area can simultaneously strengthen other areas. Simply strengthening each or even all areas will not necessarily produce a feeling of membership, however; without this critical dimension, it seems doubtful that the future of science teaching at the elementary level will change.

Positioned with Respect to a Science Neighborhood

Our early discussions revealed that all of us had the usual science experiences attributed to elementary teachers. The profile is rather bleak and consists of little or no science experience outside of school, with much of school science conveying the message that science learning consists of memorizing the information collected to this point. Language in science is thus relegated to learning vocabulary or technical terms specifically related to the different domains.

Gallagher's (1991) study of the textbooks dominating secondary science has already been discussed. At this time, however, I would like to briefly mention the second focus of that study, namely the portrayal of the nature of science by high school teachers. In an ethnographic study of 27 teachers over a two-year period, Gallagher found that 25 out of the 27 teachers placed most of their emphasis on the body of knowledge. This translated into a heavy emphasis on terminology, and infrequent laboratory work other than in chemistry and physics. Virtually no time was given to discussing the nature of science other than lessons at the beginning of the year detailing *the scientific method.*

Through multiple conversations and informal interviews, the reasons became clear. The teachers themselves had no understanding beyond the body of scientific knowledge. They had no formal education in the history, sociology or philosophy of science, and their scientific training centred on content rather than process. In spite of added scientific training, they were described as having limited understanding of applications, and consequently were unable to make connections between information outlined in textbooks (and prescribed in curricula) and the world outside school.

Although Gallagher's study represents only a small group of science teachers, the depth of the study and the credence given by other researchers in the area (King, 1991; Matthews, 1994; Pomeroy, 1993; Ryan & Aikenhead, 1992) support his description of secondary science. There is an interesting point in Gallagher's study that relates to the metaphor guiding my research. Two of the teachers in Gallagher's study had "significant depth of understanding about the nature of science and historical development of the knowledge they were teaching to their students" (p. 126). They were teachers of *Project Physics,* a course using the history of science to demonstrate the development of scientific knowledge as part of introductory physics. This course was developed under the leadership of Gerald Holton, Fletcher Watson—and James F. Rutherford, the man who originally penned the neighborhood of science metaphor!

Gallagher attributes the narrow conceptualization of science to the experience of university science. Repeatedly, post secondary science courses are described as vehicles for content delivery in which little attention is given to the nature of science. Duschl (1983), for example, points out that science courses at the introductory level (the ones preservice teachers generally take to fill the science requirement) are often survey courses geared toward the dissemination of a great deal of information and involve mainly lectures, with some demonstrations and activity labs. Generally, these classes are large and filled with science majors, often those who become secondary science teachers.

Perpetuation of a Narrow View

What is insidious about such a narrow understanding of a neighborhood of science is its propensity to be self-perpetuating. It is similar to the experiences of those who have difficulty reading. Opportunities to read usually involve assigned readings, which may be of little interest to the reader. Each act of reading is difficult; hence, it is avoided rather than sought. Moments in which the reader is truly engaged happen rarely, if ever. Because limited time is spent on reading, understanding of the process is often restricted to decoding or word-attack skills. Familiarity with text genres, multiple reading process or themes that stretch across books and thus provide a context cannot be fostered. Activities involving print become laborious and are often ignored, while places in which print dominates are generally avoided. The difficulties overshadow any enjoyment or love of reading.

So, too, with school science. Science activities are dictated by textbooks and thus may not necessarily be of interest to the learner. Often the concepts are difficult and, as long as the focus remains on memorizing terminology and content, avoided rather than enjoyed. As limited time is spent understanding the historical development of ideas or fostering appreciation of the way science has grown as an intellectual enterprise, there are few cross-disciplinary links. Because topics are often disconnected from the rest of life, opportunities to engage in science beyond the walls of the classroom are rarely taken and thus scientific endeavor remains tied to classroom activity. Curiosity, enjoyment or knowledge of the discipline are not fostered and so, once the requirements of schooling are met, the pursuit of scientific understanding virtually grinds to a standstill.

This particular discourse group embodied the vicious cycle that occurs in the presence of limitations with respect to the nature of science. These teachers entered the classroom equipped with a tradition that has emphasized a very narrow view. Because science was no longer a recognizable part of their daily lives, their most prominent interaction with science became professional, through the science curriculum. The Alberta program of studies is based on discrete units, so concepts must be taught within prescribed topics. Few of the topics are considered interesting by these teachers, so they bring a notable lack of enthusiasm to the planning table. Some of the concepts they are required to teach are difficult, and there is nothing in the program of studies to enrich understanding. Nor can they necessarily draw on their own science background, in which they remember simply "memorizing" or "digesting information" rather than developing understanding. Given past experience, in which science is seen as the need to memorize difficult content to pass examinations, is it any wonder that at times teachers resort to having their own students memorize rather than understand (e.g. tilt of the earth's axis, the path of electricity, principles of flight)?

Pomeroy (1993), in a comparison of the beliefs about the nature of science between scientists, secondary science teachers and elementary teachers, found elementary teachers "relatively contemporary" compared to the other two groups (p 272). She suggests one of the reasons for this somewhat surprising revelation is that elementary teachers have had less opportunity to become enculturated into a particular viewpoint. She postulates that perhaps, because there is a high rate of commitment to constructivism among educators at the elementary level, the attention directed to the way children construct knowledge is helping to shape teacher understanding of how scientific knowledge is constructed.

Positioned Within a Teaching Neighborhood

The education and training of generalist teachers is predicated on two intersecting thrusts. First is the belief that elementary schooling involves encouraging a love of learning in a general sense. Thus, teachers are trained to make learning relevant and meaningful by focussing on the interests of their students. These interests do not necessarily parallel prescribed topics, so teachers learn to map student curiosity onto curricular concepts, and in so doing, maintain a high level of enthusiasm and willingness to commit to the difficult process of learning. The second thrust is a heavy emphasis on language, which fosters participation in the discourses of multiple fields. The rise of constructivism and social constructivism has shifted the focus from the "teacher proofing" of materials of days gone by to the ways teachers can facilitate processes by which children augment their own understanding. Generalists are thus educated and trained to focus on the various dimensions of language that aid in this process.

This education and training has multiple benefits if teachers are comfortable in various disciplines, as indicated by the participants in this study. It was obvious from their professional as well as personal interests that they were members of the language learning community. Passion shone as they spoke confidently of their abilities to foster love of reading and eloquently about the many facets of this neighborhood. The various forms of language enacted by the scientists, (explanation, debate, analogy, narrative, description and questioning) with the exception of debate, were also used by the teachers on numerous occasions throughout the project, although not necessarily with respect to science.

While these teachers were able to design units that met the specific needs of their students in language learning and in other areas of the curriculum, in science they relied heavily on teacher guides or published materials. Reardon (1996) notes that teachers count themselves as successful in the area of reading when their students "enjoy reading, understand what they read, talk about books, and know themselves as readers" (p. 17). They define themselves as successful in the area of mathematics when their students "enjoy playing with the ideas of mathematics, recognize mathematics is useful, and use mathematics to solve their problems" (p. 17). These same teachers, however, often measure success in teaching science by how well they manage to adhere to a teacher guide or attain successful provincial test results.

Reliance on teacher guides or text series means that teachers are committed to a preordained path and less likely to respond to the abilities or interests of their students. It means the onus is on teacher guides to stimulate language forms that represent the scientific community. It also means that, without leeway to follow personal or collective interests, the likelihood that teachers will pursue questions beyond the bounds of the time allotment given to science is low. Considering that the writers of published materials are also graduates of the secondary school experience, one does not hold out much hope for the re-conceptualization of the nature of science via the educational publishing world.

Professional development is often self-directed, and teachers choose those areas in which they themselves experience enjoyable learning. These teachers had taken advantage of graduate courses, workshops and in-services in their own areas of expertise. The same cannot be said about enrichment in science, with the exception of the period after the introduction of the new program of studies. When the new science curriculum was introduced, these teachers went to in-services provided by their school board, which aimed at elucidating the new units, but in effect were merely a vehicle to sell the handbooks created by the district. As the in-services revolved around demonstrating activities and not on conceptual development of either students or teachers, it led to disappointment on behalf of the teachers in this study.

The difficulties of breaking the self-perpetuating model are immediately apparent. Since science is seen as something to be at worst avoided and at best tolerated, outside experiences that may inspire alternative viewpoints are unlikely to be fostered. For example, books about the work of scientists often provide a glimpse into dimensions not otherwise revealed. Newspapers, popular science magazines and television shows also provide enlightenment regarding the multiple dimensions that encapsulate the scientific neighborhood. Unless there is impetus to investigate the nature of science, however, it seems unlikely these particular avenues will be explored.

It also seems likely that without substantive interfacing, the experience of science as narrowly constituted will become the experience of the next generation. In this research, it was the metaphor that facilitated the re-conceptualization of a neighborhood of science and provided an impetus for moving into the intersection bordering the neighborhoods of science and teaching.

Entering the Intersection

In-dwelling. Polanyi (1962, 1983) suggests that true understanding depends on the ability one has of extending oneself into what is to be known. He proffers the example of a blind man who uses his cane in such a way that meaning is made through the tip, not the handle (Prosch, 1986). The blind man has extended himself into his cane in such a way that he dwells within his cane just as he does in his own body.

True understanding of science and mathematics, according to Polanyi (1962), requires the ability to contemplate, not from outside the discipline but rather from within, on a personal level. One feels joy with respect to theory by dwelling within that theory (or discipline) and pondering its value from inside. Simply memorizing formulae or scientific information in a routine fashion diminishes this joy. It is by dwelling within a discipline for a sufficient time that one eventually begins to pick up the tacit knowledge that allows participation in the discourse of the field. This tacit knowledge encompasses the assumptions, the procedures, the rules and a sense of what is interesting (Applebee, 1996). It is "knowledge-in-action" (Applebee, 1996) because only by participating in the tradition can one gain tacit knowledge; it cannot come only through studying about the discipline.

Here is where the mutual constitution of Rogoff's (1995) three planes of sociocultural activity comes into focus. While the tacit knowledge constituting a science neighborhood is appropriated by individual members, this process does not occur in isolation from a science community. Rather, tacit knowledge is developed through a process of apprenticeship by which members of a science community foster the participation of less experienced people. Similarly, the communication strategies and processes of engaging in activities within a science community are engendered through the guided participation of interpersonal interaction. In the case of this research, the face- to-face interaction between the scientists and the teachers provided an opportunity for both apprenticeship and guided participation in a science neighborhood of astronomy. Through the opportunity to dwell within astronomy and work with community members, the research group began to acquire some of the *knowledge-in-action* of a science neighborhood.

One of the attributes of this knowledge-in-action is that the "traditions of the discipline are not static" (Applebee, 1996, p. 16). Instead, traditions are enlivened by the discussions, the passions, the procedures, the community members; in short, by all that makes up the discipline, both past and present. It is this knowledge-in-action that offers elementary teachers the opportunity to re-cast beliefs about the nature of science developed through schooling. Rutherford's articulation of the metaphor is an attempt to bring to light some of the tacit knowledge held by members of a science neighborhood, and in doing so, facilitate entrance into the intersection between the science and teaching neighborhoods. Of note were the manifestations of *personal passion*, as well as specific *discourse practices* of the community members, which together helped strip away the myth that science deals with the objective and impersonal.

Personal passion. One of the recurring comments following the project with the scientists was surprise that they "appeared to love" science. The scientists were obviously keen about the project with our research group, and about their own work as scientists. This keenness was evident in the way they described becoming members of a neighborhood of science, the manner in which they told stories of personal discoveries and the tone in their voices while illuminating features on the slides of the night sky. At times, we heard awe, amazement and wonder in their descriptions. Once in the field, the scientists were eager to look through the telescopes, in spite of the fact that, for two of the scientists, this must have been a familiar sight. The teachers also pointed out the amazement and wonder in the writing of Galileo, and in the stories of other scientists. This lent credence to the suggestion that personal passion is part of scientific endeavor.

This enthusiasm seemed in direct contrast to the often dry recitation of fact that we had experienced in most of our collective high school/university experience. At the same time, it made us reconsider our articulation of the elementary science curriculum. The only science unit simultaneously endorsed by more than one of the teachers had been *Butterflies* (used to meet the objectives of the Grade 3 unit *Life Cycles*). Four teachers, as well as their students, enjoyed watching the process of metamorphosis, learning about similar insects, collecting the data and linking what they learned to other areas of the curriculum. Animation was evident in their voices as different aspects of the unit were discussed.

The difference in enthusiasm levels stimulated a discussion about the remaining topics in the program of studies. Why were those topics perceived as dull, difficult and unrelated to the rest of the units? The suggestion was raised that perhaps the topics outlined in the program of studies had originally engendered passion in scientists, but that somehow the process of curriculum writing had all but watered out the passion. As a consequence, unless units stimulated the background interests or experiences of teachers sufficiently to trigger their own passion, topics ran the risk of being reduced to garnering factual information, setting yet another self-perpetuating cycle in motion.

Our experience of being in a neighborhood of science broke this cycle, at least with units relating to the sky. We spent a month walking in Galileo's footsteps as we scanned the heavens with the telescopes we built, as he had built. It was this indwelling that gave rise to our comments regarding the reality of what we had seen. We were each shaken at the intensity of seeing the dry and lifeless surface of the moon for the first time, and later seeing the rings of Saturn and the moons of Jupiter, as though these had not really existed other than as facts first learned, then taught. Our initial impressions were beyond description as we were overcome with awe at a sight that up until this point we had seen only via the eyes of others. We instantly recognized that the photographs, written descriptions and television specials that had provided our knowledge base did not come near to giving us the knowledge about the moon that we now possessed.

This passion has not waned, nearly two years later. All of us look up to the sky regularly, trying to locate the planets we now know, the moon craters that are visible and the stars and constellations we can now identify. The following comment, made immediately after the project with the scientists, continues to be reiterated whenever our paths cross:

> I really look at the moon differently. I find myself *looking* for the moon, [murmurs of agreement] whereas before I—I mean, after how many days of looking for and not finding it and thinking I should drive, you know, miles to see whether I would find it. But no, I do look at it differently, and it's fun to, to be able to recognize some of the stars. [13P21S]

Engaging in a new discourse. The reciprocity of language and thought cannot be overemphasized. If one accepts the constitutive and mediating power of language with respect to thought, then one must recognize that discourse can unveil the understanding of others—individuals as well as communities. To engage in the discourse practices of a community is to demonstrate membership in that community.

Features missing from discourse become as significant as those that are present. There were notable gaps in the conversation of the research group before the project with the scientists. In spite of the fact that we had gathered to discuss a neighborhood of science with respect to elementary science education, we neither shared science ideas, nor discussed members of the science community, nor reviewed scientific advances highlighted in the media, nor spoke with enthusiasm about science—other than the two or three units we had enjoyed teaching. During the first few sessions, conversation was generally instigated by me, the researcher, and teachers either asked clarification questions or responded to my probes for information. Our discourse could be characterized as sparse and lacking in depth.

Directly after the first moon sighting, this began to change. Subsequent meetings became opportunities to see if our observations had merit, if others had noted the same things and if our conjectures were possible. We seized the opportunity to question the scientists about what we had seen and what our seeing meant. The excitement and enthusiasm was evident in our voices, in our eagerness to share ideas, in our laughter and in the fact that we were obviously reluctant to return to the warmth of the house and thus end our final night viewing with the scientists.

This excitement was not confined to the discourse group. We communicated our findings and our excitement to spouses, children and colleagues. Several of the teachers discussed the project with other staff members and brought their telescopes to school to share with students. The discourse continued to be rich after the project with the scientists was completed. Our discussion group was no longer directed by my questions. Topics were introduced by different members of the group, and at times the group split into multiple conversations, centred on science, which were too difficult to record! We freely shared ideas regarding teaching concepts and professional development, and we asked each other for help. We shared observations regarding scientific phenomena in our daily life, and discussed scientific events reported in the newspaper.

Developing New Companion Meanings

Through observing discourse practices. While materials used by elementary teachers often ring with certainty, the language used by the scientists in this project was illuminating. Often, while responding to teacher questions regarding a scientific phenomenon, the scientists bracketed their explanations with phrases such as "some say," "probably formed," "we don't know, but most likely," and "there's a debate." The uncertainty of these phrases suggests the relative tentativeness of scientific knowledge, consistent with Sutton's (1996a) claim that the language used by scientists is misrepresented in school. He posits that, as scientists engage in their work, the primary function of language is that of interpretation. Phrases such as "think of it as" (Sutton, 1996a, p. 9) are used as scientists initially interpret phenomena. In the final published form of such work, however, a significant transition has occurred so that the language assumes a labelling function. Readers who are not privy to scientists' initial, interpretive writing thus lose the opportunity to see the role of figurative language in a scientific neighborhood.

The companion meaning accompanying such a transition is that scientific knowledge, rather than being a consensual interpretation, is a body of work to be transmitted to the next generation. A significant dimension of a neighborhood of science, that is, the role of persuasion, is thus lost. Such discourse implies that the "facts" of science are simply awaiting discovery, and consequently diminishes the "process of imaginative effort and painstaking construction" (Sutton, 1996a, p.10) that characterizes scientific endeavor.

Working directly with members of a scientific community helped to dispel these companion meanings, which, we freely admitted, had helped to conceptualize our view of the nature of science and its scientific neighborhoods before this research. The idea that scientific knowledge is not certain but instead relatively tentative was made manifest on several occasions in discussions between the scientists. During one of our meetings, we became involved in a discussion regarding whether Galileo actually proved a new way of looking at the universe. Dr. Piper responded,

> This is, I think, a misconception about science, that science operates at a level of proof: Scientists have proven that . . . What science really does is, it provides convincing arguments for something, but it doesn't, it isn't in the business of supplying proof in the mathematical or geometric sense. So scientific knowledge, in that respect, has always a level of tentativeness to it. [T4AP32X2]

We learned that, while Galileo would have claimed his theories were correct, physicists today tend to claim their theories are models of the way the universe *might* move. We witnessed disagreement among the scientists as to the interpretation of events in modern science. One of the most striking was one scientist's suggestion that perhaps mathematics is not the way to understand the universe. He added that recent discoveries are suggesting universe is amathematical or nonmathematical, and that we might see the emergence of a new way of looking at the world, possibly through biological systems.

While this research noted several genres of language enacted by the scientists, there is insufficient evidence to claim that these forms are either typical or necessary in the scientific neighborhood. Further research is needed in this area, particularly regarding how discourse practices common in a science community might be enacted in the elementary classroom. Researchers (for example, Smith & Anderson, 1999) have begun to examine ways to introduce these discourse practices to preservice teachers. Most work, however, involves students who elect to engage in extra science courses as part of their preservice program. This suggests a degree of affiliation with a science community not in accordance with the general profile of most elementary teachers. Little has been done to link practicing teachers with practicing scientists.

The importance of being situated where community discourse practices may be appropriated does not lie only in the opportunity to develop facility with various language genres. Rather, the discourse practices *themselves* serve to relay companion meanings that illuminate a multidimensional view of science. In the context of this study, the genre of debate, enacted by the scientists on several occasions, gave the research group new opportunity to witness aspects of the scientific terrain. The scientists intended, through re-enactment of the trial of Giordano Bruno, to demonstrate that the work of Galileo was important, not only in advancing scientific principles but in terms of its cultural, political and social ramifications. This understanding ran the risk of being reduced to mere factual data regarding the Copernican revolution, however, were it not for the life breathed into our new understanding by the various opportunities we had to observe debate among the scientists.

The debate following the play was immediate and living evidence that scientists deal in interpretation of events. We were struck by the realization that, while events might occur in a particular way, the meaning of these events is by no means certain. During the moon project, we became aware that scientific knowledge is not accepted as knowledge simply because it emerges as the result of investigation. Rather, it becomes established as it is deemed appropriate by the scientific community at large. This point was reiterated in several discussions, through historical stories that were evoked to elucidate explanations, through the words of Galileo in *Sidereus Nuncius* and as we observed the scientists negotiate meaning among themselves.

In terms of this study, the art of debate was not so much an opportunity to practice using rationale to convince an opponent of the "rightness" or "superior logic" of one's position. Instead, the debate gave our research group the chance to experience an alternative to the textbook compendium of factual knowledge. By witnessing ongoing and successive debates, we *lived* the understanding that, in science, mere facts do not constitute knowledge. Indeed, factual information may be used as data for competing positions. At the same time, our experience pointed to the idea that a science community has both a role and a responsibility in assessing positions and monitoring debate.

Our experience of observing people we deemed experts asking multiple questions of each other was profound. The dominance of questions fostered the idea that a neighborhood of science is peopled with members who still consider themselves learners—and the growing awareness that an expert in one area of science is not necessarily an expert in all areas. This awareness, coupled with our new understanding regarding the relative tentativeness of scientific knowledge, also brought to the forefront our own questions regarding the purpose of science education and the way science learning ought to be structured.

Through examining personal practices. Participating in the discourse practices of a scientific community also stimulated examination of the language practices characterizing our own teaching of science. We articulated a need to re-characterize inquiry so that results are no longer couched in terms of right and wrong or whether they "worked" or "did not work." We realized that debate, while perhaps a genre with which we were less comfortable, should receive greater attention in our classrooms. We began to focus attention on the questions asked *by* our students, not just on the questions we asked *of* our students.

At the same time, we began to find ways to increase time for science, and to enrich the experiences of our students. We agreed that passion must factor heavily into the messages we present to our students, and so we must actively look for ways to bring science we find personally interesting into the classroom. This means looking beyond the boundaries of the prescribed topics and being attentive to the science questions in our own environments. Possible areas we discussed were weather/seasonal changes, newspaper articles that introduce topics of interest, classroom pets, plants and children's books that depict a neighborhood of science. Finally, we became convinced that our role is not to know all the answers, but instead to be able to navigate a scientific neighborhood with enough confidence to seek out these answers and begin developing the skills necessary for investigation and inquiry.

Role of Metaphor in Shaping Discourse

Introduction

Authors have indicated that overt metaphors are useful for revealing assumptions about learning and teaching (Aubusson & Webb, 1992; Briscoe, 1991; Collins & Green, 1990; Lakoff & Johnson, 1980; Milne & Taylor, 1995; Provenzo et. al., 1989; Thomas, McRobbie & English, 1999) and for stimulating change in practice (Carter, 1990; Munby & Russell, 1990; Tobin, 1990). The intent of this research was to use a new metaphor as a tool to instigate discourse regarding science at the elementary level, and to mark any changes that occurred during the months of discourse following an introduction to a neighborhood of science.

It was the metaphor which helped the teachers to reconstitute a neighborhood of science. Analysis reveals that the metaphor was a much more powerful tool than originally intended. Rather than acting only as an initial stimulant, it operated on three levels, each with a distinct purpose and function, through the duration of the research. In the first level, metaphor was used as a tool to *stimulate discourse* regarding the characterization of science and elementary science teaching among the participants. In the second level, metaphor was *an impetus for change* as teachers began to juxtapose personal areas of strength alongside areas of weakness. Finally, on the third level, metaphor became *a framework* for data analysis and for situating the research amidst the background literature. See Table 3 for a summary of how the metaphor operated in each level.

Table 3

How the Metaphor Operated at Three Levels

Aspects	Level One	Level Two	Level Three
Agent	Teachers	Teacher Researcher	Research community
Purpose	Heuristic device Stimulus	Heuristic device Impetus for change	Framework
Function	Entry into discourse	Simultaneous positioning	Situating research
Role	Figurative	Figurative	Figurative Generative

Level 1: Metaphor as a Stimulus

In the first two levels, the metaphor served as an heuristic device, instigating reflection and facilitating a process of discovery. More specifically, in the first level the metaphor operated as a *stimulus,* providing an entry into a discourse of science for teachers. Within this level, the focus is primarily on the teachers themselves and how, individually and collectively, a neighborhood of science with respect to teaching at the elementary level comes to be constituted.

The teachers in this project brought with them a wealth of experience and success in the educational field. While one of the members was a relative neophyte, the rest had, collectively, more than 100 years of experience teaching at the elementary level. They were familiar with educational trends, with learning, with teaching, with schooling as an institution, with public perception; in short, with all the dimensions that characterize the teaching profession. Several had given presentations in their areas of strength, one was recognized in the district as a mentor and two had been nominated for teaching awards. In short, these teachers brought with them not only experience, but expertise.

At this level, the metaphor is used in tradition 1 (see page 18), namely as figurative metaphor. Thus, through overt comparison, the familiarity in one scenario is used to illuminate a lesser known area. Metaphors are powerful in their ability to create new understanding as two things are juxtaposed. They have a dual effect in that they simultaneously satisfy and fascinate. In this case, the familiarity and experience of being in one's own neighborhood is mapped onto the familiarity one must help inculcate in elementary school students. This positioning is satisfying for an experienced elementary teacher, as one immediately realizes the appropriateness of such a comparison. It is intriguing in that one feels compelled to tease out the five dimensions to see if this appropriateness is sustained. New understanding is evoked through the unravelling of these dimensions as the two situations are compared.

As mentioned earlier, the strength of this neighborhood metaphor first became evident when members heard a description of the metaphor. With each description of the research project, there was an instant acknowledgement of "fit," a recognition that there was indeed similarity between elementary instruction and being at home in one's neighborhood. This fitness was never disputed and was in fact reiterated throughout the project as the neighborhood metaphor was used to describe expertise in curricular areas other than science, as well as expanding into many other areas of life.

It was this resonance that drew several participants into the project in the first place and made them willing to invest time and energy in reconstituting their beliefs about science and science education. This willingness is significant. A shift in focus, from regarding professional development as the implementation of new methods and materials to one of facilitating the change of belief systems, requires dedication and extended commitment. Teachers must not only have *reason* to change; they must also have an intention regarding the direction of the change. This intention cannot be mandated or otherwise decided by outside influence. To engender sufficient commitment, the direction must come from within individual teachers. The neighborhood metaphor provided an immediate glimpse into possible directions for change. At the onset, this glimpse was sufficiently powerful to entice the participants into a discourse; eventually, it paved the way for the need to change.

Level 2: Metaphor as an Impetus for Change

At the second level, the metaphor also acted as a heuristic device. Here it is used by the researcher as an *agent of change* through its ability to simultaneously position the teachers in areas of strength and weakness. This simultaneous positioning eventually became an impetus for change as the teachers acknowledged a need for personal development with respect to their relationship to a science neighborhood.

Simultaneous positioning. The power of the metaphor did not lie only in its ability to resonate with teachers. Its capacity to be transferred into other areas of the curriculum meant that metaphor could be used as a reference point for each teacher in individual areas of expertise. Giving teachers the opportunity to position themselves within a neighborhood of personal strength also provided a contrast to their positioning in a neighborhood of science. This contrast stimulated comparisons, not between one teacher and another, but rather between each individual's characterization as a teacher in the professed area of expertise, and as a teacher of science. By examining their expertise in one or more areas, the teachers were able to recognize the multiple and specific ways in which their expertise contributed both to successful teaching and to a feeling of comfort. To help illuminate a science neighborhood, they drew examples of what knowledge of the boundaries, acquaintance, frequent encounters, savvy and membership meant in their areas of expertise. Inevitably, this comparison encouraged fruitful discussion, for the teachers had a reference point from which to begin speaking rather than being at a loss for words in a territory of which they confessed they knew little.

Their ease with the planning, assessment and teaching of other curricular areas such as language learning (all) art (Erica), and mathematics (Sara) was evident in the rich conversation that surrounded these topics. Ideas were frequently shared, comments were made pertaining to the historical development of the profession and known experts in the field with whom they had studied as part of professional development were cited. At the same time, when discussing these particular subjects, the passion and enthusiasm of the teachers shone through.

The metaphor thus encouraged the teachers to examine themselves as they were simultaneously positioned in two neighborhoods. Once they began to discuss their positioning in a neighborhood of science in contrast with their position in a neighborhood of comfort, the teachers began to re-examine some of the reasons they proffered for the difficulties with a science curriculum. This was particularly noticeable with respect to time constraints, a factor commonly cited across the literature as a reason teachers give for decreasing the amount of time spent on science teaching. Throughout our discussion, it became apparent that, although this constraint is felt in other subjects as well, teachers freely put in compensatory measures. By examining how this difficulty was overcome in other areas, the teachers began to realize that it is not the lack of time that is at issue, but rather the decision of which subject is to be "massaged" that is the concern. These conversations inspired three of the four teachers, for whom lack of time was a real issue, to make changes that would ensure their science minutes were not only maintained, but increased.

Establishing an impetus for change. The comparison established the need for change with respect to a science neighborhood, a decision that was hardly surprising. If, as the research indicates, teachers are governed by the images they create regarding the profession as well as the subject matter, then changing an image might necessitate a subsequent change in action. Such was clearly the case with respect to this research. Once the teachers acknowledged that the metaphor was appropriate with respect to their neighborhoods of strength, they accepted that it would be equally appropriate in an area of weakness, in this case the teaching of science. Hence they were willing to discuss the implications of each of the dimensions, in spite of the fact it might point to personal and professional gaps.

The neighborhood metaphor suggests that the role of other members in the community is very important, both in modeling particular ways of behaving so neophytes can engage in participatory appropriation (such as learning the discourse practices) and in providing opportunities for guided participation. One of the outcomes of our discussion regarding comfort in a neighborhood of science was awareness that the teachers were unfamiliar on a personal level with any scientists and with the way "real scientists" work in their particular fields. They recognized that, to have their students at home in a neighborhood science, they would need to become acquainted with some of its members. Thus, in spite of a great deal of insecurity, the teachers were willing to become involved in a project with scientists to help diminish the gaps they recognized.

Level 3: Metaphor as a Framework

On a third level, the agency shifts from teachers and the researcher to the community in which this research is situated. The metaphor acted as a *framework* during all phases of the research. It stimulated the initial questions for the researcher, situated these questions within the relevant background literature, provided categories for analysis and framed the discussion and implications. The continual presence of the metaphor through the phases attests to its value as a research tool.

Situating the research. As mentioned in the literature review, Rutherford's dimensions have been explored by the research community, under different labels. The knowledge teachers have of the boundaries of science and their personal savvy with respect to science have been subsumed under issues of competence and the need to develop a more holistic view of the nature of science. Research into professional development and teacher education has focused on developing an acquaintance with various scientific phenomena and engaging in scientific inquiry (frequent encounters). Feelings of membership in the community of science have been reiterated as areas of (non) confidence.

The value of using this metaphor lies in its ability to transcend individual dimensions and instead bring into focus the manner by which the dimensions are entwined. Hence, when one issue is scrutinized, *all* issues must be considered. For example, although membership is the most crucial element of Rutherford's neighborhood, it is engendered through the interplay of the other four dimensions. Researchers examining how teachers can move towards an intersection between the neighborhoods of science and teaching may choose to focus on individual dimensions. In doing so, however, they must extract carefully, bearing in mind that a true picture will not emerge until the dimensions are rebraided and relationships are made explicit.

Rogoff (1995) terms this *backgrounding* and *foregrounding*. She cautions researchers that, while one plane of activity may be examined in the foreground, it is essential to consider the participation of other planes of focus, which continue to operate in the background. With respect to the dimensions of Rutherford's neighborhood, this was readily apparent. It was impossible, for example, to articulate how the teachers conceptualized a neighborhood of science on a personal basis, without considering the impact of companion meanings gleaned through the guided participation (interpersonal) and apprenticeship (community) experienced in other planes.

Framing analysis. The metaphor was useful in framing analysis of the data in the same way it was useful in level two, by simultaneously illuminating what was present and not present. During the first stage of analysis, the descriptions used by Rutherford to articulate the metaphor could be directly linked with the utterances of the participants. Once the initial coding was complete and the data/metaphor were examined with respect to the background literature, it became apparent that current research (e.g. work in discourse practices, multidimensional science, sociocultural learning) was missing from metaphor. Hence the need to expand the five dimensions to include qualities articulated by the participants and not by Rutherford. The power of the metaphor was not diminished by these omissions for, by appropriately situating the research in the background literature, both the need and the way were paved for additional categories.

Shaping the discussion. During the final stages, the metaphor switches from figurative to generative use. It becomes less overt, revealed not through direct mapping of one situation onto another, but through the language practices used to conceptualize science and science teaching. This use corresponds with the quality of participants' discourse. Once the project with the scientists was completed, for example, there was little spontaneous articulation of the five dimensions. Instead, the discourse centred on "science talk." In effect, the participants were no longer describing what a neighborhood of science *might* be; they were speaking from within the intersection of the two neighborhoods. The willingness of the scientists to take us on as apprentices and their efforts to engage us in guided participation (albeit in a limited fashion) provided the opportunity for us to experience membership for ourselves. Hence emerges the discussion of aspects of membership in a science community, how this membership can be developed amongst elementary teachers and how metaphors might be used to promote this membership.

CHAPTER VI

IMPLICATIONS:
LOOKING AHEAD

The narrow representation of science in effect acts as a gate-keeping mechanism for elementary teachers. Enthusiasm for various disciplines is fostered through a belief in the potential for the discipline to be relevant in daily life, and through an understanding of how to offer this potential to students. Many elementary teachers are members of multiple neighborhoods and use their work, or the work of other members, as springboards for students. Genres of print, mathematical formulae, paintings and symphonies, as well as examples of conflict resolution are routinely used in an effort to encourage students to become critical readers and writers, to solve numeracy problems, to appreciate works of art and pieces of music and to become responsible members of the democratic process.

Without being privy to the multi-dimensions of a neighborhood of science, one must rely on representations in the media or those conceptualized during school science. When science is reduced to mere factual information, a litany of what has been discovered, it is easy to forget that what we know today at one time was unknown. Without experiencing the processes of science, one cannot identify with scientists who at one time perched on the edge of the unknown and moved into the known with great excitement and enthusiasm. Without talking regularly with scientists, it is easy to believe that the community is populated only by persons of great intelligence, whose lives are dedicated to the pursuit of "Truth" and who, as a result, have little in common with members of other neighborhoods.

The comments by the research group regarding the way the moon "looked like pictures in books" exemplify how removed scientific study had become. For this reason, concern for children who live in an increasingly "virtual world," with fewer and fewer opportunities to study our world, is also concern for ourselves. How can we teach that which we do not know? How can we know that which we have not experienced through a process of indwelling? How can we be enthusiastic about topics that have been reduced to information, with little or no reason for excitement? Our own scientific knowledge typically centres on that which is remembered or delivered via curriculum documents. To dwell within a theory is impossible without an understanding of how, when and why that theory was created. Where do we as teachers have the opportunity to dwell within a science neighborhood and thus reconstitute ourselves? How can we position ourselves in the intersection between the neighborhoods of science and teaching if we have little understanding of what it means to be a member of a neighborhood of science?

Hope for elementary science rests in the use of metaphor. The neighborhood was a powerful metaphor for these teachers, stimulating an instant recognition of dimensions that were untapped. It also connected them to the discourse of others in the academic community by providing a framework for discussion so that conceptual understanding of theoretical perspectives regarding "belonging" could be made explicit. Hence while Polanyi's indwelling (1983) and Gee's Discourses (1996) were never mentioned, they were certainly articulated.

This research suggests that a metaphor can be a powerful stimulus in convincing teachers that a process of indwelling is necessary, in aiding in the process of change and in situating the research within the community of researchers. Unfortunately, there appear to be few such metaphors specifically designed to link a neighborhood of science with pedagogy. I stumbled on this metaphor while looking for ways to represent to my preservice students what the nature of science education at the elementary level might be. Since that time, I have not found any others. Given the link between thought and language, the paucity of suitable metaphors is serious.

This study has implications for both professional development and preservice teacher education programs. Our attempts to improve the quality of science education at the elementary level must go beyond the development of curricula and new teaching methods. We must find ways to introduce neophyte and practicing teachers to a *neighborhood of science*.

At the preservice level this can be done by including those activities which represent the multidimensional aspects of science. This may be in the form of readings which point to the cultural, historical and social aspects of science and through opportunities to "engage with phenomena" (Duckworth, 1996, p. 151). Projects such as plant growth, pond studies, wetland monitoring and moon studies are manageable within the confines of the academic schedule, and could be used to springboard students into experiencing what it means to reside *in* rather than simply learning *about* the science neighborhood. Having courses taught in tandem, by members of science and education faculties, would be a way of drawing on the expertise of both, and provide opportunities for preservice teachers to experience being in the intersection of two neighborhoods.

At the inservice level, experienced teachers can be linked with different communities of scientists. Rather than discrete inservices typically provided on an hourly or half day basis, discourse groups could be set up in association with the various neighborhoods of science. Projects such as the moon study in this research could be set up in various areas (chemistry, physics, biology, environmental science). Teachers would then have the opportunity to experience indwelling and increase their content knowledge, while drawing on their expertise at making learning meaningful to young children.

Through a period of indwelling, science experiences can evoke personal passion as well as encouraging ongoing discourse between teachers and members of a science community. This experience will convince teachers at all levels that they have the potential to experience membership in a scientific neighborhood, whenever and wherever they so chose. It will also aid in the development of companion meanings regarding the nature of science more in keeping with a multidimensional view. It may also increase confidence levels, as it did for the teachers in this study.

There are compelling reasons to search for other suitable metaphors and to continue in-depth examination of their use. While the neighborhood metaphor was powerful, it brings with it assumptions, beliefs and tacit understandings that may bar fresh insight. Not all people live in neighborhoods that are safe and comfortable. Nor are all neighborhoods, science included, necessarily welcoming of new members. Further investigation could examine, for example, whether the assumptions embedded in the depiction of scientists as "neighbors" are indeed fitting. These and other difficulties that arise from mapping one set of characteristics onto new terrain ought to be the focus of further work. At the same time, I anticipate this metaphor will not be effective with all teachers, and I can see potential difficulties for at least two groups: teachers without an area of strength and those with a great deal of post-secondary science education.

Simultaneous positioning, while powerful in its ability to inspire the need for change, was useful because it gave teachers the opportunity to examine personal practices from within a neighborhood of strength. Preservice, fledgling or generally poor teachers may not have an area of strength from which to draw these comparisons. While the comparison between one's personal neighborhood and a neighborhood of science may be helpful in painting a picture of what science learning might look like, without an area of strength it seems doubtful that specific dimensions related to becoming members of a science neighborhood will emerge.

Teachers with a heavy background in science, I suspect, will interpret the metaphor to fit the representation of science neighborhoods that continues to be employed in university science courses. The elementary teachers in this study were willing to set aside narrow conceptualizations of the nature of science because they freely admitted that they had little experience with formal science. The initial readings opened up the door to the possibility that science might be different than they expected, and the work with the scientists was examined and interpreted as confirmation of their new (growing) understanding. For teachers who believe that they already adequately navigate a neighborhood of science and have no reason to question their own conceptualization of the nature of science, I doubt this metaphor will transform understanding in any substantive way.

If we as a profession genuinely wish to relate theory to practice, we must begin to actively develop metaphors that act on multiple levels. This means examining the work of exemplary teachers in all disciplines, not to isolate specific successful methods, but instead to recognize the metaphors guiding their practice and then develop ways to make these metaphors meaningful to others. It means gathering a variety of metaphors, useful with multiple teaching populations. It means gleaning metaphors present in the research and literature surrounding the teaching of science. It also means looking for ways metaphors might braid the various aspects under scrutiny in the research, and thereby offer a richer picture of issues in science education. This cultivation cannot be done in isolation, nor can it be done away from the places where life is breathed into educational metaphors. It must be done with practicing teachers, and it must be done soon.

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Appendix A

Research Timeline

Date	Purpose	Duty of Chair
February 17/98	Discuss Rutherford article Flesh out boundaries	Asked to bring Cross article for next week/Set up project with scientists
March 3/98	Discuss Cross article Continue to flesh out boundaries	Asked to bring in article regarding difference between science/technology
April 28/98	Sharing background related to science Discuss Gardner et al. article	Gather supplies
May 12/98	Meeting with scientists Dramatic presentation of trial of Giordano Bruno. Discussion regarding relationship between science and history, religion Built telescopes	Same as others, locate sun, sketch, view moon, sketch Read first chapter in *Siderius Nuncius*
May 19/98	Dinner meeting with teachers to discuss experience last week	Confirm times
May 19/98	Meet with scientists. Discussion regarding why scientists chose to be in field. Discussion on Galileo, orientation to sky via slide show/discussion	Facilitate getting to know more about the scientists
August 27/98	Meet with teachers to begin the moon project. Discuss first transcripts, Outside to locate the moon	Call on others to make sure no technical difficulties in the weeks ahead
August 30/98		Problems with wobbling Locate tripods for all

Timeline continued

Date	Purpose	Duty of Chair
Sept 1/98	Meet with Sarah to set up telescope/tripod	
Sept 2/98	Meet with Erica to set up telescope/tripod	
Sept 3/98	Meet with Catherine to set up telescope/tripod	
Sept 26/98	Meet with 3 teachers and scientists to share findings and view the sky together	
Sept 30/98	Meet with 2 teachers and one scientist to share findings and view the sky together.	
October 21/98	Meet with teachers to discuss experience. Discuss metaphor in light of experience	
December 14/98	Meet with teachers. No set agenda.	
January 22/99	Interview with Erica	Develop questions to clarify any missing information about background in science/planning etc.
February 22/98	Interview with Catherine	Develop questions to clarify any missing information about background in science/planning etc.
March 3/99	Interview with Anne	Develop questions to clarify any missing information about background in science/planning etc.

Timeline continued

Date	Purpose	Duty of Chair
March 4/99	Interview with Sarah	Develop questions to clarify any missing information about background in science/planning etc.
March 10/99	Interview with Jean	Develop questions to clarify any missing information about background in science/planning etc.
March 17/99	Meeting with teachers Read transcript together Share analysis strategies, written descriptions	Prior to meeting write background descriptions
October 20/99	Meet with teachers. Discuss analysis Outline findings	Prior to meeting send copies of analysis to each teacher Outline discussion

Appendix B

Articles used to Stimulate Discussion as Requested by the Teachers

Cross, B. (1990). A passion within reason: The human side of process. *Science and Children, 27*(4), 16-21.

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Appendix C

Rules for Group Discussion: Role of the Chairperson (McKernan, 1991)

1. To define and clarify the issue to be discussed.
2. To ensure that their view is equal to others, not dominant.
3. To serve as a model for critical and reflective problem solving.
4. To ensure adequate time is given to participants.
5. To protect individual points of view and divergence.
6. To introduce new ideas into the discussion in order to provide new perspective, facilitate development of an already mentioned point, represent a new set of concepts, or challenge consensus.
7. To organize a setting conducive to discussion.
8. To facilitate the processes identified by the participants, provide the necessary supplies, etc.

Appendix D

Self-monitoring (McKernan, 1991)

- To what extent do I feed evidence and ideas into the group?
- How much do I interrupt?
- Do I press for a particular stance?
- Do I ask rhetorical questions? Questions to which I already know the answer?
- Do I press for consensus?
- Do I summarize positions at relevant points?
- Do I listen attentively to all contributions?
- Do I dominate, or make the largest contribution?
- Do I offer evaluative comments on input?
- Am I an 'authority' in my approach?

Appendix E

Expanding Rutherford's five Dimensions of a Neighborhood of Science

1. Knowledge of the Boundaries was modified to include:

   The difference between science and technological problem solving within the Alberta Program of Studies.

   Multidimensional science - expanding boundaries formed by participants' conceptualization of science as per their high school experience.

   Language used in the neighborhood.

2. Acquaintance was modified to include:

   An opportunity to know scientists.

   An awareness of what (some)scientists are like.

   Experiences with science; both in school and out of school.

   Personal interest.

3. Savvy was modified to include:

   The understanding that science is defined by culture.

   An awareness that science is connected to other areas of life.

4. Frequent Encounters was modified to include:

   Teachers having frequent encounters -with units, daily life.

   Increasing science opportunities for students.

5. Membership was modified to include:

   Personal feelings toward science.

   Seeing science as part of daily life.

   Increased comfort with the teaching of science.

Appendix F

Major Themes and Subthemes of the Analytic Scheme

1. Science and other neighborhoods
    1.1. Language Learning
    1.2. Personal interest in topics
    1.3. Curriculum
    1.4. Assessment

2. Knowledge of Boundaries
    2.1. Science and technology
    2.2. Role of language
    2.3. Forms of language

3. Acquaintance
    3.1. Stereotypes
    3.2. Previous experiences in science
    3.3. Background knowledge

4. Savvy
    4.1. Appetite for science
    4.2. Confidence with respect to science
    4.3. Value of having science experts at the elementary level
    4.4. Interconnectedness
    4.5. Discourse shaping the experience of students

5. Frequent Encounters
    5.1. The study of that which is 'real'
    5.2. Value of frequent encounters for school science
    5.3. Limiting factors for school science
    5.4. Possibilities for increasing frequent encounters

6. Membership
    6.1. Working with members
    6.2. Language practices which indicate the development of membership
    6.3. Personal enjoyment

Appendix G

Structure of the Alberta Elementary Science Program (Alberta Education, 1995, p.A.4)

Grade	Topic	Emphasis
1	A. Creating Color B. Seasonal Changes C. Building Things D. Senses E. Needs of Animals and Plants	Science Inquiry Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry
2	A. Exploring Liquids B. Buoyancy and Boats C. Magnetism D. Hot and Cold Temperature E. Small Crawling and Flying Animals	Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry Science Inquiry
3	A. Rocks and Minerals B. Building with a Variety of Materials C. Testing Materials and Designs D. Hearing and Sound E. Animal Life Cycles	Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry Science Inquiry
4	A. Waste and Our World B. Wheels and Levers C. Building Devices and Vehicles that Move D. Light and Shadows E. Plant Growth and Changes	Science Inquiry Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry
5	A. Electricity and Magnetism B. Mechanisms Using Electricity C. Classroom Chemistry D. Weather Watch E. Wetland Ecosystems	Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry Science Inquiry
6	A. Air and Aerodynamics B. Flight C. Sky Science D. Evidence and Investigation E. Trees and Forests	Science Inquiry Problem Solving through Technology Science Inquiry Science Inquiry Science Inquiry