Developing Scientific Literacy of Grade Five Students: A Teacher-Researcher Collaborative Effort

by

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

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Abstract

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The goal of this study was to develop scientific literacy of grade five students in the context of a curricular unit on Weather. To fulfill this goal, a teacher-researcher team used the *Common Knowledge Construction Model (CKCM),* designed by Ebenezer and Connor (1998), and engaged themselves in a collaborative journey to develop three notions of scientific literacy--the "what," the "how," and the "why" of science.

This was an ethnographic, classroom based study, in which the researcher was a participant observer of all school endeavors. The data were collected by means of classroom observations, interviews, students' written work, maps and photographs. Subsequently, the data were coded to generate patterns and meanings.

Qualitative evidence shows that the CKCM and the teacher-researcher collaboration contributed to the development of scientific literacy of grade five students in this particular context. With respect to the "what" of science, students developed an understanding of the concepts and principles of weather, as recommended by the Manitoba Education and Training. With respect to the "how" of science, students comprehended that scientific knowledge is: a) partially based on human imagination and creativity, b) tentative, c) socially and culturally embedded, d) empirical, and e) developed through many methods. With respect to the "why" of science, students became aware of the intricate relationship among science, technology, society, and environment (STSE).

The findings of this study have implications for teacher education and professional development. Based on these research findings, the following recommendations are made:

- Science methods courses should offer instruction about the nature of science.
- The faculty of science and education should work together to develop courses that aim at teaching science subject matter from multidisciplinary perspective. Most importantly, all pre-service teachers majoring in elementary and middle years education should be required to take such course(s).
- Science educators and beginning teachers should engage in long-term, contemporary collaborative studies, which involve working with real students in authentic classroom situations.

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Chapter 1

Background

1.1 Scientific Literacy for All

There is a clear national consensus in the United States that *all* elementary, middle, and secondary school children need to be better educated in science, mathematics, and technology. That race, language, sex, or economic circumstances must no longer be permitted to be factors in determining who does and who does not receive a good science education. To neglect educating any child in science is to take from that child an essential education hindering his or her growth for life, and depriving the nation of talented workers and informed citizens. Such convictions led the American Association for the Advancement of Science (AAAS) to initiate Project 2061 (AAAS, 1989). The project aspired to develop a shared vision that would clarify the goals and purposes of K-12 science education, and provide a long-term, multiphase plan that would make specific recommendations for achieving science literacy for *all*.

Project 2061 was organized into three phases. *Science for All Americans* (Rutherford & Ahlgren, 1990), in Phase I, served as a starting point for the long-term reform process, by providing conceptual basis for the recommended changes. The conceptual frameworks were based on the belief that the scientifically literate person is "one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1989, p. 4). These ideals of a scientifically literate person apply to *all* young people, regardless of their social and economic circumstances, language, race, sex, and career aspirations. In Phase II, *Benchmarks for Science Literacy* (AAAS, 1993) specified the knowledge, skills, and attitudes to be attained at each grade level, thus emphasizing what *all* students should know at the end of each grade. The recommended conceptual frameworks and tools laid out in theoretical frameworks documents I and II formed the bases for Phase III, to facilitate the necessary and lasting changes to produce scientifically literate citizens.

In 1996, the National Research Council (NRC) published the *National Science Education Standards,* which reiterated "*All* students, regardless of gender, cultural or ethnic background, physical or learning disabilities, aspiration, or interest and motivation in science, should have the opportunity to attain higher levels of scientific literacy than they currently do" (NRC, 1996, pp. I-6-7). The goal of the *Standards* was to create a vision for the scientifically literate person and guidelines for science education that would allow the vision to become a reality. This document also spells out the attributes of a scientifically literate person, who: "can ask, find, or determine answers to questions derived from curiosity about everyday experiences"; is able to "read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions"; can "identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed"; is competent to "evaluate the quality of scientific information on the basis of its source and the methods used to generate it"; possesses the ability to "pose and evaluate arguments based on evidence and to apply conclusions from such arguments" (NRC, 1996, p. 22).

A year after the *Standards* document was released in the United States, the Council of Ministers of Education (CMEC), Canada, issued the *Pan-Canadian Protocol for Collaboration on School Curriculum.* This protocol initiated *The Common Framework of Science Learning Outcomes, K to 12*. This *Framework* had a vision that "*All* Canadian students, regardless of gender or cultural background will have an opportunity to develop scientific literacy" (CMEC, 1997, p. 4). Specifically, the CMEC established four foundation statements, which reflect the wholeness and interconnectedness of learning with an aim to develop scientific literacy.

The first foundation, Science Technology, Society, and Environment (STSE), envisions that scientifically literate person develops an understanding of the NOS, of the relationships between science and technology, and of social and environmental contexts of science and technology. The second foundation, Skills, foresees that scientifically literate person develops the skills required for scientific and technological inquiry, for solving problems, communicating scientific ideas and results, working collaboratively, and for making informed decisions. The third foundation, Knowledge, specifies that scientifically literate person develops knowledge of theories, models, concepts, and principles in widely accepted science disciplines, such as life science, physical science, and Earth and space science. More importantly, scientifically literate persons are able to use these understandings to interpret, integrate, and extend their knowledge. The fourth foundation, Attitudes, specifies that scientifically literate person develops behaviors that manifest appreciation of and interest in science, scientific inquiry, collaboration, stewardship, and safety, which are required for the mutual benefit of self, society, and the environment.

Adapting the *Pan-Canadian Protocol for Collaboration on School Curriculum*, Manitoba Science Curricula outline five foundations that build scientific literacy: 1) NOS and Technology, 2) Science Technology, Society and Environment (STSE), 3) Scientific and Technological Skills and Attitudes, 4) Essential Science Knowledge, 5) Unifying Concepts (Manitoba Education and Training Ministry, 2000, p. 2.3). More aptly put, global interdependence, rapid scientific and technological innovations, the need for a sustainable environment, economy, society, and the pervasiveness of science and technology in daily life reinforce the importance of scientific literacy. The Ministry also recommends that scientifically literate individuals can more effectively interpret information, solve problems, make informed decisions, accommodate change, and create new knowledge.

Since the release of reform documents, science education researchers have been also attempting to reiterate the specifics of scientific literacy. When Korpan, Bisanz, Bisanz, and Henderson (1997) state that a scientific literate person should have the ability to comprehend, interpret and evaluate information and conclusions, it means they agree with the notion of developing in students the processes of scientific inquiry. What the general public needs to know *about* science (DeBoer, 2000; Laugksch, 2000; emphasis is mine) is also alluding to the development of the scientific inquiry processes. The emphasis of Zeidler, Sadler, Simmons, and Howes (2005) on the possession of knowledge, skills, and attitudes considered necessary for professional scientists refers to the characteristics that learners of science should develop to become scientifically literate. For Abd-El-Khalick and BouJaoude (1997), “a scientifically literate person should develop an understanding of the concepts, principles, theories, and processes of science, and an awareness of the complex relationship among science, technology, society, and environment” (p. 673). To achieve any form of scientific literacy, some authors point out that language development is important. Lemke (1990) argues for the development of appropriate scientific vocabulary to read with understanding. Hewson (2002) considers the ability to read and write, as literacy in its prototypical form, crucial to achieving any of the aspects of scientific literacy. Anderson (1999) agrees that someone unable to read and write is unlikely to achieve even a rudimentary level of scientific literacy for "reading and writing are the mechanisms through which scientists accomplish their task. Scientists create, share, and negotiate the meanings of inscriptions - notes, reports, tables, graphs, drawings, diagrams" (p. 973). To reading and writing, Osborne (2002) has added the necessity of argumentation skills for the development of scientifically literacy. Without these skills people are like “a ship without a sail” (p.203). Flower (2000) takes us to another dimension for developing students’ capacity to read for he states that learning to read lay articles about scientific and technological matters published in newspapers and magazines with reasonable understanding is vital.

A critical analysis of the reform documents and the researchers notions cited above points to the following core characteristics of scientific literacy: (1) interdependencies of multi-disciplines; (2) societal technological, environmental, and cultural related scientific issues; (3) understanding and use of scientific knowledge in scientific investigations and problem solving; (4) scientific inquiry processes; (5) scientific attitudes and dispositions; and (6) global interdependence and sustainable living. Despite the variations in what it means to be scientific literate, developing scientific literacy is considered to be a "good thing" (Laugksch, 2000), and has been identified as a noble goal of contemporary science education worldwide. Scientific literacy is viewed as a solution to many economical, social, and environmental challenges of the 21st century (Aikenhead, 1997).

Encapsulating the core characteristics of scientific literacy are three fundamentals: 1) "what" of science (concepts, principles and theories), 2) "how" of science (processes of science), and 3) "why" of science (science, technology, society, and environment connections). The first fundamental principle of scientific literacy emphasizes that a scientifically literate student understands scientific concepts, principles, and theories. This refers to the development of the knowledge of science (Ryder, Leach, & Driver, 1999). With *what* we know (Hodson, 1993), we may be able to "do" or "use" science (Hazen & Trefil, 1991). Doing of science refers to the ability of doing what scientists do in a specific field of study. In contrast, the "use" of science refers to the ability of understanding how new advances in the field occur, and what the consequences of these advances are for citizens. The "use" of science is synonymous with the public understanding of science (DeBoer, 2000; Laugksch, 2000). Although for Hazen and Trefil (1991), using scientific knowledge required to understanding public issues is more important than doing scientific investigations, the reform documents point to the need for both the "doing" and "using" of science to developing scientific knowledge in *all* students--to those few who will be pursuing science and/or science related careers, and those majority who will be good citizens.

The second fundamental principle of scientific literacy, the "how" of science, refers to the epistemology of science, knowledge *about* science (Ryder et al., 1999) or *how* we have come to know science, or *how* science is done (Hodson, 1993). The "how" of science is informed by the history and philosophy, which help us understand that scientific knowledge is a product of a human mind and is created by a community of researchers who are open-minded, intuitive, imaginative, and creative (Arons, 1983; Matthews, 1998). Furthermore, scientific knowledge is tentative, has limitations, and interacts with society on moral, ethical, and social planes (Arons, 1983; Ramsay, 1993). These attributes of scientific knowledge are integral to the Nature of Science [NOS] (Lederman, 1992). The understanding of the NOS in turn enables students to "do" scientific investigations, and consumers (including students) to "use" science in making wise judgments and decisions on scientific matters that involve careful evaluation of scientific claims (Zeidler, Sadler, Simmons, & Howes, 2005). The NOS—key to the development of scientific literacy in school students--will be elaborated in section 1.2.

The third fundamental principle of scientific literacy, the "why" of science, emphasizes the functional aspects of the scientific knowledge, and reflects the relationship among science, technology, society, and environment [STSE]. Understanding of this relationship, in turn, allows people to perceive the world in a different, more holistic, rather than mechanistic way (Pedretti, 1997). Such understanding, Pedretti claims, helps people reconsider human needs in relation to natural resources in an effort to maintain a life-giving and life-sustaining environment. Understanding the why of science develops the individual's ability to apply scientific knowledge for personal and societal purposes (Rutherford & Ahlgren, 1990), and leads to informed decision making and action taking (Aikenhead, 1997; Lederman & O'Malley, 1990; Zoller & Gross, 2001).

Problems and issues proliferate, requiring cooperative effort to preserve the environment so that resources would last for the future generations. The capacity and willingness to act environmentally responsible—taking an active role in recognizing problems, contributing solutions, and making decisions about local, national, and global issues is being scientifically literate (Hodson, 1998). To sum up, the third notion of scientific literacy involves the development of personal qualities and attitudes, the formation of one's own views on a wide range of issues, and the establishment of one's position, contributing to the cooperative effort for the common cause.

1.2 Natures of Science and Trends

Over the past century, as early as the beginning of the twentieth century, an adequate understanding of the NOS has been recognized as one of the most important educational goals worldwide for developing scientific literacy. Although the phrase "NOS" was not used, some characteristics of science were recommended as goals worth pursuing in science teaching. For instance, in 1907, the Central Association of Science and Math emphasized the processes of science in science teaching (Lederman, 1992).

Dewey (1916) recommended that understanding scientific method is more important than the acquisition of scientific knowledge. Jaffe (1938) included the NOS objectives in his high school textbook. Saunders (1955) described teaching about the NOS as "probably the most important purpose of science teaching" (p. 21).

In the sixties NOS became "one of the most commonly stated objectives for science education worldwide" (Kimball, 1968, p. 624). An effort was made to shift science instruction away from the primary focus concerning "What we know?" to an examination of the question "How do scientists know?" (McComas, Clough, & Almazroa, 1998). For instance, the National Society for the Study of Education (1960) established two major goals of science teaching; one being knowledge, and the other being enterprise. Hurd (1960) clarified that students should acquire knowledge of science concepts and principles as well as learn how that knowledge has been developed, and how it is used. In England, the Association of Science Education, in its policy statement on Science and Education, stressed the importance of developing an understanding of the NOS among school students (Murray, 1963). The International Conference on the Education of Professional Physicists included, among its recommendations, that the development of the understanding of the NOS "should be given most serious consideration in the modernization of physics education" (Brown & Clarke, 1966, p. 132).

At the end of the sixties and the beginning of the seventies, several books called for an inclusion of the NOS in school science curricula. For instance, Robinson (1968) published *The NOS and science teaching,* and, in the seventies, Martin (1972) published

Concepts of Science Education: A Philosophical Analysis. In the eighties, the NOS gained even greater importance because of the worldwide scientific literacy movement (Shamos, 1995). During this decade, improving the scientific literacy of the public became one of the most compelling challenges facing science educators (Lederman & Zeidler, 1987). More recently, the NOS has found a firm place in the major North American science curriculum proposals and standards that emphasize scientific literacy (AAAS, 1993; NRC, 1996; NSTA, 1991; CMEC, 1997). However, there are problems in regard to (a) whose NOS should be taught? (b) Why teacher/student deficiencies in NOS?

1.2.1 Whose NOS Should be Taught?

Science educators, sociologists, historians, and philosophers of science attach different meanings to the "NOS" (Lederman, et al., 2002). Smith and Scharmann (1999) suggest that it is probably impossible to achieve unanimity on a list of characteristics of the NOS since positivists argue with radical constructivists, who argue with empiricists, realists, feminists, Marxists, multiculturalists, universalists, instrumentalists, logical empiricists, and idealists. Furthermore, as pointed out by Suchting (1995), it is fair to assume that as science grows and our understandings of the universe increase, our views of the NOS are themselves likely to evolve. Although there is no consensus on the matter (Alters, 1997), science educators agree on several characteristics of the NOS, which are useful and relevant to the daily lives of K-12 students. Abd-El-Khalick and Lederman (2000) call these characteristics a 'shared wisdom' about the NOS.

Abd-El-Khalick and Lederman (2000), Lederman et al. (2002) and Schwartz and Lederman (2002) characterize the NOS in 6 ways, which are accessible to the students. According to these authors scientific knowledge is: 1) empirical (based on and/or derived from observations of the natural world), 2) partially based on human inference, imagination and creativity, 3) tentative (subject to change), 4) theory-laden (subjective), 5) socially and culturally embedded, and 6) developed through many methods. Two other characteristics of the NOS pointed out by these authors are: distinction between observation and inference, and between scientific theories and laws. Based on these natures of science that contribute to the development of scientific literacy, the key ones will be depicted in a conceptual change inquiry model in Chapter two.

1.2.2 Why Teacher/Student Deficiencies in NOS?

Despite concerns about the relevance of science education for nearly a century, research clearly shows that most K-12 students and their teachers hold naive views of the NOS (Bencze & Hodson, 1999; Duschl, 1988, 1990; Lederman, 1992, 1999; Lederman & Latz, 1996; Wang, 2001). Many teachers and school science curricula continue to promote a view of scientific practice that is philosophically congruent with the 1960s and early 1970s, and, as a result, many students leave school with deficient or distorted views of scientific inquiry (Bencze & Hodson, 1999). Even students with the most grade success in science do not necessarily grasp fundamental concepts about the NOS (Cobern, Gibson, & Underwood, 1999). For example, most students and teachers believe that all scientific investigations adhere to an identical set and sequence of steps known as the scientific method (McComas, 1996) and that theories are simply immature laws

(Horner & Rubba, 1979). Elements of imagination and creativity from the process of creating scientific knowledge are excluded (Meichtry, 1992). Overall many teachers believe that science is a body of knowledge consisting of the collection of facts (Gess-Newsome & Lederman, 1993; Hasweh, 1996; Simmons et al., 1999), and that the goal of science teaching is to teach these "truths" (Bryan, 2003). Learning facts, hypothesis, and theories of science seems to be the "cereals" of school science (Duschl, 1994). Any wonder students believe that science equals absolute truths (Aguirere, Haggerty, & Linder, 1990; Duschl, 1994; Horner and Rubba, 1979). Consequently, teachers concentrate their efforts to teach "what" we know without paying any attention to "how" we know (Hodson, 1993).

That teachers rarely or never go beyond science content in their instruction, and do not relate content to other domains of scientific literacy to provide a larger context is also a fair criticism (Cobern, Gibson, & Underwood, 1999). As pointed out by Lemke (2001), "the most sophisticated view of knowledge available to us today says that it is a falsification of the NOS to teach concepts outside of their social, economic, historical, and technological contexts" (cited in Bencze, Bowen, & Oostveen, 2003, p. 2). Osborne and Freyberg (1986), Rutherford and Ahlgren (1990), and Linn (1998) claim that students at the elementary, middle and high school levels do not develop an understanding of science that is useful for their everyday lives. Other studies have suggested that students do not see how science applies to everyday life (Linn & Hsi, 2000), and that there is very little integration of science within everyday thinking among students (Cobern, et al., 1999).

1.3 New Directions for Professional Development

The teachers' lack of understandings of the NOS is clear evidence that universities do not adequately prepare teachers to face the challenges of their profession. Consequently, "high quality professional development program" for in-service teachers is required to achieve the reform goals in regard to scientific literacy movement and facilitate change in teachers' practice (Supovitz & Turner, 2000, p. 694). According to various sources, a high quality professional development program should meet the following criteria:

a) Engage teachers in intense and sustained professional development activities so that evidence may be gathered to reveal how PD impacts students that they teach (Weiss, 2002; NRC, 1996),
b) Engage teachers in inquiry models of teaching (Bybee, 1993; Yager, 2005),
c) Engage teachers with their students in real teaching tasks in the classroom or in the field (Darling-Hammond & McLaughlin, 1995),
d) Focus on the teacher development of the subject-matter and pedagogical content knowledge (Cohen & Hill, 1998),
e) Ground teachers in the common set of professional development standards, and show teachers how to connect what they are learning to specific standards for student performance (Hawley & Villi, 1999; NRC, 1996).

In his most recent article, Robert Yager (2005) criticizes professional development programs for not meeting the above - mentioned criteria. To him, most professional development programs are too short, too general and have nothing to do with specific curriculum components or day-to-day teaching. He points out that in-service programs are usually offered during summer, in the form of summer institutes or one-day workshops. They happen in isolation from the students, do not parallel real teaching situations, and focus exclusively on the study of the content without any suggestions on how it could be used more effectively in the classrooms.

To transform practice, teachers need to immerse themselves as participants in the inquiry of teaching over a long period of time (McDermott, 1990). Evidence of long-term teacher transformation was obtained when teachers were residents in the Model Science Lab during a seven-year study (Harcombe, 2001). Upon returning to their home schools, teachers had permanently changed their ways of teaching to include inquiry-based learning within a community. In this program, teacher achievement was higher than expected, including their achievement in science knowledge. Harcombe's (2001) experimental studies using standardized tests revealed significant increases in students' achievement in science knowledge. However, professional development undertaken in isolation from teachers' ongoing classroom duties seldom has much impact on teaching practices or student achievement (Darling-Hammond & McLaughlin, 1995).

High quality professional development could be achieved through collaboration. This type of professional development has gained popularity in recent years, and is seen as a solution to students' low achievement and both students' and teachers' low level of scientific literacy. In fact, many organizations advocate that collaboration of practitioners from the fields of education, arts, sciences, and public schools is mandatory to achieve excellence in science education (NRC; 1996; National Science Board [NSB], 1999; National Science Foundation [NSF], 1996).

Several organizations in the United States provide funding for such collaborative endeavors. For example, in 2001, the federal government initiated Math and Science (MSP) awards, which are five-year competitive grants, to promote partnerships primarily between post secondary institutions and K-12 schools with the goal to improve performance in math and science (NSF, 2003b). The government also offers scholarships for graduate students and advanced undergraduates in science, technology, and mathematics who support K-12 science and math education in their research by working directly in K-12 schools with teachers and students (NSF, 2003a). There is also a trend to involve PhDs in K-12 science and mathematics education by offering postdoctoral fellowships (PFSMETE) in science education for recent PhDs in the sciences (NSF, 2003c).

In Canada, partnerships among graduate and undergraduate students in science, faculty members in science and teachers are also gaining popularity and funding. For example, there is a nationally recognized Let's Talk Science Partnership Program. The goal of this program is to improve scientific literacy in Canada through educational programs, research and advocacy. The mission of the Let's Talk Science (LTS) endeavor is to develop and deliver quality science education programs to youth in schools and community settings. The LTS involves graduate students, undergraduate students and faculty members who volunteer their time to share their knowledge of and enthusiasm for science with Canadian youth. I am one of the coordinators of this program at the

University of Winnipeg. This initiative is supported by the major granting body, the National Science and Engineering Research Council (NSERC). This organization also supports other partnerships of similar nature. For example, in 2005, the University of Winnipeg has received a grant (I am one on the applicants) in support of a partnership between undergraduate science students and the Manitoba Children's Museum.

More recently, collaboration among science professionals, teachers, and students has caught attention of many scholars (Ballone-Duran et al., 2005; Bartolo & Palffy-Muhoray, 2001; Caton, Brewer, & Brown, 2001; Stein, 2001). Overall the results of these collaborative studies indicate that such partnerships can positively influence the environment of learning science at school and university level. The benefits of such partnerships include insights into the NOS, improved content knowledge for teachers, increased communication, and enriched learning experiences for all students (Bartolo & Palffy-Muhoray, 2001). More specifically, Caton et al. (2001) describe a collaborative effort among energy science engineers, middle and high school students and their teachers who study energy through inquiry. The results of their study indicate that when teachers worked with science professionals on science investigations, they developed interest in science and understanding of science. Additionally, their confidence in their ability to teach science improved, and most importantly, they were willing to incorporate inquiry into their teaching. Teachers are not the only ones who benefit from this type of collaboration. The middle and high school students also developed greater confidence in their abilities to do science.

Science professionals working in collaboration with educators developed an understanding about the new trends in teaching and learning science. The energy science engineers participating in Caton et al's (2001) study, for instance, reported that they have developed familiarity with the principles of science education, a better teaching practices, as well as essential skills and knowledge for disseminating scientific research to nonscientific audience and their own students. Ballone-Duran et al. (2005) looked at the collaboration between professors from the faculty of science and those from the faculty of education as well as teachers and elementary pre-service teachers. Like in the case of Caton et al's (2001) study, collaboration with educators influenced the practice of the participating scientists who realized that they should change their instructional and curricular practices to improve the courses taken by the elementary pre-service teachers.

Those beginning teachers, especially elementary majors, are in the greatest need for professional development (Bell & Buccino, 1997; Druger & Allen, 1998; Glass, Aiuto, & Anderson, 1993). It is during the first year(s) of teaching when the teachers establish many of their techniques and attitudes toward teaching science. If during these initial years, they develop a belief that science is too difficult, and that they do not have the ability to teach science, this belief might haunt them for several years during their classroom teaching, or as a matter of fact, for the rest of their professional lives. Or, if they, for example, develop a popular habit of sacrificing science on the account of teaching other subjects, this kind of practice will probably be continued throughout their career. If, on the other hand, they develop a belief that they are competent teachers of science, they will be willing to try new approaches, redesign their lesson plans, and design new ones. Furthermore, they will be willing to adapt to the reform initiatives and modify the nature of their practice.

In general, collaboration between teachers and university researchers can follow three models: cooperative, organic, and symbiotic (Whitford, Schlechty, & Shelor, 1989). The cooperative type of collaboration usually involves short-term projects characterized by delivery of information from the university to the school. A typical example of cooperative collaboration would be something like a workshop or summer institute for in-service teachers. In this relationship, one partner is generally the "deliverer of service" and the other is the "receiver of service." In most cases, the university educators deliver and school teachers receive. Such collaboration can operate independently of any organizational support and there is no reciprocity in this type of partnership (Whitford et al., 1989).

Reciprocity and mutual self-interest, on the other hand, are characteristics of symbiotic collaborations. In this type of collaboration researchers and school personnel work together to design and implement curricular changes, instructional designs, school improvement programs, and evaluation systems. Dixon and Ishler (1992) explain that in symbiosis the attitude is: "I will help you if you will help me." For example, we will give you something you want (e.g., placement for pre-service teachers), if you give us something we need for our teachers (e.g., workshops, in-services). Mutual good or common interests are not typical of this type of collaboration. However, Whitford et al. (1989) report that common interests are not entirely absent in symbiotic relationships. They exist, but, are either assumed or are so implicit that their identification and nurturance are left largely to chance or to the heroic actions of individuals. Furthermore, contrary to the cooperative model, symbiotic collaboration is associated with the power of institutional support. This support might involve, for example, release time, credit or tuition waver. Sirotnik and Goodland (1988) advise that, although popular, symbiotic relationships are fragile and temporary and recommend organic model of collaboration between schools and universities. Unlike symbiotic relationships, organic model seeks to identify an issue that can be owned by both parties and provides for the development of common interests. In this type of collaboration, careful attention is given to identifying mutual concerns and interests. The results of such collaboration are also jointly owned and both parties are equally involved in the collaborative venture. Dixon and Ishler (1992) warn that this type of collaboration is complex and is built with much time and effort. In addition, in organic relationships, explicit attention to the identification and development of common interests would receive the institutional support necessary to sustain the collaboration.

1.4 Research Questions

A special form of collaboration is between the school teacher and university researcher inquiring into teaching science. Following the teacher researcher collaborative model of inquiry (Ebenezer, 1991; McDonald, 2004), I, a university science educator collaborated with a beginning teacher to study about scientific literacy. In this collaboration, both the teacher and science educator planned and taught a curricular unit. The collaborative partnership was based on trust and mutual understanding in which both parties were involved in most stages of the collaborative effort. Through collaboration with science educator, a beginning teacher can learn how to translate the contemporary philosophy of teaching science that was presented to them in their science methods courses, if it was the case, into their classroom practice. Through intense collaboration both the teacher and researcher can develop an urge to reflect upon their own practices. The educator can see how the philosophy and methodology presented in the science methods class play out in the field. The teacher, on the other hand, can develop greater trust in the validity of certain approaches presented in the science methods course, and willingness to change practice. In this study, I acted not only as a science educator but science professional as well. Although I am not conducting any scientific research at the moment, I have a master's degree in science and in the past I conducted research in the field of aquatic ecology. Presently, I am teaching biology in the Department of Science and I am actively involved in the LTS program at the University of Winnipeg.

This research study is concerned with the development of scientific literacy of Middle Years students in an inner city school setting, Winnipeg, Manitoba, based on the Manitoba science curricula. Prior to embarking on a complex classroom-based study of this sort, it is necessary to understand their teacher's understanding of scientific literacy. The study, therefore, explored the teacher's understanding of scientific literacy. The study then focused on how the teacher develops scientific literacy of *all* students within the context of a unit of study on weather, using a teaching model that systematically incorporates students' conceptions of the subject matter. These broad goals prompt the following research questions:

1. What views of scientific literacy does a grade five teacher hold?
2. What are grade five students' conceptions of weather? And how do these relate to their parents'?
3. How does the teacher develop scientific literacy when he incorporates students' conceptions of weather into the curriculum?
4. What aspects of scientific literacy are evident when a class of grade five students studies a unit on Weather?
5. What are the highlights of teacher-researcher collaboration in the context of developing scientific literacy?

1.5 Significance of the Study

Prairie View School provided an ideal ground to serve and develop the goal of scientific literacy of *all* students. This school has a diverse student body with a big population of Native and Filipino students, followed by Caucasians, and different Asian nationalities. There are also students with diverse diagnosed and non-diagnosed problems and disabilities, such as: abnormal behavior disorder, fetal alcohol syndrome, fetal alcohol effects, and developmental delay. In addition, the students of this school are of low socio-economic class and they do not have the same everyday experiences as compared to the students from wealthier neighborhoods. Due to the fact that the study was conducted in their classroom, these students had a chance to experience things that they would not have a chance to do otherwise. Lessons learned about the development of scientific literacy in this classroom with diverse population may be translated to similar urban school settings in Canada and developed countries that value educating the underrepresented population.

Because Middle Years students encounter a lot of science and technology in their own lives, it is important that they realize how science and technology interact with and advance one another. Furthermore, at this time the teaching of science content becomes more systematic and the students are old enough to be exposed to more detailed explanations. Moreover, Middle Years students are beginning to understand important social, economical, political and environmental problems at the local, national, and global scale and the need to take action in regard to those issues. Bringing awareness to those issues may develop an attitude of life long learning, informed action taking, and responsibility to live in a democratic society.

The study provides science teacher educators valuable information in the design of the science methods courses for educating the elementary pre- and in-service teachers, to build competency and confidence to teach their students with a goal of developing scientific literacy. Furthermore, the study points out what kind of courses should be either recommended and/or required, and more importantly, available to the teachers to prepare them to proficiently teach the curriculum, be confident in their abilities, and willing to incorporate new trends and reforms into their teaching. The study is also significant to other faculties, especially faculties of science, offering specific subject-matter courses for pre- and in-service teachers. It suggests what kind of subject matter is most valuable for teachers.

The study informs schools, school divisions, universities, and other organizations about the kind of professional development that is necessary for the teachers to help them with scientifically literacy development.

1.6 Overview of Methodology

In this study I worked with a Middle Years' teacher, Scott Brown (pseudonym), and his Grade 5 students in an inner city school in Winnipeg. The study focuses on both teacher's and students' scientific literacy and is documented in the context of a unit on Weather. I selected a unit on Weather, because I believe that the content of this unit provides an excellent ground for the development of scientific literacy.

In this ethnographic study I was an active participant in all classroom endeavors. My data collection followed the three primary fieldwork strategies: experiencing, enquiring and examining--the three Es (Wolcott, 1998). The data were collected by means of classroom observations, interviews of teachers and students, students' written work, maps and photographs. To analyze classroom observations, interview transcripts, and students' written work, I color-coded the information to generate patterns and meanings (Taylor & Bogdan, 1998). To analyze students' and parents' conceptions of weather, I used Phenomenography, an analytical tool, to understand the qualitatively different views of weather (Marton & Booth, 1997).

1.7 Overview of the Study

In Chapter one, I identify the problem as lack of adequate understanding of the NOS among students and teachers, for it is an integral part of scientific literacy. As a result, the problem might also be identified as an insufficient level of scientific literacy among both teachers and their students. Leading to the problem statement, I discuss the impetus for the development of scientific literacy in *all* students, what entails scientific literacy from the perspectives of various organizations, researchers, and the Manitoba curricula.

Since NOS is clearly revealed as part of scientific literacy, I discuss whose NOS should be taught and divagate why there are teacher/student deficiencies in the understanding of the NOS. Developing students' scientific literacy, first and foremost, requires building teacher proficiency. Thus, I argue for a teacher-researcher (science educator) collaboration as the method leading to scientific literacy development.

In Chapter two, I discuss the development of the NOS within the context of a particular content (a unit on Weather), and explain how it contributes to the development of scientific literacy. This discussion leads to the arguments for adapting a teaching model, the *Common Knowledge Construction Model [CKCM]* (Ebenezer & Connor, 1998), that promotes scientific literacy. With a critical analysis of the Manitoba curricula, and specifically a unit on Weather, Chapter two also discusses how the teaching model adopted for this study mirrors the NOS.

Chapter three traces my conceptual growth that led me to this study. This growth was evident in two ways: 1) understanding the tools of ethnographic research, and 2) growing as a science teacher educator. To illustrate the factors that helped me change my own perceptions about the NOS, I first describe an earlier study that I carried out, in the 1999/2000 academic year, with a group of elementary pre-service teachers in the context of their science methods course. To reflect upon my growth as a researcher, I discuss the lessons I learned in regard to the qualitative research methodology, especially the process of interviewing the informants. To describe my development as a science teacher educator, I outline the circumstances that allowed me to teach the Elementary Science Curriculum and Instruction course. I also explain how, in collaboration with my advisor, I co-constructed the elementary science curriculum and instruction course.

Finally, I introduce the present study in which I collaborated with a beginning teacher, Scott (pseudonym), who was a former students of mine to plan, deliver, and assess a grade five unit on Weather. I also describe the process of looking for a suitable teacher who would be interested in and committed to this collaborative endeavor. Chapter three also entails the methodology I employed in the study. My data collection followed three primary fieldwork strategies: experiencing (participant observation, field notes), enquiring (interviews) and examining (students' written work, maps, audio- and video-tapes, field notes) to seek trends, insights, and meanings.

Chapters four, five and, six answer the research questions. Specifically, in Chapter four, I analyze my conversations with Scott, which outline his views on scientific literacy, importance of scientific literacy for Middle Years students, and contributions of the unit on Weather to scientific literacy of young children. These conversations revealed that the scientifically literate student is interested in the subject matter, has appropriate vocabulary, and possesses an ability to apply the information to other context. In terms of the importance of scientific literacy to Middle Years students, Scott associated being scientifically literate with success in their future lives. In terms of scientific literacy in the topic of weather, a scientifically literate student should display two striking characteristics, which are eloquence in the vocabulary to carry out meaningful conversations on the subject of weather and the ability to apply the acquired knowledge to other contexts. Furthermore, my conversations with Scott indicated that he was determined to present a modern view of a scientist.

Chapter five describes how Scott's views concerning scientific literacy and scientists play out in his teaching of the unit on Weather, using the CKCM. In a story format, I present his teaching through the first three phases of the model. For instance, for the Exploring and Categorizing phase, I present his approach of collecting the ideas of students' and their parents on predicting and measuring weather. For the Constructing and Negotiating phase, I describe several representative lessons that best reflect the NOS leading to the development of scientific literacy of the students. For the Translating and Extending phase, I describe how Scott and his students apply science into a larger societal context. In other words, I point out how they make connections among science, technology, society, and environment (STSE).

Chapter six concentrates on the last phase of the model, the Reflecting and Assessing. I assess students' scientific literacy development in the three notions, which are the "what," "how," and "why" of science. In order to do that, I present the analysis of selected items of students' work, which are authentic and reflect students' understanding of the material and scientific literacy development. In Chapter six, I also present Scott's reflections about our efforts to develop scientific literacy as well as students' reflections about their own learning in science.

Chapter seven begins with a summary of the thesis. I then explicitly answer the research questions based on evidence. A discussion of issues pertaining to the development of scientific literacy and the NOS, the adequacy of the conceptual change inquiry model for developing scientific literacy and the NOS, and teacher-researcher collaboration for professional development follows. Implications for teacher education and for professional development are discussed. Finally, recommendations for further research are outlined.

Chapter 2

The Common Knowledge Construction Model

2.1 Introduction

In Chapter one, I presented the various aspects of scientific literacy and the NOS that are useful and relevant to the K-12 students. In this chapter, I discuss how the characteristics of scientific literacy and the NOS play out in each of the phases of the *Common Knowledge Construction Model* (CKCM), developed by Jazlin Ebenezer and Sylvia Connor in 1998. The teacher and I used this variant of conceptual change inquiry model to develop scientific literacy of grade five students in a unit on Weather.

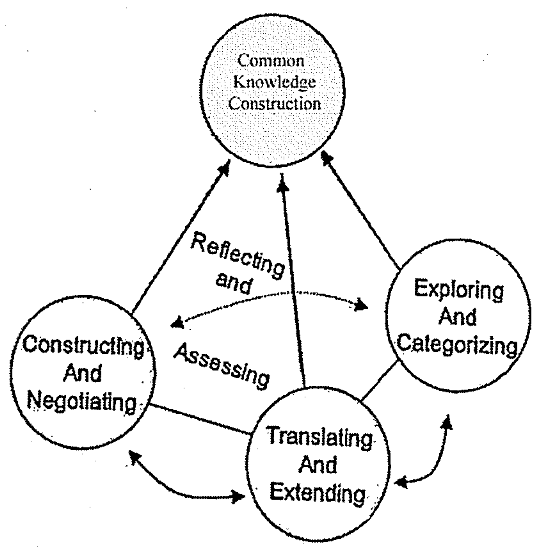
Initially, I introduce each of the phases of the CKCM, and then discuss how a particular phase reflects aspects of scientific literacy and the NOS. In an attempt to link scientific literacy, and the NOS with the CKCM, as far as possible, I provide contemporary and historical examples in the context of the curricular unit on Weather.

2.2 The Common Knowledge Construction Model for Developing Scientific Literacy

The CKCM (Figure 2.1) is a philosophically sound teaching model that is premised on Marton's "relational learning" (Marton, 1981), Bruner's view of language as culture's symbolic system (Bruner, 1986), Vygotsky's zone of proximal development mediated within a social environment (Vygotsky, 1978, 1986), and Doll's post modern thinking on scientific discourse and curriculum development (Doll, 1993). This model acknowledges that children construct beliefs about the world through personal interaction with the natural phenomena and through social interaction with others. Within each phase, learning sciences are appropriately integrated from a psychological perspective, the history and philosophy point of view, and the STSE orientations (Ebenezer, in press; Ebenezer & Puvirajah, in press).

The CKCM incorporates four interrelated worlds of meaning making: the students' world, the teachers' world, the curricular world, and the physical world. It consists of four interactive phases: 1) Exploring and Categorizing, 2) Constructing and Negotiating, 3) Translating and Extending, and 4) Reflecting and Assessing. In an attempt to integrate the foundations and the NOS into CKCM, I first characterize each phase of the model according to the authors. Then, I show how each develops scientific literacy based on the NOS, supported with examples taken from a grade five curricular unit on Weather.

Figure 2.1 Schematic Representation of the Common Knowledge Construction Model (Ebenezer & Connor, 1998).



Because the CKCM is directly related to the NOS, it was logical to use this model to develop scientific literacy of grade five students. One needs to realize, however, that our purpose was not to test the model. This CKCM has been used by many teachers in the province of Manitoba, in Canada and in the Detroit area in the USA, however, it has not been tested empirically.

2.2.1 Exploring and Categorizing

In the Exploring and Categorizing phase of the CKCM, students' ideas about natural phenomena and/or views about a socio-scientific issue are first explored and then grouped into descriptive categories, known as teacher-made categories. These categories are, in turn, matched with curricular ideas or objectives. Thus, the CKCM uses students' ideas as conceptual frameworks in further investigations.

In this phase, students' ideas are explored with the use of simple tasks, such as demonstrations, activities, pictures, diagrams, video-clips. The purpose of this phase is to find out what students attach to a natural or social phenomena. More importantly, the aim of this phase is to find out what kind of prior experiences influence students' conceptions about the natural world. The teacher's task in this phase is to carefully listen to and interpret those ideas. In other words, the teacher's role is to understand what kind of prior experiences have influenced his/her students' conceptions about natural phenomena. Another task for the teacher is to create a positive and supportive environment so the students are not intimidated to express their ideas openly and honestly. Most importantly, the teacher should encourage multiple ideas without judging those ideas for rightness s or wrongness.

The Exploring and Categorizing phase also reveals that there could be many explanations for the same phenomenon. When personal ideas are shared in class, they are exposed or made public for critical, open inquiry. Consequently, students have a chance to see that personal knowledge, like scientific knowledge, is tentative and flexible for development and change. Thus, this phase gives students a chance to see the tentative character of science and realize that it is a sign of strength rather than weakness in science learning (McComas et al., 1998). This phase gives students a chance to develop a beginning understanding that science is a discipline that attempts to explore and explain phenomena. It clarifies that science is not a discipline that collects facts and truths to be memorized.

The science education community accepts the idea that students enter the classroom with their own understandings of the world. Driver, Guesne, and Tiberghien (1985) explain that students' conceptions stem from everyday experiences, including play, conversations, and events observed through media. Additionally, students' ideas are derived from the culture in which they are brought up. Some of the cultural factors that influence the development of students' ideas are: customs, values, language, religion and beliefs (Maddock, 1983; Hewson & Hamlyn, 1984). In turn, when teachers know what their students think, they can implement instructional activities to address their students' ideas.

Several studies have been done to investigate children's ideas about weather. The exclusive purpose of those studies, however, was to identify students' misconceptions and the sources of those misconceptions about, rather than providing the opportunities to challenge them. Henriques (2000) claims that most teachers are far too busy to gather misconception data from their students and that a list of topic related misconceptions is useful to be reviewed prior to instruction. For example, she cites Fraser (2000) and Smith and Ford (1996), who found out that students believe that global warming and the greenhouse effect are the same thing. These authors report that the possible source of this misconception is the fact the greenhouse effect and global warming are often mentioned together in the press, which causes many children to link them and think they are interchangeable (Henriques, 2000).

2.2.2 Constructing and Negotiating

The second phase of the CKCM involves negotiation of new curricular ideas on the basis of students' prior conceptions about phenomena. In this phase the students negotiate new curricular ideas with the teacher and their peers. The teacher acts as a mediator, not a fountain of knowledge, who helps the students grow intellectually.
The teacher's role in this phase is to assist the young people move from their current level of performance to the maximum level that they can achieve with assistance (Vygotsky, 1978).

In this phase students learn new content for a particular curricular unit. Thus, this phase acts upon the first notion of scientific literacy, the "what" of science. Through this phase, the students develop an understanding of concepts, principles, and theories. In turn, the knowledge they acquire allows them to use science in their lives and be informed consumers of scientific information. For example, the grade five curricular unit on Weather calls for the study of the properties of air (Specific Learning Outcome 5-4-03). The principles that should be considered in this study include: air has mass/weight and volume; air expands to fill space; air expands and rises when heated; air contracts and sinks when cooled; air exerts pressure; air moves from areas of high pressure to areas of low pressure. In line with Hazen and Trefil's reasoning (1991), if the student becomes scientifically literate, he/she would be able to use the knowledge about those properties of air to understand the weather. For example the student would be able to understand that different air masses do not mix readily and what happens when the cold and warm air masses meet along a front.

The Constructing and Negotiating phase of the model also acts upon the second notion of scientific literacy, the "how" of science. In this phase the students have many opportunities to see that science is socially constructed. They construct meaning through negotiation with their peers and their teacher. They collaborate with their peers to propose and negotiate ideas, design experiments, discuss results, and draw conclusions. In this process, when the teacher and children become collaborative meaning-makers, searchers, sharers, and negotiators, they develop an attitude of collaborative scientific inquiry for the construction and validation of knowledge. This process of meaning-making portrays the tentative and negotiating character (social objectivity) of science.

By participating in collaborative endeavors, students learn about scientific inquiry. Specifically, they learn how scientists go about studying the world, how they communicate with one another, and how they propose explanations for how the world works. The students negotiate their ideas with the teacher and other students while scientists negotiate ideas with other scientists and/or graduate and undergraduate students. This suggests that scientific knowledge is a product of a complex social activity and dispels the common image of a scientist who works alone or in isolation from other scientists (McDuffie, 2001). It points out that scientists can not exist in isolation and effectively contribute to the advancement of knowledge. Furthermore, individual scientist's confidence in new information is not sufficient to be regarded new scientific knowledge. It must stand up the review and criticisms of fellow practitioners. Additionally, if the new information can not be verified, it will not be accepted by other scientists. Hence, scientists should be cooperative, willing to share their discoveries, and peer critique must be encouraged. Most importantly, scientists should be honest and willing to accept the ideas proposed by others.

The unit on Weather serves as an ideal ground to illustrate to the students the collaborative aspect of scientific work. Writing a weather forecast, for instance, is a collaborative effort of many people. One can hardly overemphasize the importance of collaboration and communication in meteorology. Rapid dissemination of forecasts, especially severe weather warnings is the vital function of meteorology. In addition to collaborating on predicting, measuring, analyzing, and then forecasting the weather, meteorologists are also actively immersed in other aspects of this field of study. For example, they conduct research on potentially hazardous accumulations of pollutants, global warming, greenhouse effect and acid rain. They are working in close collaboration with other scientists and non-scientists to offer advice on where crops may most effectively be grown, how to protect our forests, and how to control flooding.

The collaborative effort of meteorologists could be illustrated by the following example from grade five curriculum. One of the Specific Learning Outcomes (SLO 5-4-12) calls for the study of the technological advances that have enabled humans to deepen their understanding of the weather and improve the accuracy of weather predictions. These technological advances are part a worldwide network of information gathering crucial to weather forecasting. Balloons collect data from high in the atmosphere and automatically radio the data back to earth. Satellites send photographs of cloud formation back to the earth. Weather ships are permanently stationed at in specific positions at sea and send data to shore stations. Aircraft with instruments in pods beneath the wings, or attached to the nose cone, fly through storm clouds to measure temperatures, pressure, winds and turbulence. Furthermore, there are thousands of ground-based weather stations around the world, which collect the local data. All of this information is sent to the weather office where it is analyzed by meteorologists and a weather forecast is produced and then made available to the public.

Another aspect of the NOS that comes through in this phase of the model is the imagination and creativity of its practitioners. Both the students and scientists need to be creative, imaginative, and intuitive in the process of construction of new knowledge. The students require these skills to analyze data, draw conclusions, interpret meanings, weigh alternatives, and make observations. Creativity, imagination, and intuition are also important attributes of scientists. Predicting, measuring, analyzing and then forecasting the weather, often requires a lot of imagination and creativity on the part of forecasters, who make their own interpretations of the available clues. An effective television forecast, for example, often depends on the broadcaster, who acts as a computer technician, educator, journalist, and entertainer (Phillips, 1998).

The history of how the weather was disseminated in the past points to the imagination of scientists, collaborative nature of scientific work, and tentativeness of science. In the mid 1800s, meteorology and forecasting were still in its formative years. People used to make their own forecasts based on local conditions and accumulated weather lore, such as: "Red sky at night, sailors delight, red sky in the morning sailors take warning," for example. The fist scientific attempts to forecast the weather began with Sammy Morse's invention of the electric telegraph in 1844. For the first time, forecasters had a tool with which they could relay observations over vast distances to warn towns in the path of storm and to inform people of sunny skies ahead. In Canada, by 1876, land lines linked all major cities in the east. Compared with today's forecast, they were short and simple. However, distributing these forecasts was not simple, getting the word out usually meant sending the latest forecast by telegraph. On receipt, the person in charge would arrange to post, for public inspection, the forecasts in framed bulletin boards outside the local telegraph office, post office, school or railway station. However, the forecast was often an old news by the time papers were published or signs spotted. Inevitably, people began to question the reliability of the entire system (Phillips, 1998).

In the 1920s, a technological breakthrough happened with the wireless radio. Like the telegraph, the radio revolutionized the way weather data were delivered to Canadians. Information could be gathered from hundreds of remote weather stations across the country and transmitted to isolated logging communities and ships at the sea. In the 1930s, weather forecasts for Canada were issued twice daily by the staff of four meteorologists. Forecasts were distributed as widely as possible by traditional means, the daily press and the posting of daily weather maps and bulletins on public buildings as well as telephone and radio broadcasting stations. During the World War II, Canadian and American government officials banned the broadcasting and publishing of public weather information over North America. Following the war, radio became natural avenue for disseminating weather information, because reports could be updated so quickly throughout the day. This continues today. Frequent weather broadcasts are made daily over hundreds of radio stations. Canadians today call in the dial-a-weather service. Using high-capacity automatic telephone answering machines, the system responds to 60 million telephone calls a year. With the proliferation of Internet services and users, at no other time in our history has as much weather information been available to so many people (Phillips, 1998).

Although science is a "mixed bag" of history, philosophy, and sociology (Hazen & Trefil, 1991), it can not answer all of the questions, such as, questions about values, good and evil, and the meaning of life (Bird, 1998). What science can do, and has done in the past, is provide a better understanding of the natural world. Consequently, it is important for the students to realize what science can not do and what it does not aim to do (Machamer, 1998). Probably the most important limitation of science that needs to be stressed at schools is the tentative nature of scientific knowledge. The students should be aware that science is changing. This characteristic of the NOS is evident in the Exploring and Categorizing phase of the model. But, it can be further emphasized in the Constructing and Negotiating phase.

Through historical examples, students can realize that scientific knowledge is tentative. It is never a finished body of knowledge because new ideas are being proposed all the time. For example, little by little scientists kept on adding to the picture of the weather that we have now. The Greek philosopher, Aristotle, who lived 384 BC to 322 BC, believed that air, earth, water, and fire were the four elements from which everything was made (Kuhn, 1957). He also believed that the best way to find out why things happen is to observe them closely. If one event is always followed by another, then perhaps one causes the other. This was not the only way of thinking about the components of weather. In ancient Greece and Rome, for instance, most people believed that weather was caused by the gods, who could be persuaded to change it and who had the power to do so (Allaby, 1995).

It was not until about 1600 that air was found to contain gases. Carbon dioxide was the first to be discovered by the Belgian scientist, Jan Baptista van Helmont. In 1754, the Scottish chemist, Joseph Black showed that this gas forms part of ordinary air. It was not until 1894, nearly 300 years after van Helmont's discovery, that argon was identified by Lord Rayleigh and Sir William Ramsay. Then, a year later Ramsay discovered helium, another ingredient of air, and in 1898 he discovered neon, krypton, and xenon (Allaby, 1995).

After discovering the components of air, scientists started looking into properties of air. Galileo was the first person to weigh air. Then, a French scientist, Blaise Pascal, had an idea that the pressure of air is lower at higher altitudes. He imagined that the atmosphere is like a very deep ocean and that we live on the ocean floor. Thus, the weight of all the air must press down on the surface and on us. But, if we climb upwards, the pressure is lower because there is less air above us. In 1648, a brother-in-law tested this idea for Pascal by climbing a mountain and measuring the air pressure at the top (Williams, 1999).

Once scientists realized that air is a mixture of gases that they can weigh it, and that it exerts pressure, they were able to think about air in a new way. But, the question why we have weather remained. To answer this question, scientists needed to learn more about water. In about 1800, English chemist, William Nicholson passed an electric current through water, collected the gasses produced by this procedure and showed that water is made of hydrogen and oxygen. After knowing about the air and water, scientists wanted to know how these two elements work together to create the weather. But, before that, they needed to know more about the warmth we receive from the sun. The revelation that the earth revolves around the sun answered this question. This idea was stated by Polish astronomer, Nicolaus Copernicus, in the 16th century and was in contradiction with Ptolemy's theory, who suggested that the Sun revolves around the Earth (Kuhn, 1957).

Then, the German astronomer, Johann Keppler, moved on to describe the path planets follow as they move around the sun. He discovered that the earth's own axis is slightly offset in relation to the sun and the axis itself turns slowly about its own center. At that time, Keppler worked as an assistant to the Danish astronomer, Tycho Brahe, who asked Keppler to calculate the orbit of Mars. Keppler found it impossible to believe that the orbit of Mars was circular, which he and Brahe had assumed. He concluded, then, that all of the planets follow elliptical orbits around the sun. This discovery led Keppler to the development of his laws (Motz & Weaver, 1995).

Due to those earlier discoveries, today we know a myriad of science facts about the weather. The sun warms the surface of the earth. Because the earth's axis is tilted, initially one hemisphere and then the other points to toward the sun, producing our seasons. Air touches the surface of land and water and is warmed by contact with them. Warm air rises (cooling it as it ascends), and draws in cool air to replace it near the surface. This flowing of air is what we know as wind. Water evaporates in the warmer air and condenses in the cooler air, forming clouds, which are made from tiny droplets of water. When these droplets are large enough, they fall as rain, hail or snow. And, the warmth of the sun provides the energy that sets this entire process in motion (Williams, 1999).

Ebenezer and Connor (1998) claim that when historical development of ideas of a certain scientific topic are integrated into the unit of teaching, students can see that their ideas often parallel the early scientists' views. They can also realize that scientists had conceptual difficulties and struggled for centuries, sometime through intellectual debates and wars, to arrive at plausible models. At the same time, scientists were persistent in their ideas and it was difficult for them to give up, reject, or discard their ideas regardless of opposition and evidence. However, it is important for the students to understand that eventually scientists had to give up their ideas in light on new evidence. Likewise, after constructing and negotiating new knowledge with the teacher and peers, students will sometimes need to give up their ideas. However, their conceptual journey begins with their initial conceptions, which are explored in the Exploring and Categorizing phase. This experience of constructing, reconstructing, and deconstructing knowledge reveals that science in both evolutionary and revolutionary in character.

Historical examples can also give students a chance to realize that there is a difference between theories and laws. Scientific theories are the most important element of scientific knowledge and play a vital role in its growth (Duschl, 1990). It is a common mistake among students to equate theory with scientific fact or to even think that fact is more important than theory. Both of these assumptions are incorrect. Lederman et al. (2002) point out several characteristics of theories that differentiate them from laws. For instance, scientific theories are based on assumptions and point to the existence of unobservable entities. They are inferred explanations for observable phenomena. They can not be tested directly. And, they generate future investigations. Laws, on the other hand, relate to observable phenomena. For example, in 1660, British chemist, Robert Boyle published his discovery, which is now referred to as Boyle' law. He noticed that when the force pressing on air was doubled, the volume of the air was halved. This means that provided the temperature remains constant, air pressure and volume are inversely proportional to one another. Then, in 1787 the French physicist, Jacques Aleksander Cesar Charles discovered that if pressure remains constant, the volume of given amount of gas increases as its temperature rises. Boyle's law and Charles' law provide a basis for understanding what happens when air is heated and cooled and when air pressure increases or decreases. This was a very important step in the study of the forces that control the weather.

It is important for the students to realize that theories are constructed not discovered explanations about nature and that laws and theories have different roles in science. Furthermore, students need to realize that laws theories do not become laws are that laws do not have a higher status in comparison to theories. Additionally, theories involve personal subjectivity of individual scientists, who are people and have their biases like everyone else. Bird (1998), a philosopher, explains that we often assume that what we see is what is really there. But, he points out that what we see is influenced by that we expect to be there. What we expect, on the other hand, is influenced by our past experiences.

This phase of the model also emphasizes the various methodologies emphasized by scientists. The process of construction of new knowledge requires the students to set-up experiments, make observations, collect and keep record of relevant data, incorporate new computer technologies, test hypothesis, design artifacts, and conduct and analyze experiments. By doing this, the students realize that scientists also conduct inquiries by means of different methods rather than the step-by-step methodology, which is one of the greatest myths of science (McComas, 1996). This myth has been in existence ever since it was proposed by Karl Pearson (1937) in his book, *The Grammar of Science*. More recently, though, it was explicitly stated by American Association for the Advancement of Science and the National Research Council that a single method does not exist (AAAS, 1993; NRC, 1996). Regardless, McComas (1996) claims, that the Pearsonian, step-by-step method has a firm place in pre-college science textbooks and is explicitly taught by many teachers. Williams and Stinner (1996) suggest that teachers favor the scientific method because it can be easily taught at every grade level. It follows accessible to the students, recipe-like procedure, which includes: observation, hypothesis, experimentation and data collection, and conclusions.

Although the step-by-step methodology might be followed by scientists, who conduct their research in the laboratory, it is foreign to others, such as geologists, astronomers, ecologists, or meteorologists who rely heavily on observations outside the laboratory setting (McComas, 1996). Consequently, it is important that students understand that scientific knowledge is gained through many different methods, including observation, analysis, speculation, library investigation, and experimentation. It is true that scientists hypothesize, experiment, and frame conclusions, but, there is no specific sequence of activities that all of them follow at all times.

A unit on Weather provides many opportunities to illustrate to students that not all scientists follow the step-by-step scientific method. Firstly, students will have a chance to realize that meteorology is a science that relies heavily on observation. The students can see that by analyzing current science of meteorology or by studying historical examples. By analyzing modern meteorology, students can realize that, due to present day technology, scientists are able to watch how the weather system moves and develops, which requires detailed observations, followed by measurements made at the weather stations all over the world. By analyzing historical examples, on the other hand, students can realize that observations were also important to many of the early discoveries.

Giving another weather related example, Sir Fraancis Beaufort, who is known for the Wind Force Scale, came up with this scale based on his extensive observations of the weather. At the age of 13, he began his career as a cabin boy in the British Navy. While at the sea, he recognized the value of being weather wise and began keeping a meteorological journal. In 1805, Beaufort was given his first assignment and the commander of his own ship, the "H.M.S Woolwich." It was during this time that he made up a scale, based on description of the wind, to measure the wind force. In 1829, Beaufort was appointed hydrographer for the British Navy and it was then that the Navy adapted his ideas and started recording a meteorological journal on every Navy vessel. The Wind Force Scale now bears his name, the Beaufort Scale, and is still used by meteorologists, especially at the sea (Allaby, 1995).

Ebenezer and Connor (1998) claim that empirical data play a major role in scientific knowledge development. Through experience, the students come to know how scientific knowledge is constructed and how conceptual change occurs. For example, it is believed that Galileo opened the door to modern astronomy because he was able to support his observations with evidence, including careful measurements (Motz & Weaver, 1995). He combined geometry with empirical evidence to explain the Earth's movement. In 1609, Galileo constructed a telescope and subsequently made several discoveries. First, he pointed his telescope at the moon and learned that the surface of the moon is not smooth, but, it is uneven and rough with "mountains and deep valleys" (Motz & Weaver, 1995, p. 101).

Galileo's observations of the moon contradicted the belief of that time that the heavens were perfect and unchanging, and that heavenly bodies were perfectly smooth and spherical (Van Helden, 1985). Next, Galileo looked at the stars and saw many more stars than appeared to the unaided eye. This observation clashed with the old argument that the stars were created to help humans see at night (Van Helden, 1985). Galileo also observed sunspots on the sun. This observation seemed to indicate that the sun, like the moon, was not perfect. He also noticed that the sunspots moved across the face of the sun in a regular pattern. Moreover, he described the shape of the Saturn. To Galileo, Saturn was visible as a disk, which seemed to carry bulges around its equator. Now we know that he was observing the rings of Saturn, which he could not distinguish with his telescope (Motz & Weaver, 1995).

Like Galileo, Tycho Brahe adapted empirical methods to further scientific knowledge. He concluded that astronomy needed new observations that should be gathered over many years to create a satisfactory theory of planetary position. For this he needed instruments and built Castle of Heavens, also known as Uraniborg (Walker, 1996). His castle consisted of fully equipped observatories, library, laboratory, shops, and living space for staff, students, and observers. It was a place where scientists, technician, and students from many countries could gather to study astronomy (Walker, 1996). Thus, Brahe's approach to study astronomy was very similar to the one utilized by many scientists where there is a group effort to advance knowledge in a particular subject area.

2.2.3 Translating and Extending

As the title of the phase implies, this phase of the CKCM allows the students to translate their understandings of science into other contexts, such as technology, society and environment. Hence, this phase emphasizes the STSE connections. In turn, understanding of these connections is necessary to live in today's society and to be considered scientifically literate (Hodson, 2003). This phase, then, acts upon the third notion of scientific literacy, the "why" of science.

The purpose of an STSE orientation in science education is to teach children about the "social responsibility in collective decision making on issues related to science and technology" (Aikenhead, 1994, p.49). This approach has wide support in Canada, where it appears as a guiding principle in every provincial science curriculum document, and is considered fundamental to the national Canadian school science curriculum, *Common Framework of Science Learning Outcomes* (Council of Ministers of Education, 1997).

In Manitoba, STSE education is recognized by the science curricula as an essential component in an effort to develop scientific literacy of the students. The 5-8 *Manitoba Curriculum Framework of Outcomes*, for example, emphasizes that it is mandatory that students understand the values related to Science, Technology, Society, and the Environment (Manitoba Education and Training, 2000). One of these values is appreciation for the importance of sustainable development. To this end, the *Manitoba Curriculum Framework of Outcomes* integrates the Sustainable Development Strategy established by the province of Manitoba in 1994. This strategy "considers the needs of both present and future generations and integrates and balances the impact of economic activities, the environment, and the health and well-being of the community" (Manitoba Education and Training, 2000, p. 2.7).

Currently, the STSE education is of great importance because of the range and extend of environmental crisis facing us, such as ozone depletion, global warming, land, air and water pollution, deforestation, and so on (Bencze, 2000; Hodson, 2003). McMurtry (1999) says that we are in the cancer stage of capitalism. Like cancer, our actions are causing massive degradation to our environment. In light of this environmental crisis, Hodson (1998) notes that the STSE approach should go beyond simply learning about the dynamic relationships between science, technology, society and the environment. To help children find hope, students must have the opportunity to act on their insight through direct involvement in participatory democracy. In his *Teaching and Learning Science* (1998), Hodson argues that the STSE science education must ensure students acquire the knowledge and skills to intervene in the decision-making process and ensure that alternative voices, and values are brought to bear on policy decisions. It is not enough for students to learn that science and technology are influenced by social, political and economic forces. They need to learn how to participate and they need to experience participation, Hodson claims (1998).

The Translating and Extending phase of the CKCM answers the calls for the STSE education. This phase consists of two stages: issue-based, and design process. The issue-based stage involves identification of an issue (problem) and extension of that issue into other disciplines, such as society or environment. Furthermore, this phase motivates the students to become active citizens by encouraging them to take action and by providing opportunities for them to do so. Suitable action might include conducting surveys, making public statements and writing letters, organizing petitions and consumer boycotts of environmentally unsafe products, publishing newsletter, working on environmental clean-up projects.

Those action taking skills are, consequently, associated with the development of other capabilities, such as: identification and in-depth understanding of the problem, framing questions, gathering and analyzing data, sharing and evaluating findings, drawing possible solutions and suggestions, and choosing and implementing actions. Science educators refer to STSE teaching as "authentic science" or interdisciplinary science, which places it within a larger societal context (Ebenezer & Connor, 1998). This kind of teaching allows the students to see that today's society faces numerous problems and issues, which require collaborative and cooperative effort to be resolved. Solving those issues requires imagination, creativity, intuition, and open-mindness of the people involved in the process.

There are many important environmental issues for the students to act upon within the curricular unit on Weather. The weather is of enormous social importance in Canada, in such activities as farming, recreation, energy and transportation. There are many decisions that the students need to answer on everyday basis. People in Canada probably experience more weather in one year than most people do in a life time. Canadian students are faced with making decisions related to weather on everyday basis. Some of the questions these students need to answer, hence, decisions to make every day are: What is the wind chill factor? How to dress warmly for school? Will we be allowed to play outside during recess? Is there a risk of frostbite? Does our family have the necessary equipment in our car to be prepared for the snowstorm? Science education can contribute to solutions, firstly by making children aware of those societal problems, and secondly by helping them to deal with these problems, propose solutions and make informed decisions.

In addition to making the simple, everyday decisions regarding the weather, students in Manitoba have a chance to utilize their knowledge of the weather to act upon a local issue of floods. For example, the Red River Flood of April and May of 1997 left behind lots of damages to be repaired as well as many decisions to be made and actions to be taken for the future. It was the most severe flood of this river since 1826, which caused 28,000 people to be evacuated and $500 million dollars in damage to property and infrastructure. Called "The Flood of the Century", the 1997 flood had a probability of occurrence of about once in 100 years, and came close to overcoming Winnipeg's existing flood protection system. Fortunately, Winnipeg was saved thanks to the Red River Floodway, which was constructed by the province in 1968 (www.floodwayeia.com).

In the aftermath of the Flood of the Century, Manitobans demanded increased levels of flood protection. Subsequently, the Canadian and Manitoba governments charged the International Joint Commission with reviewing the situation and recommending options that would increase flood protection for the residents of the Red River Basin. A variety of local options were considered and eventually the expansion of the current floodway was deemed to most cost effective way to protect residents. Since 2003, Canada and Manitoba have announced $240 million to begin work on the $700 million floodway expansion. It is believed that the Expanded Floodway will protect residents against a flood larger than the 1997 "Flood of the Century," excavate more than 30 million cubic meters of earth to construct the expanded channel, require upgrading and improvements to twelve bridge crossings, utilities and drainage services, generate thousands of direct and indirect employment opportunities, result in recreational and economic development opportunities for local organizations, businesses, communities and the province. The bottom line is that the full expansion of the floodway will dramatically improve the quality of life for Manitobans by helping with the security of residents, improving the environment, providing economic development opportunities and establishing an international model for public consultation and community involvement (www.floodwayeia.com).

Public involvement is a critical element of the environmental assessment process for the proposed floodway expansion and provides an excellent opportunity for the students take ownership and feel empowered in the decision making process. In the next few years, there will be ongoing opportunities for citizens to receive information on, and provide their views about potential project effects, measures to mitigate those effects and various other requirements associated with the project's environmental impact. Thus, in line with Hodson's (1998) recommendations, the students can be personally involved in this issue. And, in line with Aikenhead's (1992) vision, the students can understand how decisions are made at the local, provincial, and national government levels in regard to the floodway expansion project. For example, the students can evaluate the pros and cons of this development, examine potential benefits and costs, and recognize the underlying political and societal forces, which drive this development (Aikenhead, 1992).

In additions to making decisions in regards to those everyday issues mentioned earlier, and local decisions in regards to the floodway system, the unit on Weather calls for action in regards to the global climate change problems. The Specific Learning Outcome 5-4-18 requires recognition that climates around the world are ever changing and identify possible explanations. The examples of the issues associated with this change include volcanic eruptions, ozone depletion, greenhouse effect, El Nino, deforestation. Although unable to make exact predictions, scientists believe that our atmosphere's carbon dioxide level is likely to double over the duration of the 21st century (Berger, 2000), which will rise the world's temperature. Thus, an enormous amount of work lies ahead if we are to limit global warming. Fortunately, ordinary people, including students, who are deeply committed to this goal can make a difference. They can thereby change the course of history by making the right decisions, taking action, educating others and, most importantly, being model citizens themselves.

The issue based component of the Translating and Extending phase of the model emphasizes several characteristics of the NOS. In addition to being creative and imaginative in proposing solutions to problems, it forces the practitioners to appreciate ideas proposed by others, be open-minded and considerate. Additionally, it often requires the cooperative effort of many to arrive at reasonable solutions to pertinent issues. Hence, it emphasizes the social construction of scientific knowledge. I reason, however, that the most obvious characteristic of the NOS that is emphasized in this phase is that science is socially and culturally embedded. This phase emphasizes that each society faces slightly different problems and that science is influenced by the culture and the needs of a particular society. For example, within the culture of this country, the province of Manitoba has different societal issues, than the province of Alberta.

Furthermore, the technological and social needs of a society often dictate the type of research to be conducted. Public attitudes influence the sort of questions scientists ask when they conduct their investigations, the way they evaluate their data, and the way those data are transferred to public policy. The current environmental issues, which I have already presented could be an example of these relationships. For instance, the issue of the greenhouse effect is probably more important to the governments and scientific communities of the industrialized than developing countries. It is a difficult and potentially damaging environmental problem of the present times, and it should be confronted by governments and scientific communities. Through their policies, governments should make efforts to reduce the burning of the fossil fuels. Scientists on the other hand, should concentrate their research efforts on finding solutions to solve the problem. Most importantly, the general public should learn to consume smaller amounts of fossil fuels. Planting a tree is always a good thing to do, regardless of the greenhouse effect.

The second component of the Translating and Extending phase is known as the design process. It involves construction of an artifact based on the information acquired throughout a science unit. Each of the Manitoba K-8 curricular units specifies the type of artifact to be designed by means of a several-step design loop. For example, in a grade five unit on Weather calls for the design of the weather instrument (Specific Learning Outcome 5-4-05). The design process requires the students to brainstorm possible alternatives, discuss solution with others, evaluate choices, select the best materials, engage in debates with others, and communicate information. In order to do that, the students need to be creative and imaginative, work well with others, open-minded as well as industries in making choices and selecting the best methodologies to construct artifacts. Consequently, this phase of the CKCM emphasizes the creative and imaginative character of scientific knowledge. Moreover, it highlights the social construction of knowledge and the application of many methods.

2.2.4 Reflecting and Assessing

In this phase of the CKCM, both reflecting and assessing occur. One needs to realize, however, that reflecting and assessing are ongoing authentic experiences, which should be incorporated into each of the phases. The NRC (1996) denotes two assessment *Standards*. The first one stresses that assessments must be consistent with the decisions they are designed to inform. Secondly, it informs that achievement and opportunity to learn science must be assessed. Summarizing from the *Standards*, teachers should collect information about students continuously, in order to improve their classroom practice, plan curricula, develop self-directed learners, report student progress, and research teaching practices (NRC, 1996, pp. 87-89).

Barba (1998) narrates that four basic questions should guide the teaching process and teacher's reflections on that process: 1) What do my students know? 2) What do I want my students to learn? 3) How will I help them learn?, and 4) What have they learned? The CKCM allows the teacher to easily address these four questions. For example, What do my students know? refers to the ideas that students bring into a classroom. It focuses on what students bring to the lesson from a developmental perspective (Driver, 1990). This knowledge is explored and hence assessed in the Exploring and Categorizing phase of the model. It may involve questioning, classroom discussions, concept mapping, simple conversations with the students, semi-structured interviews, writing and drawing answers to questions, journaling, diagrams, and portfolios.

The second question, What do I want my students to learn? involves an examination of the goals and objectives of the teacher, the school, the school division, and the curriculum. The majority of these goals and objectives are implemented during the Constructing and Negotiating phase of the CKCM. In this phase the teacher negotiates with the students to meet his/her own goals as well as the goals of the school, division, and curriculum. This is the phase in which the common understanding among the four worlds of meaning making (teacher's, students', curricular, physical) is achieved.

The third question, How will I help them learn? is a pedagogical question, which can be answered, based on students' prior knowledge and the science concepts to be learned. At this point, the teacher is using his/her pedagogical content knowledge (PCK) to make professional decisions. The PCK refers to a teacher's unique knowledge of how to create learning opportunities that make particular content more comprehensible to others (Shulman, 1987). This addresses two aspects, which are: 1) the knowledge of the topic-specific instructional strategies to teach the subject matter and the 2) knowledge of learners and their requirements for developing meaningful understandings (Zembal-Saul, Krajcik, & Blumenfeld, 2002).

What have they learned? is a reflective teaching question that involves assessment. All of the phases of the CKCM provide the teacher with many opportunities to assess students' knowledge of science as well as their scientific inquiry skills, behaviors, attitudes, beliefs, and social skills. The Exploring and Categorizing phase of the model, for example, allows the teacher to assess his/her students' scientific attitudes. In this phase students realize that there could be many different explanations for the same phenomenon and the teacher may assess whether his/her students are ready to accept these different ideas or views. In other words, the teacher will have a chance to evaluate whether the students in his/ her class are open-minded, non-judgmental, honest, and appreciative of the ideas proposed by others. This could be evaluated through observation, anecdotal records, journal writing, and on-going conversations with the students.

The second phase of the model, Constructing and Negotiating, gives the students opportunities to see how scientists go about studying the world, thus, it acts upon the second notion of scientific literacy, the "how" of science. In this phase the students are familiarized with the scientific way of knowing the natural world. Consequently, throughout this phase the teacher has opportunities to assess students' scientific inquiry skills. The teacher evaluates how the students plan investigations, gather, analyze, and interpret data, propose answers as well as communicate and negotiate the results with others.

Through this phase, the students have many opportunities to negotiate their ideas with others and to work in collaboration with their peers, which in turn give the teachers a chance to evaluate students' attitudes. This is also the phase where the acquisition of new knowledge occurs. Consequently, in this phase the teacher can assess students' understanding of newly acquired scientific concepts and principles (the "what" of science). This could be assessed through both on-going (formative) assessment and culminating (summative) assessment strategies. The on-going assessment may include observations, self-assessment, peer assessment, journal writing, checklists, anecdotal records, rubrics, interviews, etc. Culminating assessment should be authentic and should replicate everyday situations Wiggins (1989, p. 703).

The Translating and Extending phase allows the teacher to mostly reflect whether the students are able to translate the knowledge they have acquired into everyday situations and technology. The issue-based component, for example, requires brainstorming possible alternatives, discussing solution with others, evaluating choices, engaging in debates with others, communicating information undergoing evaluation by peers (Ebenezer & Connor, 1998). Hence, in this component the teacher can assess students' social skills, ability to make informed decisions and implement these decisions, and leadership skills.

The technology-based component (design process) also develops science inquiry skills and attitudes as well as social skills, all of which could be assessed by their teacher. The students are expected to work cooperatively, discuss their ideas with both the teacher and other students, and value the ideas and contributions of others. For example, for grade five unit on Weather, students are expected to use a design process to create a weather instrument. In the process of designing their instruments, the students discuss possible materials that could be used, and should not be used in their designs. Finally, they present their designs to the whole class, answer questions in relation to their designs, and accept criticisms.

2.3 Chapter Summary

It this chapter I described how each of the phases of the CKCM develops scientific literacy, based on the NOS. I supported my discussion with examples taken from a grade five curricular unit on Weather. The Exploring and Categorizing phase emphasizes that personal knowledge, like scientific knowledge, is tentative and flexible for development and change. This phase also gives students a chance to develop a beginning understanding that science is a discipline that attempts to explore and explain phenomena. It clarifies that science is not a discipline that collects facts and truths to be memorized.

The Constructing and Negotiating phase develops an understanding of concepts, principles, and theories. Thus, this phase acts upon the first notion of scientific literacy, the "what" of science. More importantly, this phase allows the students to use science in their lives and be informed consumers of scientific information. The Constructing and Negotiating phase of the model also acts upon the second notion of scientific literacy, the "how" of science. It provides many opportunities for the students to realize that science is socially and collaboratively constructed. By collaborating with the other students and the teacher, the students learn how scientists negotiate their ideas with others. This, in turn, suggests that scientific knowledge is a product of a complex social activity and dispels the common image of a scientist as someone who is isolated from other practitioners. It points out that scientists can not exist in isolation and effectively contribute to the advancement of knowledge.

The Constructing and Negotiating phase of the model also points out to the imagination and creativity that are required to develop scientific knowledge. Furthermore, it emphasizes the tentative nature of scientific knowledge. Through this phase students can realize that science is never a finished body of knowledge and that new ideas are being proposed on on-going basis. Additionally, this phase illustrates that science is both evolutionary and revolutionary in character. Moreover, this phase of the model emphasizes that there are many different methods of conducting scientific inquiries, that empirical data are crucial in the development of scientific knowledge, and that there is a difference between theories and laws.

The Translating and Extending phase of the model acts upon the third notion of scientific literacy, the "why" of science. It manifests the STSE orientation in science education, which is an important goal of the national and provincial science curriculum documents in Canada. This phase gives students a chance to make decisions and take actions in regard to many societal and environmental problems at the local and national level. It empowers the students and gives them hope for a better future. This phase of the model reflects several characteristics of the NOS. It further emphasizes that scientists must be creative and imaginative in proposing solutions to problems. It points out that scientists must appreciate ideas proposed by others, be open-minded and considerate. Additionally, it illustrates the cooperative effort of many practitioners to arrive at reasonable solutions to pertinent issues. Also, this phase of the CKCM underlines that that science is socially and culturally embedded. And, the design process points out the creative and imaginative character of scientific knowledge. Moreover, it emphasizes the social construction of knowledge and the application of many methods.

The Reflecting and Assessing phase of the CKCM allows the teachers to evaluate the NOS development and reflect upon their practice. It also allows the students to reflect upon their own learning.

Chapter 3

Methodology

3.1 Introduction

In this chapter, I trace my conceptual growth that led me to the proposed study. My learning is situated in an earlier study that I carried out with a group of elementary pre-service teachers in the context of their science methods course that accentuated the contemporary philosophies of science teaching and learning. Having taught biology to the undergraduates for several years using the "scientific method," I was keen on knowing how the methods course developed pre-service teachers' understanding of the nature of scientific inquiry. My interest grew when the professor began the methods course by exploring her students' conceptions of the nature of scientific inquiry. Before long, I committed myself to study pre-service teachers' developmental ideas of the nature of scientific inquiry during their methods course and subsequent practicum teaching. To reflect upon my conceptual growth from the foregoing study, I report "phenomenographic results" (Marton, 1981) of pre-service teachers' prior instructional conceptions of the nature of scientific inquiry, and present a case study that tracks one pre-service teacher's developmental ideas. My conceptual growth is evident in two ways: understanding the tools of ethnographic inquiry, and growing as a science teacher educator.

After recounting my own conceptual growth, I explain the process of looking for a suitable teacher who would be willing to collaborate with me in my Ph.D. data collection. Then, I tell a story of my collaboration with Scott, the public school teacher, who allowed me into his professional life.

Finally, I explain the methodological frameworks in line with the research objectives of the proposed study. In addition, I describe the techniques that I used to collect and analyze data. In addition, I describe the reliability and validity of the study from a qualitative perspective.

3.2 My Conceptual Growth

I completed my bachelor of science and education degrees at the University of Wroclaw, in Poland. After graduating from the university I taught grade six science for a period of one school year. After coming to Canada, in 1990, I started my master's degree in science, major in ecology. After completing this degree, I obtained a job as a biology instructor at the University of Winnipeg. Since I enjoyed teaching, in 2000, I decided to do my Ph.D. degree in science education. In the first year of my Ph.D. program, I was curious to learn what constituted elementary pre-service teacher curriculum and how they were taught. A science teacher educator at the University of Manitoba told me that the best way to learn about educating pre-service teachers is to "be there" to observe and actively participate in a methods course, which emphasized the notion of learning to teach science. Thus, I audited the methods course that this science teacher educator taught and with this step I started a collaborative endeavor with the educator, pre-service, and novice teachers.

3.2.1 Science Methods Course—Science Curriculum and Instruction (EDU 81.402)

EDU 81. 402 Science Curriculum and Instruction (C & I) is a mandatory course that leads to elementary teacher certification. I attended the C & I course throughout the year, which consisted of 9 weeks in the Fall Term and 9 weeks in the Winter Term. Each class was 1 hour and 20 minutes long. The science teacher educator encouraged me to document the events of the science C & I course as they unfolded. Thus, while in the C & I class, I took field notes, I carried out document analysis, and I audio taped the conversations between the science teacher educator and her students and among student peers.

At the beginning of the Fall term in her first class (September 13, 1999), before she introduced the course, the science teacher educator explored pre-service teachers' conceptions to find out what meanings they attached to the nature of scientific inquiry with two questions: 1) What are your views about how scientists conduct scientific inquiry? 2) What are your views about how elementary science teachers should help students conduct scientific inquiry at school? Students responded to these questions in writing. The science teacher educator then used pre-service teachers' initial ideas in her subsequent lessons to develop the notion of the nature of scientific inquiry. She started her class each week with pre-service teachers' ideas and linked them appropriately to the lessons on the CKCM.

To familiarize her students with the CKCM, the science teacher educator first modeled each phase to the pre service teachers using a unit on *Light* with research-based activities disseminated by Feher and Price (1989), and Price and Feher (1990). At the end of the modeling of the Exploring and Categorizing phase, a small group of pre-service teachers was required to teach this first phase to their peers in small groups based on their preferred topics. At the end of the modeling of the Constructing and Negotiating phase, another group of pre-service teachers was expected to do peer teaching to practice the second phase based on the ideas of a science concept explored and categorized by the first small groups. Similarly, based on the selected topics, the other two phases were also peer taught. After every phase of the model, the teacher educator explored and emphasized the significance of the nature of scientific inquiry and its translation into classroom science using examples from her modeling and the pre-service teachers' peer teaching. During peer teaching, the teacher educator circulated among the groups and picked themes or key words representing NOS to further elaborate on them at the end of the class. I noticed that the science teacher educator did not lecture to them about the NOS, but she sought opportunities to talk about the NOS in the context of pre service teachers' scientific inquiry.

The science teacher educator often asked the presenter to explain how his/her presentation relates to the NOS. For example, consider the following conversation between the science teacher educator (STE) and a pre-service teacher (PT):

STE: How does your presentation relate to the NOS?

PT: Science is changing.

STE: Right on! Science is always changing. But you have to remember that the core theories took a long time to change and it was with great struggles. For *example, first we thought that the earth was in the center (Class Discussion Excerpt, September 20, 1999).*

Furthermore, often at the end of a class, the teacher educator had a powerful statement to the pre-service teachers about science and the teaching of science. For instance, note the following excerpt:

> *"You as teachers of science in elementary classrooms are the ambassadors--the diplomats. You are representing the scientific community in your classroom. So keep that in mind and try to portray the right kind of image of science and scientists. If you paint or portray the right image, children will come to know what scientists do. But, if you ask them to memorize a bunch of facts and ask them to fill in the blanks...Is this science? After grade five they give up science. So, I hope that you are going to carry out authentic science to show them how scientific knowledge is generated, how it is established, and how it changes." (Class Discussion Excerpt, Science Teacher Educator's Talk in Class, September 20, 1999).*

In the winter term pre service teachers were required to develop a detailed mini-unit plan to depict the CKCM in a topic of their preference.

3.2.2 Pre-service Teachers' Conceptualizations of the NOS

This yearly practice of the science teacher educator gave me the opportunity to assess pre-service teachers' prior-teaching conceptualizations of the nature of scientific inquiry. When I examined the pre-service teachers' responses, I was eager to watch how these pre-service teachers will transform their thinking about the nature of scientific inquiry. Hence, I invited the pre-service teachers to take part in a study that would help me track their developmental ideas of the nature of scientific inquiry. Twenty one (70%) out of 35 pre-service teachers gave me a written consent to participate in my study. Thus, while auditing the science methods course I conducted a study entitled *Pre-service* *teachers' developmental understanding of the nature of scientific inquiry.* In the first step of my study, I analyzed pre-service teachers' responses to the two prior-instructional questions mentioned above. I used "phenomenography" (Marton, 1981) to make sense of the responses that the science teacher educator gathered.

Phenomenography is a qualitative research method which is concerned with understanding and describing the qualitatively different ways people experience and comprehend the world around them (Marton, 1981). It involves analyzing the responses to questions about a phenomenon and grouping those responses into qualitatively different conceptualizations. In other words, it is a research specialization that aims to study the different conceptions of a phenomenon. These conceptions are termed categories of description (Marton, 1981; Marton & Saljo, 1984). Accordingly, each conception has a how and what aspect. The former relates to the act of conceptualization and the latter to the meaning of the phenomenon as conceptualized (Marton, 1981). For example, the "how" in this study refers to the pre-service teachers' conceptualizations and the "what" refers to the nature of scientific inquiry (a social phenomenon). The categories are the main results, not the number of people holding a certain conception; and they are linked to the investigated phenomenon, not to the various individuals. The phenomenographer maps individual participant's conceptions for analytical purposes only, but for reporting research results the individual participant's conceptions are not the focus. The researcher attempts to understand the categories of description and to relate them to each other and to the whole. The method assumes that there is a limited number of categories or qualitatively different ways in which the particular phenomenon could be understood. Phenomenographic research enables a researcher to map students' conceptions into descriptive categories and use them in lesson sequences. Finding a limited number of categories motivates a teacher to use research results in the classroom. It also gives a teacher the opportunity to appreciate and account for different understandings.

Because of her extensive experience with phenomenographic research to understand individuals' conceptions, the science teacher educator helped me to analyze the data and group pre-service teachers' conceptions of the nature of scientific inquiry into meaningful categories. We took the following steps to determine the phenomenographic categories of the nature of scientific inquiry:

1. We initiated the descriptive categories by reading and understanding what the pre-service teachers are attempting to say.
2. We highlighted the statements that conveyed certain meaning that helped us to group the responses into categories.
3. We differentiated the following four categories, which describe the nature of scientific inquiry:

   a) Using a systematic and logical approach (n = 16),

   b) Discovering by accident (n = 1),

   c) Conducting inquiry in random fashion (n = 2), and

   d) Exploring how and why something works (n = 2).

In accordance with the basic assumptions of phenomenography, the foregoing categories are not a description of the participants, it is a description of "the outcome space," of possible ways of thinking about the nature of scientific inquiry. Hence, even if there is a conceptual representation by one pre-service teacher, it has been taken into consideration. For the purpose of demonstrating my conceptual growth, in this chapter, I describe only the most frequent descriptive category: *Using a systematic and logical approach*. Seventy six percent of the pre-service teachers were grouped into this category. Those pre-service teachers considered that scientists conduct scientific inquiry by means of the step-by-step scientific method. This method is similar to the scientific method explicated at the beginning of many university biology textbooks, which consists of several steps including observation of a phenomenon, hypothesis, experimentation, data analysis, and conclusions (Campbell & Reece, 2005; Cells and Organisms Laboratory Manual, 2005). The following pre-service teachers' comments characterize the first descriptive category:

> *"Scientists conduct scientific inquiry by posing a series of hypotheses which they then test. Based on their results they either make some conclusions or revise their previous hypothesis and make more guesses as to how something might work."*
>
> *"It is my understanding that scientists break down tasks into smaller pieces and test their ideas. The testing is done using the scientific method."*
>
> *"...scientific process consists of eight to seven steps including: defining the problem, forming a hypothesis, testing that hypothesis, collecting data and running tests, analyzing the data from the tests, forming conclusions, and communicating the results of the tests in scientific objectivity."*

Most pre-service teachers who supported the textbook classic several-step procedure also believed that scientific inquiry in an elementary school should be "done in a similar way." Note the following excerpts:

> *"I believe elementary teachers should lead their children in much the same way scientists inquire - but instead of the teacher dictating what should be done and how the students should do it- the student should become the scientist - they should ask the questions and decide how to find the answers and solve the problems."*
>
> *"I think elementary teachers should conduct scientific inquiry in the same kind of outline as scientists, but even better."*
>
> *"Science teachers should approach science deduction with the same steps as a research scientist would. By showing our students that any problem, no matter what the difficulty, can be solved when approached logically."*

Then, I continued my research with seven out of the 21 pre-service teachers who represented the phenomenographic categories. I video-taped pre-service teachers' oral presentation during the Pre-Service Teacher As Researcher (P-STAR) conference (10 minutes); examined pre-service teachers' written assignments which consisted of four detailed lesson plans and an assessment plan; tape-recorded pre-service teachers' conversations with peers during group work (approximately 50 minutes); collected pre-service teachers' answer sheets to their midterm exam. In addition to university class observations and analysis of their (pre-service teachers) written work, I individually interviewed these seven pre-service teachers. Each of these seven pre service teachers was interviewed three times (for about 30 minutes every time): at the beginning of the C & I course, after the first teaching practicum, and during the second teaching practicum.

In the following paragraphs, I present the data that I collected for one of these seven pre-service teachers--Natalia.

3.2.2.1 A Case Study of Natalia

Data sources collected from Natalia are in the following chronological order: written answers to prior-instructional questions collected on September 13 (field notes # 1); audio-taped participation in a group discussion on November 1, 1999 (field notes #2); audio-taped interview #1 on November 11, 1999 (field notes #3); written midterm exam on November 12, 1999 (field notes #4); audio- and video-taped P-STAR conference presentation on January 27, 2000 (field notes #5); audio-taped interview #2 on February 2, 2000 (field notes #6); written final assignment (field notes #7) due on March 6, 2000; audio- and video-taped interview #3 on April 20, 2000 (field notes #8).

To analyze the data, I first carefully read each set of the field notes and at the same time I color coded the information to generate themes. Several themes that emerged from this stage of the study, for example: teacher guided inquiry, student led discovery, mechanics of teaching, making connections to everyday life, teaching and learning through senses, scientists as children, importance of verbal instruction, curriculum assessment, tentative character of scientific knowledge, importance of history and philosophy of science, the scientific method, and many methods of conducting scientific inquiry. Table 3.1 presents presence/absence of the designated themes throughout the field notes. The presence of a particular theme in a specific set of the field notes is indicated by a plus sign (+).

Table 3.1 Themes Constructed from the Pilot Study.

Theme Title	*Field Notes (by number)*							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
The scientific method	+		+	+		+		+
Student led discovery	+		+	+	+	+		+
Social construction of knowledge				+	+	+	+	+
Importance of history and philosophy of science						+	+	
Making connections to everyday life		+			+		+	
Many methods of science vs. the scientific method							+	
Curriculum assessment					+			
Teacher guided inquiry					+	+		+
Practicing what was instructed at the university			+					
Motivation				+				+
Teaching/learning through senses		+	+		+	+		+
Comparison between traditional teaching and teacher guided inquiry						+		
Importance of the Internet in research						+		+
Mechanics of teaching and classroom management		+			+	+		+
Scientists as children			+			+		
Importance of the meaningful verbal instruction			+					
Importance of testing one variable at a time			+					
Tentative nature of scientific theories						+		
Finding balance between books and hands-on						+		
Teacher's responsibilities						+		

At the beginning of the academic year, prior to any instruction in the elementary science Curriculum and Instruction class, Natalia, like many of her colleagues, believed that scientists conduct scientific inquiries by means of the step-by-step scientific method. Consider Natalia's comments:

> *"It is my understanding that scientists break down tasks into smaller pieces and test their ideas. The testing is done using the scientific method".*

On her midterm exam, Natalia pointed out that "*...all throughout our school career and through texts and media, I have come to understand that scientists follow the scientific process.*" During the first interview she again mentioned that scientists "*...go through the same process and you reformulate in your mind it is kind of like the scientific process. You have thought, you come up with a plan on how you are going to figure it out, you try it, if it does not work well we go back to the drawing board. If it did work, you think, great, but maybe now I want to try something else too, what will happen now if I do that? I think it is the same process*". Natalia's thoughts and understanding of the NOS gradually changed with the progression of the elementary science Curriculum and Instruction course. During her second interview she summarized that scientists conduct scientific inquiries by "*...reading, researching, talking, and experimenting*". Thus, Natalia's understanding has matured since the commencement of the C & I course. She no longer believed that the only way to do science is to follow the step-by-step scientific method. At that stage, she was able to identify several characteristics of the NOS. For example, she recognized that scientific knowledge is tentative by saying that "*...things are always changing. Even if you think you have proven something you have to keep revisiting it to see if it still stands true based on the new information or new things that have come up in the world or something, you have to always be revisiting it to see if it is still true.*"

During the second interview, she also acknowledged the importance of the history and philosophy of science as well as the social construction of scientific knowledge, two characteristics of the NOS. Consider the following excerpt: "*By research I mean reading,* *constantly going and looking at other people's work, things that have been done, papers, textbooks in the history and in the present things that people have written about."*

During our last interview, Natalia clarified that scientists conduct inquiries "*...through a lot of talking, and experimenting, and discovering, and meeting with people, and reading books, and trying stuff out, just always questioning."* Natalia was also able to recognize that there are many ways of conducting scientific inquiries, for example: "*...you can not always do it in the same way."* She also acknowledged the importance of the history and philosophy of science in teaching and learning science. For example, she mentioned that scientists analyze the "*...things that have been done, papers, textbooks, in the history and in the present, things that people have written about."*

Natalia's understanding of how elementary teachers should conduct scientific inquiries also changed with the progression of the events in her academic year. At the beginning of the academic year, Natalia likewise theorized that elementary science teachers should *"...give children some options on what they would like to learn about and together develop a scientific method."* Natalia's midterm exam revealed similar understanding. Natalia wrote that *A...elementary school teachers need to conduct scientific inquiry in much the same way scientists do. In schools, the teachers are guided by the curriculum, however it is still much the same."* During the first interview, she did not mention anything that would imply that elementary science teachers should also utilize the steps of the scientific method. At that time, Natalia stressed a theme, which I identified as "student led discovery." She believed in giving the students many opportunities for their own discovery. Consider the following quotation: *"... let them lead the way, let them try and go through the discovery on their own."*

After her first teaching practicum, Natalia realized that the *"true scientific inquiry"* is not necessarily based on the scientific method. During the second interview, conducted after her teaching practicum, Natalia declared that *"...teacher's role is to be ever vigilant..."*. She added that *A...the role of the teachers is to bring in more opportunities and just keep guiding them, pushing them forward."* During her last interview Natalia mentioned that elementary science teachers should conduct scientific inquiries with their students in a way which is *"...very similar to scientists."* She added that she would like *"...to allow students opportunities to discover in many different ways."* She also provided some guidance of what could constitute the many different ways of school scientific inquiry. Her examples included: searching on the Internet, learning from other students and guest speakers, experimenting, and discussing.

In summary, I noticed that Natalia's written answers are very different from her verbal replies. Her written work (field notes # 1 and 4) seems to be very superficial. Natalia emphasizes the scientific method and student led discovery. Her answers to the same interview questions, however, are much more meaningful and knowledgeable. For example, in her last interview she reveals that there are many methods of science. Natalia admits that *"...partially through the course, through reading the text book and the things we have done in class..,"* and through the*"...work in the schools with the students..."* she realized that the *...scientific method does not always work..."* and "*... that a lot of discovery that they are making is things that they are learning from other people...."* For example, *"We have speakers come in and doing things and all of a sudden something is adding on to their information so "It is not always doing an experiment."*

In her interviews she additionally talked about tentative character of science, social construction of knowledge, importance of history and philosophy of science, and practical implications of science, which are the demarcations of the NOS (Lederman et al., 2002; Matthews, 1998; Stinner, 2001). Furthermore, she recognizes the relationships among science, technology, and society, which are the attributes of the scientifically literate students (Aikenhead, 1997; Hodson, 2003; Pedretti, 1997).

My plan was to trace Natalia's developmental understanding of the NOS throughout her science methods course, teaching practica, and then to observe how she translates the knowledge she acquired at the university into her first year teaching practice. Thus, after completing the first part of the study, I made arrangements with Natalia to observe her and her grade seven students in Georgetown School (pseudonym) located in one of the suburbs, located about 10 kilometers north of the city limits. I made necessary arrangements to visit Natalia's class at the end of the school year, every day, for a period of one month. The main purpose of my visits was to observe how she portrays the NOS to her students.

After two weeks of my classroom observations, Natalia decided that she would like to use the time assigned to science to finish the French curriculum. Consequently, I had to terminate the classroom observations. While in Natalia's classroom, I assumed a role of a critical observer who tape records all of the classroom conversations. Bogdan and Biklin (1992) would classify this routine as non-participant observation. I never offered the teacher any help with lesson planning, class preparation, or teaching. We have never met to reflect on the lessons either. I also did not feel that I was part of the class or school community, because I myself have never made any efforts to come into their worlds or to be seen as a participant of their community. I did not talk to any of the students or staff members. I am pretty sure that nobody in that school, except for the principal, knew that there was a researcher in one of the classrooms.

When observing the science classes in Georgetown School, I often had a feeling that the teacher did not have a long-term plan as to how to teach this curricular unit and that every class was treated as an isolated case. Sometimes I even had an impression that her students were wasting time. I also observed that she struggled with the content of this curricular unit. The teachers herself admitted: *"I felt unprepared, I felt that I did not have any knowledge in science, I did not know what to teach. I was even afraid of their questions. I was totally lost...I was looking forward to the professional days when I could meet other teachers and share ideas...." (Teacher-Researcher Interview June 20, 2002).* Additionally, she taught science contrary to what was advocated in her science methods class.

At this point, I realized that to collect meaningful data, I need to collaborate with a teacher in every step of the "teaching" journey: planning, teaching, and assessing.

3.2.3 Lessons I Learned

In this sub-section, I delineate the lessons I learned as a result of my pilot study. They are: understanding the tools of inquiry and growing as a science teacher educator.

3.2.3.1 Understanding the Tools of Inquiry

The coincidence of Natalia making significant statements about the NOS during the interview, rather than writing about it, emphasizes the importance of interviews in qualitative research. Many researchers have discussed the implication of the interviews. A number of investigations have yielded rich data by using written responses for open-ended questions in combination with the interview method (Fleming, 1987; Howe, 1985; Lederman, 1999; Lederman & O'Malley, 1990; MacDonald & Bridgstock, 1982; Ryder, Leach & Driver, 1999). For example, Lederman and O'Malley (1990) recommended that the interviews allow the researcher to clarify the precise meaning of ideas revealed by the respondent. In my study, I also observed that the follow-up interviews are imperative to clarify participants' comprehension of the investigated issues. In my study, for example, when I asked Natalia to elaborate on her written statements about the scientific method, she explained: *"...I am referring to the process that we were always taught in school where you have a hypothesis, you make a guess at what you think is happening, then you try - you determine how you are going to test it, your variables, your different..."* Her oral reply, then, confirmed that she referred to the step-by-step scientific method that, as reported by Campbell and Reece (2005), consists of observation of a phenomenon, hypothesis, experimentation, data gathering and analysis, and discussion and conclusions.

In addition, the interviews can identify the experiences, which have altered each student's beliefs in the past and/or in the duration of a particular investigation (Lederman & O'Malley, 1990). For example, when I asked Natalia about the sources of her beliefs and about any factors that might be responsible for the transformation of her ideas, she acknowledged the program. She also identified that her teaching practicum played a role in the development of her understanding. Consider the following statement: "*...My views have changed partially through the course, through Dr. Ebenezer, through reading her text book and the things we have done in class, and I have learnt through this year doing work in the schools with the students that the scientific method does not always work that a lot of discovery that they are making are things they are learning by doing and talking with other people.*"

During the second phase of data collection, I myself had a chance to learn a lot about the qualitative research methodology, especially about the process of interviewing. If I had a chance to redo the foregoing study, I would have conducted my interviews in a different manner. Firstly, I would video-tape all three interviews, which would tell me a lot about Natalia's face expressions and gestures. In this investigation, I only audio-taped the first two interviews and both audio- and video-taped the third one. Secondly, after each interview, I would write comments and thoughts about the interview procedure, Natalia's behavior, topics discussed, conversations that took place outside of the interview situations, etc. In other words, as recommended by Taylor and Bogdan (1998), I would keep a detailed interviewer's journal, which I have overseen, in this pilot study. Thirdly, I would maintain an eye contact and listen patiently without interrupting the informants. I was not aware of that till I started transcribing the tapes. In my field notes then I wrote:

> *"As I am transcribing, I realize that my above statement could have led Natalia to think that I am satisfied with her answer and that it is o.k. to stop answering this question. While listening to it now, I actually have a feeling that she wanted to continue but I have stopped her from doing that. I think that I rushed Natalia because I was nervous myself and I wanted to move on to the second question. I do not think I was listening very carefully. Instead, I was thinking about my next question."*

I also realized that it is important to transcribe the tapes either immediately or shortly after audio-taping. When I transcribed shortly after taping, I was able to better recreate the context what is evident in my field notes which are detailed. For example, I transcribed the first interview with Natalia shortly after it was recorded and because it was still fresh in my mind I was able to draw a map of the room in which we were conversing (Field notes # 3), and in the Observer's Comments I wrote:

> *"I met with Natalia immediately after her Science Curriculum and Instruction Class. We agreed to meet in Dr. Ebenezer's office. I wanted to meet there because Dr. Ebenezer did not use this room at that time. Instead, she was working in her research office on the fourth floor. Consequently, it was an uncluttered and quiet place to talk. Indeed the room was very tidy. There was nothing on the desk, the books in the bookcase very well organized. Natalia arrived on time. She did not seem to be nervous or intimidated...I was glad that I have invited Dr. Ebenezer to this interview. Because of her experience with qualitative research I wanted her to be there and show me a proper approach to interviewing. If she were not there, I would have ended our conversation after 5 minutes. I would have concentrated on the two major questions and would not have asked anything else." Dr. Ebenezer's approach, on the other hand, has helped me understand that it is important to listen and ask additional questions for further clarification."*

Most of the tapes, however, were transcribed several months after they were recorded. At that time I had to recreate the context in my mind. It was not always and easy task for me, especially because the interviews were not video-taped. As a result most of my Observer's comments are rather laconic. For example, consider the following journal entries:

> *"As I am transcribing I recall that Natalia has not talked smoothly. She paused, stopped, and rolled her eyes up. To me it looked as she was thinking very carefully about every sentence she was saying."*
>
> *"Natalia was very comfortable while answering this question. I could feel that she had a lot to say and that she was very enthusiastic about this question."*

This pilot study also helped me realize how much time needs to be allocated to the transcription of the tapes. It took me, for instance, several hours per tape. Some tapes though were easier to transcribe than others. For instance, the transcription of the interviews went smoothly and much faster than the transcription of a discussion (Field notes # 2) or a P-STAR conference presentation (Field notes # 5). It was very hard for me to fully transcribe the discussion that took place after the peer teaching. At some point in my Observer's Comments, I gave up and wrote:

> *"The conversation continues for about five minutes. The students are talking about pesticides and lawn fertilizers. However, I can not recognize much. It is even harder for me to determine who is talking. After a while the conversation becomes very casual, not related to science or to the topic, which was presented. There is a lot of laughing and giggling which obscure the conversation."*

I could have eliminated some of the above-mentioned mistakes if I had taken the Qualitative Research Methods for Education (EDU 129. 784) course prior to conducting my study. While taking the course, however, I noticed that because of the experience I gained through the pilot study, and because I was in constant dialogue with my advisor I had a much better understanding of qualitative research methodology than other students in my class. For example, I was familiar with the ethical issues associated with using human informants. I knew a lot about interviewing and transcribing. I was aware of various types of qualitative studies. I was also familiar with data triangulation and data analysis.

3.2.3.2 Growing as a Science Teacher Educator

Through this study I also grew as a science educator because while I was auditing the Elementary Science Curriculum and Instruction course the professor asked me to critically evaluate her approach to teaching. Thus, in each class I wrote my observations, comments, and suggestions and after each class, we met to discuss the events. I benefited from this experience during the second year of my Ph.D. program. During that second year, I was awarded several scholarships, which allowed me to take a leave of absence from the University of Winnipeg, where I was teaching, and concentrate on my studies at the University of Manitoba. At the same time, I got an opportunity to teach two sections of the Elementary Science Curriculum and Instruction course at the University of Manitoba and my advisor was assigned to teach the other two sections. Consequently, it was an excellent opportunity for us to co-construct the C & I course.

We met every Friday to plan the agenda for the next week's class. We decided that we both would implement our shared ideas into the phases of the CKCM. I liked the idea of using the model because it characterizes the NOS, as discussed in Chapter two. I also saw a correlation between the model and Manitoba science curriculum. In other words, I noticed how by introducing this teaching model, I can help my students--the future teachers--to teach Manitoba curriculum in a simple yet innovative way. Also, because I was going to teach this course for the first time, I knew that if I use the model, my classes would be organized, meaningful and well structured. We made certain changes to the previous year's course outline.

We decided to teach the model using grade four unit on Sound. In line with the first phase of the CKCM, we initially taught the pre-service teachers how to explore students' ideas. We asked the pre-service teachers to write and draw how sound travels into their ears. To help them visualize how sound travels we popped a balloon. Then, on the basis of their responses, we showed the pre-service teachers how to categorize their own students' answers. In our C & I class, we were able to categorize our pre-service teachers' responses into several groups corresponding with the specific learning outcomes of the Manitoba science curriculum.

In the second phase, we planned a series of lessons to illustrate the specific learning outcomes that emerged from our exploration activity. Then, we modeled how to translate and extend the knowledge into everyday life experiences. In other words, we were demonstrating how to address the Science Technology , Society, and Environment (STSE) issues. In line with the Manitoba science curriculum, we planned a lesson on noise pollution (Specific Learning Outcome: 4-3-12). Finally, to solve a technological problem, we followed a Design Process to design a musical instrument (Specific Learning Outcome: 4-3-06). At the end of the course, we concentrated on various assessment strategies. I think that our lessons on assessment were very well planned, and also appreciated by the pre-service teachers. We discussed both on-going and culminating assessment. However, we paid special attention to the performance-based assessment. To simulate the hands-on approach to this type of assessment, the pre-service teachers were asked to circulate among various stations, which we set-up in the laboratory. At each of these stations they were asked to perform a different task. I also incorporated a video on grade four performance-based assessment strategies, which has been recorded by the Fort Gary School Division in Winnipeg.

In addition, the pre-service teachers presented at the Pre-service Teacher as a Researcher (P-STAR) Conference. For these presentations, students were asked to assess the Specific Learning Outcomes of the unit of their choice based on the five Foundations for Scientific Literacy outlined in the elementary science curriculum guide. In other words, they were supposed to evaluate to what extent the curricular unit reflects the five Foundations for Scientific Literacy. In their presentations, the pre-service teachers were asked to conduct at least one hands-on activity and state where it fits with respect to the Foundations.

Additionally, I wanted to emphasize certain important issues in science education. For example, I wanted the pre-service teachers to understand the principles of *science literacy for all*, since it has become a strongly emphasized topic in science education. I decided to concentrate on the language minority students. As a preparation for this class, I asked the pre-service teachers to read an article by Spurlin (1995), entitled *Making Science Comprehensible for Language Minority Students*. To illustrate to the pre-service teachers the emotional struggles experienced by the language minority students, I started the class by talking in Polish rather than English. I gave a 15-minute lecture in Polish on how to add and subtract in math. Although I wrote everything on the board, I could sense that some of the pre-service teachers felt uncomfortable with the fact that they did not understand what I was saying. I also noticed that some of them felt embarrassed when I asked them to repeat the pronunciation of numbers or mathematical symbols, such as one, two, three, plus, minus, etc. After, that presentation we had a discussion on multicultural science education in relation to the assigned article.

At the end of the first term, I realized that most of the pre-service teachers do not have a strong science background and hence laboratory skills and I wanted them to learn, at least, how to use a microscope. I managed to teach them how to use compound light microscope, dissecting microscope, and video flex camera. During that class we concentrated on microscopic techniques. We observed several permanent microscopic slides and learned how to prepare a wet mount using red onion epidermis and flower pollen grains.

3.3 Looking for a Suitable Teacher

After conducting the pilot study and teaching the Elementary Science Curriculum and Instruction I was curious to find out how the CKCM plays out in the school classroom with respect to the NOS. Specifically, I wanted to get first hand experience by being involved in the planning of the lessons and by witnessing how the lessons are being taught. In other words, I was interested in a teacher-researcher collaborative effort in planning, teaching, and assessment. This time, however, I was eager to work with a teacher who would actually incorporate the CKCM into his/ her teaching. Additionally, I wanted to collaborate with a teacher who understands and includes aspects of the NOS into his/her science teaching. I also preferred working with a teacher-researcher who understands and is committed to research. I was particularly interested in finding a teacher who is a former student of mine and who is familiar with the model, since working with such a teacher would allow me to observe how she/he translates the NOS I addressed in the C & I class into his/her classroom practice.

Throughout December of 2002, I started looking for a suitable research partner. I contacted six pre-service teachers of the 2001/2002 class. Unfortunately, they either did not have a permanent contract or were not assigned to teach science. Then, I decided to contact pre-service teachers whom I taught during the 2000/2001 academic year hoping that more of them are teaching by now. I contacted four individuals from that cohort. Three of them returned either my calls or e-mails. They were all positive and open to my project and one of them, Scott Brown (pseudonym), was able to participate in my study. He also met all of the criteria I specified in the above two paragraphs. Although, he was not teaching science this year, he was willing to change his teaching assignments with his teaching partner from the same school.

I decided to collaborate with only one teacher because it is a long-term, in-depth project which requires a lot of dedication and hard work from both the teacher and researcher. I believe that it is impossible to do such an in-dept study with more than one teacher.

3.3.1 Scott

I met with Scott and his principal, Anna Zahn (pseudonym), on December 18, 2003. The purpose of this meeting was to personally talk about ethics and specifics of my study, and to seek Anna's permission to carry out the project in her school. After that, to learn more about Scott, I visited him twice in his school (on January 8 and on January 22, 2003, See Appendix A for Schedule of events). When I first met Scott, he has been teaching, on full time basis, for one and half years in the Red River School Division. Thus, Scott was a beginning teacher and, as mentioned earlier, I believe that such teachers can benefit the most from the collaboration with researchers. Furthermore, collaboration with the beginning teacher allowed me to observe how he translates knowledge acquired in his C & I class into his classroom practice. Scott's school, Prairie View School (pseudonym) was located in Winnipeg's inner city. His teaching assignment included Mathematics, Language Arts, French, and Physical Education. Before receiving this full time contract, while still a student at the University of Manitoba, he was offered a two-month substitute position in the same school division. Thus, he started working as a teacher in May of 2001, immediately after graduating from the University of Manitoba with a Bachelor of Education degree.

During our meetings we talked about his background, characteristics of an inner city school, his experiences in an inner city setting, scientific literacy, and nature of Middle Years students. I tape-recorded our conversations and then I transcribed them verbatim. The excerpts, in italic, from our conversations are used throughout this dissertation. These conversations with Scott further assured me that he will be a good research partner. He took time to talk to me and gave me detailed explanations to all of my questions. I also found it engaging to listen to him and learn about his rich experiences both as an individual and as a teacher. I knew him as a diligent student. But, through our meetings, I have come to know him as a person and as an ambitious professional. For example, I realized that he has leadership qualities and that as a professional he likes to be involved in various extracurricular activities. During that school year, for instance, he was the head of the Social committee, Leadership Committee, Technology Committee, Safe Schools Committee. He was also a member of a Budget Committee and a Literacy Committee. In addition, he was the head of the French Department. Furthermore, he ran Intermurals and coached basketball and floor hockey. With his teaching partner, he did Problem Solving Challenge and ran the Jeopardy Club.

His involvement and busy schedule indicated to me that he is not only a leader but also a hard worker, who likes to be fully immersed in whatever he does: *"I like to immerse myself completely in whatever I do. So I mean it is not enough for me to be there just on the surface."* Scott was also a "team player" as his principal, Anna, put it. He felt that it was his *responsibility to be an active staff member*.

Scott was not always such a busy, fully *immersed* person. He mentioned that he was a much different and rather interesting character while growing up. His *"High School years were not exactly his best extracurricular kind of days"*. Apparently when he was attending Junior High and High School he was a rather interesting character who had a lot of social difficulties and behavioral problems. He admitted that he " *had lot of issues with a lot of different people when he was in High School, violent behavior, number of suspension and stuff.*" He was also affected by "*severe ADHD*" and had a hard time to focus on anything. He mentioned that he found Language Arts and Social Studies challenging, but, *for some reason,* he did really well in Mathematics and Sciences.

While at the university, Scott *started becoming more of the social person.* This is when he started *going out, joined different clubs and started doing many different things.* (Teacher interview – January 8, 2003). Scott spent the first two years of university on "*finding himself a lot.*" Everything changed during his third year when he joined Student Council at the Faculty of Education. After the experiences in the Student Council, he became the section representative, sat on the committee for hiring the new dean of education and on the Faculty Council. His GPA also reflected his gradual growth: He indicated to me:

> *"My grades while they were not average were not the best. I believe, I mean now a lot of people would be happy with these. But, I mean let be honest I am somewhat of a perfectionist. So at the end of my first and second year my cumulative GPA was around a three, which is average but for me it was kind of like I can do better than that. My third year I was at a four and my fourth year I was at a four point three. So, you know obviously, you know, with finding myself and becoming more and more involved I expected more of myself and I met those demands".* (Teacher interview – January 8, 2003).

In terms of his science background, in high school, Scott took all of the university entrance sciences, such as: physics, chemistry, and biology. At the university, Scott, like most other teachers in the elementary stream, completed six credit hours in sciences. He chose geological science firstly because this course *is* most relevant to the elementary and middle years science curriculum. Secondly, he chose geological science rather than, for example, any biology, physics, or chemistry course because in his first two years of university he was very unsure of the direction he wanted to take and this course was recommended to him by a friend, who had taken the course. Natalia took the same course to fulfill her science requirement and she gave me the same reasons justifying her choice. I disagree with both Scott and Natalia. According to me, geological science prepares the future teachers to teach only two units of the elementary and middle years curriculum, which are Rocks and Minerals in grade four and Weather in grade five. My recommendation would be that the future teachers take a course that explores science from the interdisciplinary view point, with an aim to foster scientific literacy and develop critical thinking skills. Such course needs to draw topics from biology, chemistry, geography and physics. Furthermore, these topics must be relevant to the Manitoba elementary and middle years science curriculum. The University of Winnipeg, for example, is taking steps to implement a multidisciplinary science course, which is aimed at Education and Liberal Arts students looking for a general knowledge of science at a qualitative level. Refer to Chapter seven, section 7.3.1.2, for discussion of an interdisciplinary course for developing teacher scientific literacy.

3.3.2 Inner City School Setting

Throughout this section, I highlight the characteristics of Prairie View School generated from my conversations with Scott and Anna, which I conducted prior to my classroom observations. I compare Anna's and Scott's descriptions of the school with my own perceptions of Scott's class and the school in general, which came to my mind while being there as a researcher. From my conversations with the teacher and the principal, I learned that the first thing that characterizes Prairie View as an inner city school is the socio-economic status of the community in which it is located. Kids don't have proper clothing, they don't have proper food. They also do not have everyday experiences typical for kids who live in other neighborhoods. For example, Scott mentioned that "*many of them have never been on a car trip.*" When I was there, I did not observe lack of proper clothing. Their wardrobe was simple and inexpensive, they did not were brand name clothes. But, whatever they wore was appropriate for school and sufficient for the time of the year. But, I fully agree with Scott that his students did not have the experiences other children took for granted. For example, none of them has ever been to the Forks, a well-known meeting place for tourists and Manitobans of all ages. The Forks is especially popular among young kids because of the skating ring, water taxi, biking and cross country pathways, ice cream, etc. Furthermore, Royal Dance Academy, Manitoba Theatre for Young Children, and Manitoba Children's Museum are located right there.

Anna, the principal, used the word - poverty - to describe her students' situation. By poverty, Anna meant not only *"lack of money"*, but, also *"lack of proper skills and understandings."* She explained that because of the lack of money, *"many of their students don't eat or do not have warm clothing for the winter."* Because of the lack of skills, on the other hand, *"the students come to school without usual readiness skills required for each grade level."* For example, younger kids often do not know their name and address. They are not familiar with books, because they do not have them in their homes, and nobody has ever read a book to them. They do not know how to properly hold a pencil and how to draw with crayons.

Anna wanted to improve the situation of the young students in the community. She believed that the best gift the staff can give their kids is the ability to read, write, and do basic math, and everything in her school was done with this notion in mind. Her mission then was to make sure that the students have the basics to move on in life. For example, she developed a full day kindergarten program. In addition to the kindergarten program, the school adapted guided reading approach, which involved the students from the whole school. I wanted to see how it works and decided to participate in one of the guided reading sessions with Scott's and his colleague's students. It was ran by Scott's teaching assistant. While sitting there and listening to various students take turns and read aloud, I realized that indeed all of the staff members are making every effort to help the students from Prairie View Elementary succeed in life.

Another characteristic of this school, like any other inner city school, is a very diverse student population. Both Scott and Anna mentioned that the school has a significant Native population from various reserves around the province (about 60%), big Filipino and Caucasian populations, followed by different Asian countries, such as: Laos, China, and Vietnam. There were also students from Sri Lanka, Saudi Arabia, and Sudan attending the school. These students and their parents often did not speak English and were considered English as a Second Language learners (ESL). There were seven children in Scott's class, whose parents either did not speak English or spoke with an accent: Nick, Emillio, Ian, Scott, Rose, Han, Matthew. However, all of those kids were fluent in English and did not require any assistance from the ESL teacher. All of them spoke without or maybe with a slight accent and except for Nick they did not seem uncomfortable with the fact that they were from a minority group and that their parents did not speak English.

Only Nick felt uncomfortable and had a hard time admitting that his parents did not speak English. A homework assignment was to interview their parent(s) about causes of flood. For this assignment, the students were required to take the recorder home and to record their conversation with their parents. All of the students were very enthusiastic about this assignment, maybe not because they were thrilled about talking to their parents, but because they got to take the recorder and play with it at home. Nick, however, kept on making excuses whenever I suggested that it was his turn. For the first time, he mentioned that his parents won't be home. Then, he said that they were going away for the weekend and finally, when I approached him for the third time, Sammy just said: *"he does not want to take it home because his parents do not speak English."* Nick responded: *Yup*. Then, I asked whether his older sister can do it but he said that *"she is* *too busy applying her make-up,"* and insinuated that he *"might consider taking it some other time."* I knew that that was it and never brought up the topic again, but, that incident made me think about two things. Firstly, it made me think about my own family, specifically about my relationship with my daughter. I wondered whether my daughter will ever feel uneasy to admit that she does not speak English at home; Will she ever pretend that she does? And How will she behave in front of her friends? Secondly, it made me think about Nick and other kids from "immigrant" homes. For example, I was presently surprised that Nick who spoke only Laotian at home was so fluent and eloquent in English. Furthermore, this boy, who d*id not like science because it was boring* was very strong academically and achieved great marks, obviously without any help from his parents. He was a witty boy, always full of questions, always ready to fight for what he considered fair.

This incident with Nick also proves that the school in inner city is indeed involved in educating citizens, shaping their character, beliefs, and attitudes. I was intrigued by all of those "immigrant" kids in Scott's classroom and often talked to him about them. Scott told me, for example, that Nick's parents are working several jobs and are seldom at home and that the boy spends a lot of time either at school, at his Anglophone baby sitter's house, or friends' houses, which might explain his competence in English.

The school also has students with diverse diagnosed and non-diagnosed problems and disabilities, such as: abnormal behavior disorder, fatal alcohol syndrome, fetal alcohol effects, and developmental delay. To give an example, in Scott's class, there was Shane who was a cute Aboriginal student who had ADHD. Additionally, Shane was emotionally disturbed and required direct supervision of the educational assistant at all times, including transportation to and from school. He was considered violent to other students when unsupervised. I really liked Shane and I did not consider him violent. He always wanted to please, was very interested in our study, asked good questions, and was always ready to participate and ask questions. Out of all of the students in this class, Shane was the one who either answered or asked the greatest number of questions. I think that both Scott and his educational assistant – Grace (pseudonym) showed him that he can trust them and this helped him to show his better side. He really respected Scott and sometimes I had a feeling that he was missing a male figure in his life and was treating Scott as one. Shane only lived with his mother. Actually, toward the end of the school year, Shane's behavior improved greatly. He was no longer driven to and from school. They trusted him to walk by himself from school. But, to make sure that he does not pick fights, he left school five minutes after everyone else and needed to call the school as soon as he gets home.

Jane was another problematic student. She was academically delayed but, her specific problems were not diagnosed because her mother refused to get her tested. Her mother also did not give her permission to participate in my study. Jane was a very immature, overly sensitive, attention-seeking girl. She constantly wanted to say something, but it was usually irrelevant. Scott did his best to attend to her needs but, sometimes it was impossible to assist Jane and to teach the other students. Because of Shane's and Jane's behavioral and academic problems, Scott had a teaching assistant, who was founded by the government. Grace's job was to supervise Shane on full time and Jane on part time basis. Thus, Grace was present in Scott's classroom at all times. Not every teacher had a TA, but, according to Scott every teacher of the Prairie View requires one. Grace was instrumental overseeing the daily routine. She had her eye on everyone, not just Shane and Jane. Every morning, for example, she checked if everyone did their homework and after lunch she always made sure that Timothy made his daily trip to the office to get his medication. Tim had been diagnosed with severe ADHD. However, because his mother was a single mom of three and a full time college student, she did not always remember to give this medication to Tim who, was not able to concentrate without it. Thus, the principal decided that it would be best to have these pills in the office *to make everyone's life easier*.

Like in any other school, I suppose, there was a whole spectrum of other students who required extra time and attention of the teacher. There was Han, who required weekly speech therapy and Charlene and Yolanta, who were academically belated. Charlene was an Aboriginal student who moved to the city from the reserve at the beginning of the school year. She was very quiet. I did not see her talking to any of the students. Yolanta, on the other hand was very talkative, but, she was also immature for her age and did not behave like a fifth grader. There was also Alek, who could not spell, Joey who did not do any work, Sebastian who seldom came to school, Daniel who had many unrelated stories to tell, and Sammy who, was very smart, but, did not bother to pay any attention.

Like in any other school, there were hard working students who always wanted to please everybody, including myself. For example, Emillio was very involved, enthusiastic and passionate about everything we did. Kristofer was obedient, always had his homework done on time and wanted to do well at school. His dream was to become a police officer. Kathy, who spoke French, was industries, witty, quick and good in everything she has undertaken. Her friend Hanna shared some of those qualities. There was also Jessica who was smart and passionate about animals. She wanted to become a veterinarian. Dorothy seemed mature for her age and devoted to school. She was Tim's cousin, they were very close. She was eloquent and able to articulate her thoughts clearly.

Rose, a little Filipino girl, was another smart girl. She, as Scott put it, was *like a gem in a rough.* She was very strong academically, but, it was hard to notice her qualities because of her obedience and quiet nature. In addition to being strong academically, she was also a great artist. She really made great sketches for her group's poster and her journal was also very impressive. Scott told me that she wanted to become an illustrator when she grows up. But, when I asked her about her future aspirations, she told me that she wanted to be an inventor. To accommodate the various needs of such a diverse group of students, the school had to develop various programs and hire professionals whose assistance is not normally required in other schools. For example, to accommodate the needs of ESL students, the school had an ESL educational assistant who worked in cooperation with the resource teacher. In addition, the school employed a speech therapist to assist students with various speech problems. In Scott's class, Han, a sweet Chinese boy, had speech therapy lessons once a week, for two hours. He was indeed very hard to understand. But, he was born in Canada and he was not considered ESL.

To help the students overcome their behavioral and emotional problems, the school modeled acceptable behavior, attitudes, and social skills. According to Scott, the teachers needed to show their students how to behave appropriately, because *"they don't get it at home."* For example, they taught them that it's polite to say thank you and you are welcome, or that it is rude to interrupt while others are talking. Scott and Anna explained how it is being done. Consider the following comments by Scott:

> *"We have ensemble completely dedicated to that. We teach the skill, we model it for them, we have students and teachers interacting in front of them in a little skid to show them how it works. Like things like please and thank you, saying hallo back when someone says hallo to you. Things like how to deal with it when you are not chosen first for a team or you know how to, how to come and tell somebody the difference, of gossiping verses of, you know, telling. What's important to tell to the teacher, you know. Just things that the kids aren't getting from home, let you assume sometimes that they do have, you know basic social skills. You know, lets talk about how you react when somebody is calling you a name verses going on a rampage and acting violently. So, I mean there are things the students don't have coming into here and you can't make any assumptions."* (Teacher interview – January 8, 2003).

I was able to witness how the school models appropriate behavior during a school ensemble where Scott and physical education teacher, Mr. Boyd (pseudonum), were trying to model the difference between telling and tattling. The message the students were supposed to learn from the teachers' performance was that we tell when we want to help, and we tattle when we want someone to get in trouble.

At the time of my research, Anna was working at Prairie View School for seven years and she was happy about the positive changes she has observed in students. At the beginning of her reign, she needed to spend about 80% of her day dealing with discipline issues and when I was there she only needed to resolve discipline issues on very limited bases, probably once every few weeks. According to Anna, the *"classrooms were completely under control, the teachers knew what to do, and the students really loved their school and they loved their teachers, because everybody there was fair, firm and consistent."* She mentioned that when she first came to Prairie View, she found behavior and attitude unacceptable and that she, together with her staff, spent countless hours on changing the culture of the school, teaching social skills and on *"drawing some lines in terms what was acceptable and what wasn't."* To do that, she needed to change the attitude of the whole community because, as she explained, *"there seemed to be a feeling in the community that they were calling and determining how, what behavior would be accepted at school."* Consider the following example, which clearly illustrates her point: *"If someone would get into fistfight, if you spoke to parents about it and explained this was not acceptable in school. They would tell you - "No, that's O.K. because I have told them that they can punch whoever and whatever because they bug us and we don't like that family".... And if so, I just said not at school."*

Anna's attitude was: *"if there is a problem, it's not my problem or your problem it's our problem and we work through it."* That was evident when Joey, who happened to be in Scott's class did not return to school after lunch as he was supposed to. It was not only Scott's or Anna's problem, but the whole school was involved in finding him and then dealing with the issue discretely. Apparently, little Joey was easily influenced by other students and in this particular case e was encouraged by another student from Mr. Sobolewski's class to stay in his home. As I was told later, that other student was famous for that.

In addition to being diverse, the population of Prairie View School is transient. According to Scott, the Community College located across from the Prairie View School contributed to the mobility of the community. Scott explained that the *"...parents often move down from the reserves up north to take a course... They show up the first day of school, because that's when the parent's start. A lot of parents tend to drop and what do they do? They turn directly back to family, they move up north and the kids are gone two weeks later. Those, of them that stick around leave once their parents are done their program in April or May. They leave, and so they miss the last two months of school, they go back up north to where their family is."* (Teacher interview – January 22, 2003).

Another characteristic of an inner city school is lack of parental involvement, which is associated with poor attendance and often poor students' performance. Students often do not come to school unless the school sends an officer to visit their homes to further clarify the situation. Anna suggested that they have adopted this strategy of sending the officer to students' homes to let people in the community know that the school cares about the students and to make parents responsible and accountable for their actions. Consider Anna's remarks:

> *"We don't say why is it that your kid is not in school, we say such and such was not in school and are worried about them. You know, are they at home, and are they sick, what is wrong with them? ...We want to let the family know that we care if their kids are not here. And secondly, I guess, to create a little bit of accountability so that the parents know that somebody is going to be knocking on the door if they don't, if we won't hear from them."* (Principal interview – January 22, 2003).

This approach, however, is not always successful. Bonny, for example, has missed more days than he has attended, despite the many efforts on Scott's part, the resource department, and the social workers. When I asked Scott to clarify Bonny's situation, he explained to me that she often visited her family over the weekend and either did not come back to start school on Monday or came back in the middle or at the end of the week and in that case Bonny's mother did not believe that it was worthwhile to her daughter to school.

I did not have a chance to observe the transitory character of the population, but, parental negligence was obvious in Scott's classroom. Bonny's mother is a good example of parental negligence. Sebastian's mother did not care either. It was Sebastian's own responsibility to wake up early in the morning to make it to school on time. He was also responsible for his little brother, so if the boys felt like going to school they did, and it was entirely up to Sebastian to either take his brother along or not. Parents also did not care much about their children's homework. Scott seldom assigned homework because as he put it *"it did not get done anyway."* When he did give students homework, he had to make sure that it was done during the last period of the school day.

Despite of all, Anna was happy with her accomplishments. According to Anna, her greatest accomplishment was being able to transform the school from being *"out of control"* to being *"in control,"* where the *"kids love to come, the parents love to send the kids and the staff likes to be"*. Her greatest challenge, however, was trying to *"deal with irrational situations in a rational way"*. She gave the following example to illustrate her point:

> *"There is a gentleman who lives over across the street. And, he is a senior, he doesn't have any children, but one of the things he keeps trying*

> *to do is to lure kids into his home with candies from our playground. And, so, that is difficult. When we tried to explain to him that we are trying to teach children that, you know, that is not appropriate behavior. He said that he will do whatever he wants, and he just felt that that was ridiculous that, you know, we were trying to train the children to not to go to strangers' homes."* (Principal Interview – January 22, 2003).

3.3.4 Ethical Considerations

In December of 2002 I met with Scott and Anna, his principal, for the first time, to discuss the study in more detail. For that meeting, I prepared a first version of the letters and consent forms, which I intended to distribute to the students, parents/guardians, teacher, principal, and superintendent. After reading the letters, Scott recommended that I clarify that students' personal and medical records will not be accessible to me at any point of the study. He also volunteered to send the letters to student's homes, once I have them approved by the University of Manitoba Ethics Committee. My research was approved by the Ethics Committee in February of 2003 and after that I started gathering written consents of all parties involved in the study.

To get parent/guardian approval, on March 26, 2003, Scott asked every child to take the letter and consent form home and return it on the next day of classes (see Appendix B for the copy of this letter and consent form) . In the letter, I explained the purpose, significance and child's involvement in the study. In addition, the parents were informed that I would like to analyze written work done by their child, such as: science notebook, and science assignments and tests. Through this letter parents /guardians were also informed that participation in my study was voluntary and that only those students who receive parental permission and give written consent themselves would be audio- and/or video-taped, or their work would be analyzed. Except for two, all of the students' parents/guardians gave their children written permission to participate in my study.

To recruit student volunteers, on March 27, 2003 I visited Scott's grade five class to explain the purpose, significance, and their involvement in my project. At that time, I also answered students' questions. Then, I asked the students to read the letter, and if willing to take part in the study, sign consent form, and return them to their teacher on the next day of classes (see Appendix B for the copy of this letter and consent form). All of the students signed the consent forms at my presence and returned the forms to me at the end of our meeting.

I also received written consent from the teacher, principal, and the superintendent (copies of these consent forms could be found in Appendix B).

3.4 Methodology

In this subsection, I describe the research design and data collection techniques and analytical procedures. I also describe Scott's and my collaborative effort of planning and teaching the unit on Weather.

3.4.1 Research Design

This study is of qualitative nature, which Strauss and Cobrin (1990, p.17) define as "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification." It is a process that results in conclusion derived from data gathered by a variety of means, such as observations, interviews, documents, videotapes, researcher's personal reflections. According to many authors qualitative studies could be characterized by the following features: 1) They are field focused and rely on self as a research instrument; 2) They are descriptive, interpretative in character and rely on the use of expressive language and the presence of voice in the text; 3) They consist of data which are analyzed inductively (Bogdan & Biklen, 1992; Janesick, 2004; Strauss & Cobrin, 1990).

The researcher is the key instrument in qualitative studies because researchers enter and spend considerable amount of time in schools, like in the case or my study, neighborhoods or other locations. Sometimes the researchers use video equipment and other recording devices and_sometimes they go to the field unarmed. In both cases, however, the data collected are supplemented by researcher's understanding gained by being on location.

The data collected are in the form of words or pictures, rather than numbers, and have a descriptive character (Bogdan & Biklen, 1992). In collecting these descriptive data, qualitative researchers approach the world with an assumption that nothing is trivial, that everything has a potential of being a clue that might lead to a more comprehensive understanding of what is being studied. Bogdan and Biklen (1992) explain that in qualitative studies nothing is taken as given and no statement is unimportant.

Furthermore, qualitative researchers do not go to the field to prove or disprove their hypotheses. They develop their theories about what they have been studying after spending some time at the field. The big picture takes shape after being there and putting all of the emerging parts together. The process of data analysis is like a funnel, which means that things are widely open at the beginning (at the top of the funnel) and more directed and specific at the bottom. This systematic, inductively derived method is known as grounded theory (Strauss and Corbin, 1990).

Valerie Janesick (2004) in *Stretching Exercises for Qualitative Researchers* uses dance as a metaphor for qualitative research design. In her book, the concept of stretching implies that one is moving from a static point to an active one. In other words, one is moving beyond the point at which he/she now stands, not by memorizing formulae, but by relying on his/her intuition. Janesick explains that, just as the dancer must stretch the body and mind to begin what eventually becomes the dance, qualitative researcher must use various techniques to collect and analyze data. Like a dancer, the qualitative researcher must train the mind, the eye, and the soul together. The researcher must use the mind to ask relevant questions during interviews; the eye to be a careful observer; and the soul to interpret data. Janesick also writes that by starting qualitative project a researcher automatically begins a labour-intensive and challenging journey. This journey is similar to a journey of a dancer from warm-up and initial stretches to backbends, headstands, and other postures that involve the body and mind. Furthermore, a researcher, just like a dancer, must be fine-tuned at seeing (observation), hearing (interview), writing (researcher reflective journal), and conceptualizing.

The researcher, as the only research instrument, is dealing with lived experiences and must posses the ability to use all the senses, such as sight, hearing, touch, smell, and taste to complete the four cycles (Janesick, 2004). Furthermore, after living in the field with participants over time, the researcher also uses the sixth sense, an intuitive sense, to understand certain behaviors or situations that emerged from observing or interviewing.

3.4.2 Data Collection Techniques

Sandra Mathison (1988) in the article entitled *Why triangulate*? addresses the issue of validity in qualitative studies. She explains that "good research practice obligates the researcher to triangulate to enhance the validity of research findings" (p.13). As suggested by Mathison and many other qualitative researchers (Bogdan & Taylor, 1998 Janesick, 2004; Strauss & Corbin, 1990; Wolcott, 1998; among others), I collected multiple sources of data, which is referred to as triangulation. My data collection followed the three primary fieldwork strategies, such as experiencing, enquiring and examining, known as the three Es (Wolcott, 1998, p.19).

Table 3.2 Data collection techniques (the three Es).

Experiencing	Enquiring	Examining
Through observation and Field notes 1.participant observations 2. field notes associated with participant observations	When the researcher asks: 1. interviews	Using and making records: 1. students' written work 2. maps 3. audio-and video-tapes 4. field notes

Classroom Observations

In this study I was an active participant observer. According to Spradley (1980) participant observations are undertaken with two purposes in mind: 1) to observe the activities, people, and physical aspects of situation, and 2) to engage in activities that are appropriate to a given situation that provide useful information. In line with Spradley's recommendations, as a participant observer, I purposefully looked for opportunities to actively participate in various tasks, and I made sure that students saw me as an active participant.

All classroom interactions, (both large group and small group) were video- and/or audio-taped. The video camera was directed at the whole class and a recorder was placed on every group's bench. Subsequently, I transcribed all electronic recordings verbatim. These transcripts also include comments about the students, teacher(s), school, as well as my interpretations, hunches, preconceptions, and comments for future inquiry. Hence, my transcripts consist of descriptive information and personal comments, which are designated as O.C. for observer's comments (Taylor & Bogdan, 1998).

Interviews

Three times in the duration of the study, I conducted in-depth interviews with individual students to understand their developmental understandings of science. All interviews with the students took place at school in a small room next to the library. The questions I asked were related to the material studied in class. For example, can you tell me how, according to your opinion, scientists conduct scientific inquiries.

I also planned to conduct formal interviews with Scott for his meaning making of the development of scientific literacy in his classroom. But, it was hard for him to find a longer period of time to sit down with me and answer all of my questions. Thus, I always carried a tape recorder with me and captured every conversation we had throughout the time I spent at his school. Most of our conversations happened either before the science class, during breaks, or sometimes after school.

All formal interviews with the students were audio-taped, and subsequently transcribed verbatim. Then, the transcripts were color coded to generate themes.

Students' Written Work

Students' written work, such as: science notebook, homework, assignments, and tests were collected, photocopied, and then returned to the students.

Maps and Photographs

I took photographs of each group of students, with the weather instrument they designed, posing in front of the weather bulletin board. I also drew a map of Scott's classroom.

3.4.3 Data Analysis

1) Field notes recorded after every class were coded and themes were generated. Like in my earlier study, I generated patterns and meanings from the collected data by color coding (Taylor & Bogdan, 1998).

2) Interview transcripts were color coded and themes were generated. The field notes contained the following information:

a) An outline of topics discussed in each interview to help me keep track of the topics.

b) List of emerging themes, interpretations, hunches, striking gestures, and non-verbal expressions, which I will consider as essential for future analysis.

3) Students' written work was analyzed and color coded to establish themes.

4) Maps and photographs served as a reflective tool to recall episodes such as, the traffic flow in a classroom, teacher's interactions with the students and other staff members, and individual student's interactions with the teacher and with the other students, student faces, etc (Taylor & Bogdan, 1998).

3.4.4 Validity and Reliability

Descriptive validity refers to accuracy with which the researcher is able to report factual data. In other words, it is concerned with things that can be observed by the researcher.

Interpretative validity refers to accuracy with which the researcher interprets data. It is related to accuracy of the interpretations with regard to the participants' intentions, beliefs, and attitudes. In other words, it is concerned with the subjective meanings of the events and behaviors of individuals. It relates to those things that cannot be observed, but, can only be interpreted. In my research, to give accurate account of the events that I observed and to demystify the research process I use ordinary language that does not distance the reader from what I have experienced (Janesick, 2004).

Theoretical validity is concerned with an explanation as well as a description and interpretation of an account (Janesick, 2004).

Interpretative validity refers to being concerned with the subjective meanings of the objects, events and behaviors of individuals. It is concerned with those things that cannot be observed. It is concerned with the accuracy of the interpretations made by the researcher with regard to the participants' intentions, beliefs, attitudes, and evaluations (Janesick, 2004).

3.4.5 Unit Planning Phase

Just as dancers who need every step of their performance to be carefully choreographed, Janesick (2004) believes, that qualitative researchers should likewise engage in careful planning of every step of their projects. Prior to the planning of the unit, I dissected the curriculum, based on the similarity of the specific learning outcomes, into three phases entitled: 1) *Weather Forecasts: Different Ways of Predicting and Measuring Weather, 2) Properties of Air and Clouds, 3) Weather and Climate (STSE).* Scott and I took 4 sessions, total of 28 hours to choreograph the lessons within the unit on Weather. Our planning started with a "warm up session" on March 11, 2003, followed by an intense, 3-day session from March 30 to April 2, 2003, which coincided with Scott's spring break. During the first sitting, we generally brain stormed what kind of lessons could be done within the unit. We did not, however, write any lesson plans or make any final decisions as to how to address any of the specific learning outcomes. The second session was very productive and during this session we managed to write the lesson plans and homework assignments for the two above-mentioned components. We also planned the filed trip and talked about the quests that we would like to invite to our classroom. The last component was planned after we started teaching. Session # 3 took place on April 21, followed by session # 4 on May 4, 9, and 13. Planning of the last component took place in Scott's school, usually during breaks. See Appendix A for detailed calendar of the planning sessions.

The primary mode of work between me and Scott was conversation. We were learning through talking with each other. While planning the weather unit, we also talked about the physical set-up of the classroom and the resources that will be beneficial for both the students and the teacher. Scott took care of all those things. When I arrived on the first day, his classroom was totally rearranged. It must have been intriguing to the students to see so many changes. For example, Scott striped everything off one of the boards for the students to, later on, record their daily weather measurements. On the side of the room, there were two tables, where Scott placed weather related books. The individual desks were organized into big tables for each group to sit around. There was a red duo tang placed on the desk of each of the students, where they were clipping all science related materials.

3.4.6 Teaching Phase

Table 3.3 lists the Specific Learning Outcomes (SPO), with their descriptions, as well as the titles, lengths, and dates of the corresponding lessons. Note, that the last column of the table matches selective lessons with the pertinent phases of the CKCM. The phases of the model are bolded. The Specific Learning Outcomes, in the first column, are listed in the chronological sequence as they were taught. As seen in this table, there are several lessons that do not have a corresponding Specific Learning Outcomes from the curriculum (see steps 5, 6, 7, and 26 in the last column). Although, these lessons do not have direct connections with the curriculum, we felt that it was necessary to include them in our investigations for legitimate reasons. For example, the necessity for the lesson in step five (see it in the last column) emerged from the exploration activity in the first phase of the model. Specifically, a few students responded to our exploration question, which was: *How people predict and measure weather?* that people use thermometers or other instruments to measure weather. In line with the CKCM, these ideas should be included in the Constructing and Negotiating phase of the model. Hence, we included three lessons where the students had a chance to learn how to use a thermometer, barometer, anemometer, weather wane, and rain gauge (see step 5 in the last column of the table). Secondly, because students' parents took part in the Exploring and Categorizing phase, and because they also believed that people use various instruments to measure weather, we felt that it was necessary to elaborate on it in class. Thirdly, the curriculum does not require the students to learn how to use any of the weather instruments. However, it does require that the students use instruments to measure weather over a period of time. It also requires the students to use the design process to construct a weather instrument. Furthermore, it requires the students to identify and describe components of public weather reports forma variety of sources. In turn, the components of the public weather report are temperature; relative humidity; wind speed and directions; wind chill; barometric pressure; humidex; cloud cover' ultraviolet index; warm and cold fronts; amount, types, and probability of precipitation. Because of the above-mentioned curricular requirements we decided that it would be beneficial for the students to learn how these instruments look like and how they are used to meaningfully construct knowledge.

Table 3.3 A Sequence of the Specific Learning Outcomes and Corresponding Lessons on Weather.

Specific Learning Outcome and Number	Outcome Description	Lesson(s) Title(s)
	Phase 1 *Weather Forecasts: Different Ways of Predicting and Measuring Weather*	
5-4-10 Investigate various ways of predicting weather, and evaluate their usefulness.	Examples: weather-related sayings, traditional knowledge, folk knowledge, observations of the natural environment...	1. Students' ideas on how people predict and measure weather (1 lesson; April 7, 2003) – **Exploring and Categorizing phase of the CKCM.** 2. Weather -related sayings (1 lesson; April 14, 2003) – **Constructing and Negotiating phase of the CKCM.** 3. Plant, animal, and sky folklore (1 lesson; April 15, 2003) - **Constructing and Negotiating**

		phase of the CKCM. 4. Aboriginal wisdom (1 lesson; April 15, 2003).
		5. Learning how to use a thermometer , barometer, anemometer, weather wane, and rain gauge (3 lessons; April 8-10, 2003) - **Constructing and Negotiating phase of the CKCM.**
		6. Water cycle (1 lesson; April 11, 2005).
		7. Lives of: Beaufort and Celsius – integrating Science with Language Arts (2 lessons; scattered over several days).
5-4-12 Describe examples of technological advances that have enabled humans to deepen their scientific understanding of weather and improve the accuracy of weather predictions.	Examples: satellites collect data that scientists analyze to increase understanding of global weather patterns; computerized models predict weather…	8. Preparation for the field trip to the Environment Canada Weather Office (2 lessons; April 16, 2003) **Constructing and Negotiating phase of the CKCM.** 9. Field trip to Environment Canada Weather Office (half a day ; about 4 lessons; April 17, 2003) - **Constructing and Negotiating phase of the CKCM.** 10. In-class summary technological advances that have enabled humans to deepen their scientific understanding of weather and improve the accuracy of weather predictions (1 class; April 21, 2003).
5-4-05 Use the design process to construct a weather instrument.	Examples: an instrument that measures wind direction, wind speed, rainfall…	11. How to build my weather instrument? Research (2 lessons; April 23, 2003) – **Translating and Extending (design process) phase of the CKCM.** 12. Building weather instruments (2 lessons; April 24, 2003) - **Translating and Extending (design process) phase of the CKCM.**

		13. History behind Stevenson's screen and building Stevenson's screen – after school activity (1 lesson; April 24, 2003) - **Translating and Extending (design process) phase of the CKCM.** 14. Weather instrument brochure – integrating Science with Language Arts (1 class; April 25, 2003) - **Translating and Extending (design process) phase of the CKCM.**
5-4-06 Observe and measure local weather conditions over a period of time. * done over two weeks	Using student-constructed or standard instruments, and record, and analyze these data.	15. Mechanics of measuring weather using our instruments (1 lesson; April 25, 2003).
5-4-07 Identify and describe components of public weather reports forma variety of sources. * done over two weeks	Include: <u>temperature</u>; relative humidity; <u>wind speed and directions</u>; wind chill; barometric pressure; humidex; cloud cover' ultraviolet index; warm and cold fronts; <u>amount, types, and probability of precipitation</u>.	16. Mechanics of reading weather reports using Environment Canada web site (1 lesson; April 28, 2003). 17. Presentation by the TV weather anchor (1 lesson; April 25, 2003).
	Phase 2 *Properties of Air and Clouds*	
5-4-03 Describe properties of air.	Include: has mass/weight and volume; expands to fill a space, expands and rises when heated; contracts and sinks when cooled; exerts pressure; moves from areas of high pressure to areas of low pressure.	18. Students' ideas on air (1 lesson; April 28, 2003) - **Exploring and Categorizing phase of the CKCM.** 19. Properties of air (2 lessons; April 29, 2003).
5-4-04 Recognize that warm and cold air masses are important components of weather, and describe what happens when these air masses meet along a front.	Include: in a cold front the cold air mass slides under a warm air mass, pushing the warm air upwards; in a warm front the warm moist air slides up over a cold air mass.	20. Cold and warm air masses (1 lesson; May 1, 2003) – **Constructing and Negotiating phase of the CKCM.**
5-4-11 Contrast the accuracy of short and long-term weather forecasts, and discuss possible reasons for the discrepancies.	Include: long-term forecasts may not be accurate as weather is a complex natural phenomenon that science is not yet able to predict accurately.	21. Long vs. short-term weather forecasts (1 lesson; May 2, 2003) - **Constructing and Negotiating phase of the CKCM.**

5-4-14 Explain how clouds form. 5-4-15 Identify and describe common cloud formations.	Relate cloud formation and precipitation to the water cycle. Include: cumulus, cirrus, stratus.	22. Cloud formation and cloud types (1 lesson; May 2, 2003).
		23. Station-to- station test (1 lesson; May 5, 2003) – **Reflecting and Assessing phase of the CKCM.**
	Phase 3 *Weather and Climate (STSE)*	
5-4-16 Differentiate between weather and climate.	Include: weather includes the atmospheric conditions existing at a particular time and place; climate describes the long-term weather trend of a particular region.	24. Students' ideas on climate (1 lesson; May 6, 2003) – **Exploring and Categorizing phase of the CKCM.** 25. Weather vs. climate (1 lesson; May 7, 2003) - **Constructing and Negotiating phase of the CKCM.**
5-4-17 Identify factors that influence weather and climate in Manitoba and across Canada, and describe their impacts.	Examples: jet stream, proximity to water, elevation, chinook…	27. Factors affecting weather and climate (1 lesson, May 9, 2003).
		26. Accuracy of our weather instruments (1 lesson; 05.12. 03)
5-4-09 Provide examples of severe weather forecasts, and describe preparations for ensuring personal safety during severe weather and related natural disasters.	Examples: tornado, thunderstorm, blizzard, extreme wind chill, flood, forest fire…	28. Students' ideas on flood formation (1 lesson; May 12, 2003) - **Exploring and Categorizing phase of the CKCM.** 29. How do floods form? (1 lesson; May 13, 2003) - **Constructing and Negotiating phase of the CKCM.** 30. How to stay safe in case of flood situation (1 lesson; May 14, 2003) – **Translating and Extending (STSE) phase of the CKCM.** 31. Educating the school community **Translating and Extending (STSE) phase of the CKCM:**

		a) poster (2 lessons; May 15, 2003) b) letter (1 lesson; May 16, 2003)
5-4-02 Describes how weather conditions may affect the activities of humans and other animals.	Examples: heavy rainfall may cause roads to wash out; stormy conditions may prevent a space shuttle launching; in excessive heat, cattle may produce less milk…	32. How did the flood of 1997 affected our lives? (homework) - **Translating and Extending (STSE) phase of the CKCM.** .
		33. Written Test (1 lesson; May 20, 2003) – **Reflecting and Assessing phase of the CKCM.**

It took 6 weeks, about 44 lessons to teach and assess the Specific Learning Outcomes listed in Table 3.3. Like always, during the teaching of the unit, Scott was accommodating and flexible. For example, I was concerned that we might not have enough time to finish the unit. Scott, however, was prepared to move periods around and *"borrow time"* from French, Language Arts, and recess. Even before we started teaching the unit, he insinuated that this was *"an option"* and that he *"did not have a problem doing that."* According to him the only subjects that *"could not be touched"* were the two-hour guided reading sessions, because both his and his colleague's students participated in them.

There were several occasions where we indeed needed to move periods around or to borrow a little bit of time to finish Science. However, the time that was borrowed from the other subjects did not affect the realization of the other subjects' curricula. Scott actually finished teaching all subjects earlier, and he had enough time to review the material and prepare the students for the divisional exams. Scott was honest with the students and always *"paid them back"* for the borrowed time. Furthermore, the pay back was usually worthwhile for the students. Consider the following example: *"Because Mrs. Biernacka is here and we want to finish something before we move on for the week, I am going to ask you guys, if it is o.k. with you, to work through recess…and if we do a good job, I am going to take us outside for the last period today. Is that o.k. with you?"*

I was an active participant in all of the school's events. I was always there with my equipment. If not in the classroom, I was in the library either interviewing the students or transcribing the interviews. I think that I was able to actively participate in all of the school's endeavors largely because of Scott' attitude toward this project. His approach set the stage for me and helped me connect with the students. For example, Scott always used a plural form while talking to the students about science. He used to say: *"Mrs. Biernacka and I would be teaching you about weather"* or *"Mrs. Biernacka and I are interested to see what you are thinking about what we do so again you have permission to write and draw to us."* He also made the students believe that because of my presence at the school, their classes are more interesting and certain things are happening only because of my research. For instance, when I brought thermometers from the university, Scott emphasized that *"Mrs. Biernacka was so nice to lent those thermometers to you so we can do our experiments today."*

I am sure that because of Scott's attitude towards me and his constant efforts to include me in his class, I became trustworthy in the eyes of the students and they were open to share their work and stories with me. The students treated me as if I were one of their teachers. They asked my permission to leave the classroom, asked me questions related to their school work, showed me their homework, and they were happy to see me entering the school through the "day care door". I, on the other hand, complemented their work, listened to their stories, and sometimes stayed with them after class to help them with their homework.

I felt that I not only became part of Scott's class but that I also became a big part of the school community. The other students, especially these from the other grade five class, must have heard about me from Scott's students. One girl said to me: *"I know you, you are that weather person from Mr. Brown's class. Are you coming to our class after you are done with them ?"* I also felt welcome by the principal and other teachers. Whenever Anna, the principal, saw me in the school she asked about my progress. She was very supportive and, from the very beginning, saw the project as an opportunity for the students and for Scott. When I met with her for the first time, to seek her "blessing" she mentioned that it was: *"... a great opportunity for the students, a great opportunity for Scott."* Once the project was in full swing, she embraced all of our ideas. For example, she allowed the students to use the intercom, on daily basis, to make weather reports, gave us permission to go on the field trip, and supported the guest speakers.

I also think that because of my dedicated involvement in the project, I managed to sincerely engage Grace, Scott's teaching assistant, in our classroom endeavors. For example, during the design process of the weather instruments, she offered that she and her husband, who is a carpenter, can build a professional Stevenson's screen to house the thermometer. She saw this screen in one of my books. She also recommended that after the study is over, the screen could be placed in the school's play ground as a reminder of our study. As promised, Grace's husband donated the wood and pre-measured and precut all of the pieces for us. Grace brought the pieces to school and pained them with a group of students, who volunteered to do it during recess. She also brought the cordless screw driver and nails to assemble it together. We all stayed after class to put the screen together, and the students really enjoyed the process.

Although, the study was intense, the students seemed to enjoy the material. At the end of the unit they gave me a laminated poster, where every student expressed their gratitude and wished me luck in my studies.

3.5 Chapter Summary

In this chapter, I have related a story about my experiences as an educator and researcher prior to conducting the final research project. The chapter outlines that as an educator, I learned how to design a solid science curriculum and instruction course. And, as a researcher, I learned what it takes to design and conduct a qualitative research study, which leads to meaningful data. Furthermore, through all of those experiences, I realized what the needs of the pre-service and consequently novice teachers are with respect to their preparation to teach science after they graduate with their degree from the Faculty of Education.

I also described the setting where the study was situated, and I introduced the teacher as a person, professional in an inner city school, and research partner. To describe the inner city school setting, I described and presented excerpts from my conversations with the teacher and the school principal, which I compared them with my own observations. To introduce the teacher, I analyzed excerpts of our interviews, casual conversations, and my field notes. I also described the techniques I used to collect and analyze data. Furthermore, I presented the events of the pre-instructional and instructional phases of this study, and I outlined the teacher-researcher collaboration in each of the two phases.

Chapter 4

Conversations with Scott about Science Literacy

4.1 Introduction

The study of scientific literacy and enabling school students becoming scientifically literate caught my interest. After some years of reading about science literacy, I thought, "It is time to study the concept in a school classroom setting." So, I decided to collaborate with Scott, a former student of mine. Before I launched into this collaborative project, I was curious to know Scott's views on scientific literacy, primarily to find out whether there would be any changes in his views as the study progressed. Hence, the following three questions pertaining to scientific literacy were put forward to Scott:

> *1) What do you think scientific literacy is? Or whom do you consider to be a scientifically literate student?*
>
> *2) Why is it important to develop scientific literacy?*
>
> *3) How do you think that the unit on Weather can help the students achieve scientific literacy?*

In my attempt to understand Scott's view on scientific literacy, I generated themes by systematically analyzing the interview transcripts. Each theme begins with a brief discussion, followed by an interview excerpt providing supporting evidence. In each excerpt, the verbal expressions characterizing scientific literacy are highlighted in bold letters. I ensured that the meanings as well as the interpretations of the verbal expressions are delineated. Wherever possible, the interpretations are connected to the literature.

4.2 Scott's Views of Scientific Literacy

A focus of this chapter is to understand Scott's views of scientific literacy. According to the *Conversation Excerpt # 4.1* (below), Scott seems to distinguish the following three characteristics in a scientifically literate student:

1) A definite interest in the subject area
2) The vocabulary to support understanding
3) A willingness to explore, and apply information to another setting

Each of these characteristics is discussed in more detail in the sub-sections following the conversation excerpt:

Conversation Excerpt # 4.1: Teacher-Researcher Conversation

Beata: I want to know what you think about scientific literacy. What would you say about a scientifically literate student?

Scott: Ok, well, a scientifically literate student would have to have a lot of different characteristics in order for me to claim that they are scientifically literate. First of all, they have to have a ***definite interest in the subject area****. I don't know if it's possible for people to be literate in any area without expressing an interest. Second of all, they definitely have* ***the vocabulary to support whatever you know****, like they have to have that vocabulary to be considered literate. I know that in the curriculum guide the first outcome on almost every cluster is the vocabulary for that cluster. After that there's definitely a* ***willingness to explore*** *that. This characterizes scientifically literate students. Noticing the difference between a student that will* ***take the information that is presented to them and apply it in another setting versus a student who simply absorbs the information and does not apply that in any way****. Now, I mean, the research in education will show us, and research in learning shows us that when you take* ***the knowledge acquired in the acquiring phase, and you***

> ***use it in the applying phase of every typical lesson plan****, that retention of the knowledge is a lot higher. So it is that* ***application*** *of the knowledge that they acquire within scientific learning, that's what characterizes them as a scientifically literate student.* (Teacher – Researcher Conversation, January 22, 2003).

4.2.1 Student Interest in the Subject Area

It is futile to expect the students to become scientifically literate, if they lack interest in the subject, says Scott. Without the ardent interest and probing minds of men and women in the past, science wouldn't have advanced to the present stage. Darwin's keen interest in natural science, and the years he spent delving into the origin of species resulted in his Theory of Evolution, and his book, *On the Origin of the Species* in 1859 (Levine & Miller, 2000). The aspect of " interest" as a key element in scientific literacy is also noted in the curriculum (Manitoba Education and Training, 2000). Evidently, an interest in learning science unlocks the doors of imagination, creativity and curiosity, as well as develops a proper attitude towards science (Carin & Bass, 2001; Ebenezer & Connor, 1998; Martin, Sexton & Gerlovich; Tolman (2002). Tolman (2002) for example, claims that interested minds with a yen to solve problems are responsible for the great scientific advances of today. If interest is not developed in the student's formative years, this will impede their life-long learning (Carin & Bass, 2001; Sunal & Szymanski-Sunal, 2003). Thus, based on various sources that support the significance of a person's interest in science in developing scientific literacy, one can agree with Scott in that developing students' interest in science actually leads to a proper attitude towards science.

4.2.2 The Vocabulary to Support What One Knows

Vocabulary development is another vital aspect in building scientific literacy, believes Scott, agreeing with Bruner's statement (1986) that learners should learn the symbolic system of science to be part of the scientific culture. Being fluent in the language of science enables them to confidently interact with others, and participate in scientific reasoning and arguments at ease. Attaining scientific literacy involves learning to talk and argue in the language of science (Lemke, 1990).

Well, the question is, "How are the teachers facilitating such participation in a class setting?" The Manitoba Curriculum Framework of Outcome encourages the usage of appropriate vocabulary in scientific investigations (Manitoba Education and Training, 2000.) Nevertheless, the teachers tend to misread the curriculum, and thus get the students to define the scientific terms listed in the curricular unit, ahead of getting into any investigations. For example, in my pilot study, the teacher asked the students to define a list of words given in the curriculum guide in the unit on Forces and Structures. During her first lesson on this unit, she provided the students with a list of words and requested them to write down, the definition of each word in their notebook. This kind of approach is claimed to be one of the most traditional practices developed over the past century (Barton & Young, 2000).

When pre-service, and novice teachers are asked to teach, they often choose to define the words first, and then ask the students to classify the substances according to the definitions. Ebenezer and Connor (1998) point out that when asked to teach a model lesson, the elementary pre-service teachers often preferred to start with the definitions. In their book, *Learning to Teach Science: Model for the Twenty-first Century,* they provide an example, where a pre-service teacher started a unit on light, by first defining the terms, " transparent," " translucent" and " opaque," to the class, and then presenting them an activity, where the students are expected to classify the materials based on definitions. Because of such practice, one can assume that when Scott talks about the importance of vocabulary, he means- defining the scientific terms before they do any investigations. This inference is clearly supported with my interactions with Scott. Note what he says, when I asked him how he taught the unit on Weather earlier.

Conversation Excerpt # 4.2: Teacher-Researcher Conversation

> *Beata: How did you teach this unit before?*
>
> *Scott: Uh, ooh, it'd be pretty long to sit here, and think about exactly everything that I did.*
>
> *Beata: Just give me a few sentences.*
>
> *Scott: Well, I'd have to say that* ***I started with a traditional approach of vocabulary****, and you know the step-by-step approach. By the end of it, I found myself getting bored with it, and wondering why the students would ever want to learn it. And so I took a different approach to it where I try to think up fun and exciting ways of inspiring the students to really search their minds for what they knew, and apply that to what we were doing ...* (Teacher-Researcher Conversation, January 22, 2003).

Here, Scott refers to vocabulary teaching as a traditional approach. His statement indicates, he is aware of alternative ways of teaching too. Further, Scott admits to the fact that the traditional method could be boring, and as such will not be conducive for the students to learn science with much interest. In the following *Conversation Excerpt # 4.3*, Scott describes in detail, a different way of teaching, which is similar to what the contemporary science educator promotes.

Conversation Excerpt # 4.3: Teacher-Researcher Conversation

> *...I don't know if I told you about a unit we were studying; I guess the air pressure, which is part of the weather unit. And we had different sized bottles, and we took a balloon, and we inverted it into the neck of the bottle, and they had to blow this balloon up. You and I know that because the air has nowhere to go, when they blow on it, it's not going to inflate at all, it's the fact that air has volume. Air has properties, and it's the properties of air piece of the weather unit. So when these students were trying to blow it up, they thought that it was hilarious that the smallest student in the class, that had the biggest bottle, could blow it up effortlessly, while everyone else was turning red in the face. And there was a hole, I punched a pea-sized hole in the bottom, nobody noticed it at all, and then* ***we started hypothesizing about, what it is about "she can blow harder," and we started recording the different ideas.*** *And then I said "Ok, now let's look at the ideas and say,* ***let's say what is logical and what's not.*** *" And the kids themselves* ***deduced,*** *from you know, "she can't blow harder than him, look at the size of him. He's got huge lungs" "Ok let's get rid of that." And we did the* ***process of elimination and deduction,*** *and the kids were so into it, and it's* ***something that will stick with them.*** *They will remember that.* ***It's something that they can build what they know onto it.*** *And at the end, we made the connection, that air have property, or air has volume, it's that's a property of air. It takes up space, oh you, "well of course it takes up space," and you know by the end of that lesson we had them all, I didn't even, you know usually you say you've got a science journal or something.* ***The kids had their science journal out, and they were drawing diagrams of, and I didn't request it.*** *They just wanted to draw the picture of it. And so, and, and that to me was you know, something, it was a way of taking science from the "ok, let's build a weather vane" to a different level, that they're going to understand and apply in their everyday life.* (Teacher-Researcher Conversation, January 22, 2003).

In the above excerpt, Scott points out to a type of a lesson in science that does not begin with definitions. Here, he talks about a class he taught during his practicum, where he allowed the students to participate in an activity on the properties of air. The aim was to allow the students to observe and learn the properties of air, such as: air occupies a space and it has a certain volume. In this activity, Scott had three students of different heights (tall, medium, and short) blowing air into balloons, which were inserted into the necks of three transparent bottles of different sizes. The shortest student was given the biggest bottle, while the tallest one had the smallest bottle. In addition, Scott pinched a small hole at the bottom of the biggest bottle, used by the shortest of the three students. He explains that, at the beginning of the activity, the students had a lot of fun seeing the smallest girl being able to easily inflate the balloon and outperform the tallest boy. He also observed that the activity sparked students' interest, to find out why this tall boy "with huge lungs" was unable to inflate the balloon. Driven by curiosity, the students then proceeded with the "process of elimination and deduction" to understand the purpose of the, this approach helped the students to conclude that air has volume and the demonstration. Consequently, this approach helped the student to learn that the air has volume and it occupies space.

Although, Scott realizes that the students do not learn by merely defining the unknown vocabulary, he, too seems to have fallen into the trap of providing the list of definition in advance. One may come to surmise the following reasons for that. Probably, Scott has learned science in a similar manner, like many other teachers. And, he is probably misreading the curriculum. In my view, the teachers tend to misread the curriculum, because the First Specific Learning Outcome, in every science unit in the *Manitoba Curriculum Framework of Outcomes*, reads that "students will *use* appropriate vocabulary…." in their investigations. For example, in the unit on Weather, the curriculum states, " the students will *use* appropriate vocabulary related to their investigations of weather" (Manitoba Education and Training, 2000, p. 3.20). Furthermore, the curriculum provides a specific list of vocabulary, consisting the following words- weather, properties, volume, pressure, air masses, fronts, weather instrument, severe weather, forecast, accuracy, water cycle, climate, terms related to public weather reports, and cloud formations. A curriculum presented that way could be misleading and easily misinterpreted. How can anyone know, what was in the Manitoba curriculum developers' mind, when they wrote such a statement? Probably, they expected the teachers to have their students learn the definitions, before they use them in any investigations. This is why, it is crucial that the science teacher educators clearly define such statements in their methods courses, and provide justifiable pedagogical meanings for the teachers.

Following is another conversation I had with Scott regarding the vocabulary approach. It took place on the first day of our planning, when we debated about how, and from which Specific Learning Outcome to start the unit. Our conversation revolved around the question: When should we introduce the vocabulary?

Conversation Excerpt # 4.4: Teacher-Researcher Conversation

Scott: We're not going to introduce ideas about weather?

Beata: No.

Scott: Okay.

Beata: That will come out after.

Scott: Alright, good.

Beata Where did you start before? Didn't you start here?

Scott: When I did my practicum– I started there too. I did – actually what I used to do was we used to as part of like a – just almost like an activating *activity, I guess you could say, what we did was* ***we would create a title page*** *and on the back of the title page we would create our own* ***dictionary****, so you would have an "A" section, a "B" section and so on and so forth, so – and then when – once we got into the unit we would go back and add* ***vocabulary words*** *–*

Beata: *We can do that, we can do that too, but see that's against everything she teaches, if we start from the vocabulary. Like it should come -*

Scott: *No, no, it's not a – let's put all the vocabulary in the front, it's – we make a page where we can go back and record it so that for* ***the purposes of you know testing*** *or whatever the case may be at the end, they can go back and review everything we've learned.* (Teacher-Researcher Conversation, March 11, 2003).

In the earlier two conversations *(Conversation Excerpts # 4.2 and # 4.3)*, Scott mentions that from his past experiences, he has come to realize that the students do not favor the traditional approach of memorizing the vocabulary and there are other ways of teaching and learning. However, as seen in the above excerpt, Scott looks surprised when he is told that we are not going to introduce the ideas about the weather, right at the beginning of the unit. Seeing Scott's reaction, I reassure him that it "will come later," and inquire, how he usually began the unit in the past. At this point, he recalls his practice teaching, and tells me that, he often started with the introduction of ideas by creating a title page and a dictionary of related words at the back of the page. Since, I consider this introductory activity as an escape mechanism, and totally against such approach, I confront him by telling, "this is against everything she teaches," referring to my science teacher educator who originated the Common Knowledge Construction Model. Thus, I argue the point based on the "expert opinion" (Walton, 1997). Scott, however, defends his position by arguing that students should create a vocabulary list, for the sake of tests and later reviewing. His argument indicates that the tests Scott gives require the students to remember all the vocabulary they have studied during the entire unit.

4.2.3 Willingness to Explore and Apply Information to Another Setting

Scott's third characteristic of the scientific literacy is the willingness to explore, and apply the knowledge to another setting, rather than simply absorb the information. Scott thinks that the ability to apply information is the striking characteristic of a scientifically literate student. I claim this, because toward the end of the unit, I asked him if he thinks that our students developed scientific literacy. And he replied that they did, because the students were able to " apply the acquired knowledge to their everyday lives," as he expected. However, I presume that the scale of application Scott has in mind, is not as grand as the one advocated by others in the foregoing paragraphs. Consider the following conversation:

Conversation Excerpt # 4.5: Teacher-Researcher Conversation

> *Beata: You talked about exploratory nature of a student, can you elaborate on that?*
>
> *Scott: Yep, for sure. The* ***exploratory nature of students****, I believe in fact that* ***students naturally inquire*** *and that's a big plus for kids. Because you know, the younger you are the more your brain wants to know. And as we,* ***as we get older and older sometimes we lose that sense of curiosity*** *that takes us to the next step. And with regards to science thought, I mean, you see, even in my situation where not a lot of kids want to take homework home, but outside if something* ***catches their interest****, ah, particularly in science,* ***they want to explore it that much further****, and they take it past, what we're doing in the classroom. Uh, for example, there's right now, we're studying changes in matter, and properties and changes in matter. And one of these students saw the experiment that we did with vinegar and the baking soda, and right away he took, he asked me if he could take*

> *home one of my books that has the experiment listed so he could try it at home with his parents, and that they could build a volcano with it, and this is completely separate from anything else, but it's* ***that exploratory nature where they want to take what they've seen in class and apply it somewhere else****. That's what I mean by exploratory nature.* (Teacher-Researcher Conversation, January 22, 2003).

In this excerpt, Scott talks about the exploratory nature of young students. He claims that these students possess the natural ability to explore and are usually very inquisitive. Once their interest in science is sparked, these students, equipped with information, would embark on exploration to apply their acquired knowledge, he adds. Scott provides an example, where one student who got so inspired by the experiment they did with vinegar and baking soda in the class, he borrowed one of Scott's books, with the listed experiment, to build a volcano with his parents at his house. That is a perfect demonstration of what happens, when the student's interest is ignited, explains Scott. Once captivated, the students, equipped with information, enthusiastically venture into discoveries to apply their acquired knowledge, acclaims Scott.

In the *Conversation Excerpt # 4.1*, Scott explains that a student who "simply absorbs the information, and does not apply that in any way" can not be considered as scientifically literate. In this example *(see Conversation Excerpt # 4.1),* Scott makes references to a "learning cycle," which is a one of the methods for planning lessons, teaching, and learning (Marek & Cavallo, 1997). Depending on the author, the learning cycle consists of either three (exploration, concept invention, and application) or four (exploration, explanation, expansion, evaluation) phases. Marek and Cavallo (1997), for example, recommend the latter, 4-E cycle.

Regardless, of the number of phases, the cycle should culminate with students' ability to discover new applications for the information that they have acquired. Accordingly, Scott claims that scientifically literate students have the ability to translate the knowledge that they have acquired in the acquiring phase of the lesson and use it in the applying phase of the lesson. Thus, he narrows the application of knowledge to different phases of the same lesson. He does not seem to associate that application with making connections on a larger societal and environmental scale. He also states that, according to research in education and learning, such ability leads to greater retention of knowledge.

4.3 The Importance of Developing Scientific Literacy

Because of the reform documents' emphasis on the development of scientifically literate citizens, I wanted to get Scott's opinion on this issue. Before we began teaching the unit, I asked him about the significance of scientific literacy for the middle-year students. Consider the following conversation:

Conversation Excerpt # 4.6: Teacher- Researcher Conversation

> *Beata: I would like to know about why it is important to develop scientific literacy in middle years?*
>
> *Scott: Hmm, that's a good question. Um, I think that a big part of developing scientific literacy or the importance of it is because,* ***so much of what students will encounter in the future revolves around scientific literacy.*** *As students get older their subject areas become more and more scientific. Even looking at, uh, myself going to university there is a science to education.* ***There is a science to language arts.*** *There is a science behind everything, and when they say there is a science, it means there, there is a,* ***a way of thinking about it, a way of breaking it down and characterizing***

everything. ***Uh, a way of exploring it and piecing it together.*** *Like in the real world, people that you encounter have* ***developed structure*** *whatever it is that you are going to be doing scientifically. In a particular way, students have to be ready for that. They have to know how* ***decode and how to read into those situations,*** *and how to be prepared for those, and how to* ***behave in those situations.*** (Teacher-Researcher Conversation, January 22, 2003).

Here, Scott associates science with a specific way of thinking. Later on, in another conversation, he calls it a scientific way of thinking. This scientific way of thinking involves "breaking it down," "characterizing everything," and "exploring it and piecing it together." He claims that students need to cultivate this way of thinking, so that in the future, it will help them "decode and read into certain situations and how to prepare and behave in those situations." For Carl Sagan (1993), the notion "science is a way of thinking" refers to a process of finding about the universe. The quality of the knowledge about the universe is linked to the quality of the process used to generate such knowledge. I wanted to get a clearer picture, a more detailed explanation for this scientific way of thinking. So, I asked Scott to elaborate on his statement. Consider the following excerpt:

Conversation Excerpt # 4.7: Teacher-Researcher Conversation

Beata: So you said that everything revolves around science.

Scott: Mhmm, yep.

Beata: And, you also said that there is a science to everything, there is a science to language arts, there is a science to computers and there is science to everything else. What do you mean by this scientific way of thinking?

Scott: For sure, ***science is definitely a way of thinking.*** *Um, there, there are, um, now, I mean, granted this all my opinion, um, if I had science, uh, scientific research on how to substantiate this, uh, it might be a little bit more, uh, you know, it might be a little bit more concrete. But, um, in my* *opinion, there are definite, um, there are* ***definite different ways of thinking.*** *Um, even though sometimes we ask, um, sometimes we ask our students to think in different ways, and to learn in different ways, I think that there is* ***definitely a difference in the way you think when you're, when you're looking at something scientifically.***

Beata: Why?

Scott: (Laughs) I knew the question was coming, and I, and I wasn't sure what I was going to say.

Beata: What is that way of thinking?

Scott: ***It's hard to characterize. And I, I don't know, you might know, has anybody really characterized that? Like has anybody concretely, characterized that in research?*** (Teacher-Researcher Conversation, January 22, 2003).

Scott reiterates in so many words that science is a way of thinking, and that the scientific way of thinking is quite different from the kind of thinking involved in other subjects. Nonetheless, he struggles to articulate what he means by "science is a way of thinking." His statements are studded with many "ums" and "uhs." He tends to laugh, and answer my question in a fairly general term. He says that scientific way of thinking is hard to characterize. He also admits that "he doesn't know", but claims, that I, as a researcher, might know how to define it. He also wonders, "If anybody has really characterized that?" I do not give up, though, because I really want to get a more detailed answer. So, I ask him to explain something that he mentioned earlier *(see Conversation Excerpt # 4.6)* that "there is science to Language Arts."

Conversation Excerpt # 4.8: Teacher-Researcher Conversation

Beata: Ok, so let me go back one step, then.

Scott: Mmhmm.

Beata: Uh, there is, you said there is a science to language arts.

Scott: Mmhmm.

Beata: Elaborate on this.

Scott: Ok, um, the science to language arts would be um, um, it's tough to, it's tough to go back and characterize it, but when we look at the way some students learn, you look back at it and ***science is concrete, is it step-by-step****. And in language arts, a lot of things are* ***abstract, and not concrete.*** *Um, but the way that we* ***present the information to the students, to allow them to learn it, is not always abstract.*** *Now students will have to, students will have to learn, um, in an abstract way but, for the most part, everything that we're given is concrete. Um, to a certain extent, I mean,* ***when you get to university things start becoming a little bit more abstract****. But* there ***are a lot of things that are concrete, and it's those concrete things that we build upon, to understand the abstract.***

Beata: Ok, so is that scientific way of thinking?

Scott: Mmhmm...

Beata: Step-by-step thinking?

Scott: Yeah, I, I think there's a lot to be said about ***scientific process, a step-by-step****. Um, you, I, I mean I can think all the way back to* ***when I was uh, when I was a kid****. There were* ***certain procedures to follow****, to do a* ***science project****. There was* ***your hypothesis, there was your procedures, there was your materials, there was step-by-step-by-step****. And,* ***your conclusions, or results, at the end.*** *Then, you* ***go back and visit your hypothesis and did we prove or disprove our hypothesis****. And so it's* ***very logical*** *and very step-by-step when we think about science. Um, now,* ***I know there are abstract concepts in science, like it's not a one-way street****. It's, science is not completely characterized by concrete, but just as in language arts, there is abstract and concrete,* ***in science there's abstract and concrete.*** *So I think that, I think it is something that we see, in a lot more areas, um, than we really realize.* (Teacher-Researcher Conversation, January 22, 2003).

Scott clarifies that science is more concrete in comparison to Language Arts. What he means is that science has a certain process that helps the students to understand the abstract concepts. It is more of a step-by-step process of analyzing the world. He also says that the information given to the students at school, for the most part, is concrete and only later, " once you get to the university, things start becoming a little bit more abstract." Tracing back to his early childhood years, he tells how science was presented in a step-by-step method throughout his school years. He remembers that there were certain procedures to be followed when doing a science project, and that these procedures included hypothesis, procedures, materials, results, and conclusions. One could assume the following two things from his statement.

Firstly, it seems that throughout his science career, he was taught to associate science with laboratory procedures. He does not seem to realize that many scientists use non-experimental techniques to advance their knowledge. For example, astronomy is based on extensive observation, rather than experimentation. Copernicus changed our view of the solar system by his mere observational evidences. Like many eminent researchers, Darwin kept a journal to record all his extensive observations. He hardly spent his time performing laboratory experiments. Neither did Jane Goodall and Diana Fossey in their primate studies.

Secondly, Scott remembers that this so called "scientific method," was presented to him during his school years (Levine & Miller, 2000). However, I wanted to know, whether he is aware of different methods used by scientists, other than the step-by-step scientific method he mentioned. So, I asked him about it in the following conversation.

Conversation Excerpt # 4.9: Teacher-Researcher Conversation

Beata: Is every scientist using the same method then?

Scott: That would be a generality. I could, couldn't make that generalization obviously, because, I mean, there may be some scientists that choose other ways, but I think for the most part, I mean, I think most of us work in that way. I mean, how do I, how do I look at, I mean; I consider teaching to be a science. I consider what most people do to be a scientist. Because, when you get down to it, we have a certain way of approaching things that is a

> *step-by-step manner. I may need to teach these students how to read, and that's the ultimate goal, but I have a step-by-step process that I use to get there. I may have to write report cards and that's a goal, but I have a step-by-step process that I use to get there. Our processes may vary, greatly sometimes, but I still believe that, you know, people always follow a process of some sort, of some way or another.* (Teacher-Researcher Conversation, January 22, 2003).

According to Scott, the step- by- step method is the mainly method used by most scientists. His response suggests that he doesn't recognize the fact, that different techniques are being used in various fields of science and that it is almost impossible to use the step-by-step method in certain fields like astronomy, paleontology, or meteorology. McComas (1996) states that the notion of "the common series of steps is followed by all research scientists must be among the most pervasive myths of science" (p. 11). McComas (1996) further states that, contrary to this common belief, scientists approach science and solve problems mostly utilizing their imagination, creativity, perseverance and prior knowledge. Furthermore, he explains that the scientific knowledge is gained in a "variety of ways including observation, analysis, speculation, library investigation and experimentation" (p.15). He also urges the reader to realize that scientific investigation is no different from solving a puzzle in any other human endeavors.

In the above *Conversation Excerpt*, Scott says, that "Most of us work in that way." Also, he points out that this method can be translated to other areas. For example, he says, that he considers teaching to be a science, because teachers have a certain way of approaching things in a step-by-step manner, regardless of whether they teach reading, writing, or write report cards. Here Scott doesn't seem to share the views of McComas

(1996) by not taking into account, imagination and creativity used by most problem solvers. Methodical process is what Scott has in mind, when it comes to completing a task. Scott strongly believes that being able to analyze things by the step-by-step method would prepare Middle Years students for the future. According to him, the students need to adopt a certain way of thinking and follow a definite process, regardless of what they study in the future.

In the next excerpt, I continue my conversation with Scott about the importance of scientific literacy to students:

Conversation Excerpt # 4.10: Teacher-Researcher Conversation

Beata: Ok. So then going back a few steps, when I asked you why it is important to develop scientific literacy in middle years, you said " that it is important because everything the kids will encounter later on, is science." Why else it is important?

Scott: Why else would it be important? Well, um, how do you mean? Like I think, I think, that's probably the thing that's of greatest importance. The biggest reason that they need to, that they need to be prepared or ***scientifically literate****, and not just the vocabulary, but that the need to explore,* ***the way of thinking, the step by step thinking****, the uh,* ***and the just being prepared to learn in that fashion, or for themselves to be organized in that fashion for when they become adults, and they start going into the work place or to university and they may have the need to create and accomplish.*** *You know, they're going to need processes by which to follow. So I don't, I don't know, like I mean, that's sort of what I was getting at, I don't know if I, I answered it enough, but I mean like that, that* ***one concept though sort of branches into everything that they're going to be doing in the future****, I guess, so.* (Teacher-Researcher Conversation, January 22, 2003).

In this excerpt, Scott once again emphasizes the importance of the step-by-step manner of thinking. To me, this method sounds almost like a survival skill for the students to master, in order to succeed in their future endeavors. Scott fails to consider the steps outlined by Pearson (1937) as well as what he has already mentioned in the *Conversation Excerpt 4.8*. According to him, a logical process of thinking is what the students need to develop in order to succeed in their workplace, university, and "everything they're going to be doing in the future." His reasoning resonates with that of Rutherford and Ahlgren (1990) who claim that scientific mind can help people to sensibly deal with the problems, which they encounter in their day to day life.

4.3.1 Portraying Appropriate Image of Scientists

I was curious to know what kind of mental picture Scott has of a scientist. Hence, during my second interview with him, even before we started planning the unit, I asked him about it. The following conversation reveals Scott's perception of a scientist.

Conversation Excerpt # 4.11: Teacher-Researcher Conversation

> *Beata: Research shows that in Middle Years students, start to isolate themselves from science. That certain populations start to isolate themselves from science, because of the typical, stereotypical view of a scientist. Did you notice that?*
>
> *Scott: I don't notice is so much here, because we try and get a different image of what science is, and* ***I think that we have to do our best to build a different image of what science is****. Um, now let's be honest, I mean you and I grew up in an era where in the media, in movies, in books, and comics, um, scientists or, kids were into science, had a stigma. They were, they, they were um; they were characterized as being loser, the, the not cool bunch. The anti-high school quarterback,* ***the people who wore glasses and a pocket protector and a lab coat all day long.*** *And they were depicted, but they were depicted that way. Um, in, in, our um, youth when we grew up. And um, and I think that there's a fair amount of that that still*

> *exist today in the media, but here in school,* ***I don't see the students in this classroom, making that connection.*** *Um, and, the reason for it is because when we teach science, we try and teach it more as a* ***life skill, and more as something that you can get your hands into, and become interested in. It's not something that the "losers" are good at in here. The "cool kids" in here are great science learners.*** *And we're trying to; we're trying to endorse that. Um, now as the students move up, um, now this is grade 4/5, as they go into middle school, that stigma, that stereotype, may um, may, I guess evolve a little bit, or may be a little stronger, as you go in. You know, like if you're good a chemistry, you know, like "well, I don't want to be near you" and that kind of thing. Um, and there's a lot to be said about the streaming that goes on, particularly in uh, our division. Um, anybody who is um, who is very strong, um, we send to the* ***ACE program.*** *Uh, did I speak to this last time? There's, there's streaming that happens from our fives to, so as they move on to the middle schools, they, anyone who's very strong in math, language arts, science, everything across the board, would go to the ACE program, which is an, an accelerated learning program, and everybody who's not would go into the other program. Now, I think the positive thing about that is that everybody who is in the ACE program, will remain in the ACE program throughout their middle years, um, and I think that the peer groups, and the* ***relationships that they form in there will sort of combat that stereotype****, about, you know, they, they won't feel that they're being ostracized or outcast because they are, you know, into science, and they like it, and they're good at it. Um, whereas the other group, it would be interesting to see that. Um, I can't speak to it personally, cuz I haven't taught at that level of science, so I, I'd be interested to see the results of that.* (Teacher –Researcher Conversation, January 22, 2003).

This prior-teaching conversation reassured me that Scott is not going to portray the stereotypical image of a scientist in his classroom. This conversation is just a preview of the image Scott modeled through out his teaching. I have given a detail picture of it in Chapter five. Obviously, Scott must have acquired this stereotypical image of a scientist from books, movies and television. However, he seems determined to build a different image in his classroom. "We have to do our best to build a different image of what science is," he affirms, meaning that whoever is involved in the education of young people must strive to dispel the media's portrayal of the stereotypical scientist. He also claims that he has already started endorsing that in his classroom, and as a result, his students do not see a scientist as someone who "wears glasses and a pocket protector and a lab coat all day long." In Scott's classroom the "cool kids" are the great science great science learners and they are the ones who will be the "future university science majors." Scott believes, such a positive approach towards science is made possible, because of the following two reasons.

Firstly, he and his colleagues strive to develop an interest in the subject, and teach science as a life skill with hands on experience. Secondly, the school supports "these great science learners" by placing them in the accelerated program (ACE program), where they, not only thrive academically, but also develop the comradeship with the peers, which would help them to eradicate the typical stereotypical image. If this is true, many students from Prairie View School have a chance to choose science as a career because they are given a chance to see it as an exciting pursuit. Sheila Tobias in her book, *They're Not Dumb, They're Different* (1990), argues that many capable students who have a need for creative outlet tend to eliminate science from their future plans because of the way it is taught. However, this does not seem to be the case in Scott's school.

4.4 Contributions of a Weather Unit for Developing Scientific Literacy

I asked Scott, how the unit on Weather could help the students to achieve scientific literacy. Consider the following conversation:

Conversation Excerpt # 4.12: Teacher-Researcher Conversation

Beata: So we will be teaching a unit on Weather. How do you think this unit can help students in achieving scientific literacy?

Scott: I particularly like the unit on Weather because it's something that ***is always and issue.*** *Um, you walk into a room of people that you know, and the first topic of conversation is the weather. " Boy, cold enough for you out there? Geez, I haven't seen this much rain in years!" or the first topic of conversation it's always the weather. And I don't know why, I, I can't really say why, I don't know. But for some reason,* ***the temperature, the weather, our surroundings are always the topic of conversation and for that reason I think it's something will get right into.*** *I, I'm, I was so happy to see, um, during my students teaching, when I first looked at the curriculums that weather was a part of the grade 5 curriculum, because, I, I think* ***it's just fabulous that the kids are able to, study something that influences their lives, their everyday lives, so closely.*** *I think that, and, and as* ***far as, you know developing the scientific literacy goes,*** *I don't think there, we could have picked anything that, uh, that the kids, could build on that would be better. Um, like I mean one thing that we know about, uh,* ***about learning itself, is, um, that kids build on prior knowledge right? It's the common knowledge construction model.*** *They* ***take what they know already, and they associate, and they connect, and they learn, and they associate, connect and learn.*** *They build that schema, they you know, and you know we provide certain scaffolding for them while they're doing that and when we remove the scaffolding, we're hoping that it's built strong enough that it remains. Um, now the weather* ***unit is something that they have a lot of PK on, they've got a lot of prior knowledge in that area, uh, and so I think that it's a great way to, foster that literacy, the exploratory phase.*** *Kids have a* ***tough time getting into, and exploring, and fully understanding something that they've never seen before.*** *You know research shows us that. Um, now there's something to be said about curiosity, uh, you know they,* ***the kids you know, it can spark their interest, but if they've never, if, if it's something completely unrelated that they've never seen or heard of before, it's, it's tough for them to take it to that next level.*** *Whereas if they've got something, that they've, that they've got something to build on, uh even if it's just "how cold is it outside today?" "Oh I'll tell you, it was really cold" "Ok, well let's look at how we measure cold and hot" And, and that's something to build on. Um, did I answer that in a roundabout sort of way?*

Scott says that he is fascinated by the fact we chose the unit on Weather as a tool to develop scientific literacy. Because, weather has always been a favorite topic for conversation, he seems to like this particular unit. And, he was well pleased to see the unit as a part of the grade 5 curriculum. He thinks that the kids will greatly enjoy as well as benefit, if they are allowed to study something that closely influences their everyday lives. Furthermore, he thinks, the unit will allow the teachers to build on the students' prior knowledge, enhance their interest, and thus help them learn the material. At this point, he recalls the CKCM and envisions how to employ the model into the unit on Weather. He says that the students "take what they know already, and they associate, and they connect, and they learn, and they associate, connect and learn." He also adds that the "exploratory phase is a great way to foster that literacy." I, however, would like to know more about "that literacy". So, I try asking him again. But, this time, I tend to be more specific. Consider the following conversation:

Conversation Excerpt # 4.13: Teacher-Researcher Conversation

> *Beata: Mmhmm, mmhmm. So you are saying that the unit on Weather is something related to their everyday lives, if they're scientifically literate, what would they be able to do after we have taught that unit?*
>
> *Scott: Scientifically literate person, or scientifically literate with respect to weather? Um, by the end of the unit I think that they should have, um,* ***I think that sometime*** *we place a little bit too much emphasis, on certain aspects of the curriculum. We, we emphasize more that a you know, that a student* ***should know and understand, a barometer and be able to cite that it's measured in Kilopascals*** *and you know, and when we, when, like I mean, we have to do* ***that sort of thing because other things are just to difficult to measure in an assessment way, where we have to provide a percentage.*** *Um, so we do have to do that kind assessment, and we do have to do those kind of activities. But a scientifically literate student with respect to weather, I would say* ***is somebody who could carry on a conversation with you****, regarding the weather, uh, and, and know the,* ***know and meaningfully use the vocabulary that's been used throughout*** *the* ***unit to describe what's going on, or what they would like to see, or, or to put it into other context.*** *So I think that a, a scientifically literate*

student, with respect to weather, would have to be able to do that, otherwise, you know, otherwise what would be the point to having the student learnt he information? I mean ***they could, they could know that a barometer is used to measure uh, atmospheric pressure, they could know that it's, uh, that you measure it in kilopascals, but you know, if you don't say to them you know, or if they can't use that in some sort of way, if they can't apply it in some sort of way, then what's the point to them learning it?***

In this excerpt, Scott first evaluates the curriculum. He points out, that the curriculum's emphasis on certain aspects, like what the students should know and understand, do not necessarily make them literate. He explains, however, why the teachers follow the curriculum, and teach about barometer and Kilopascals in this unit. The reason behind this approach is that, it is too difficult to assess the other things on tests. According to Scott, in the unit of weather, a scientifically literate student is not someone, who knows that the barometric pressure is measured in Kilopascals. Instead, it is someone "who could carry on a conversation about weather, and meaningfully make use of the vocabulary learned through out the unit." In other words, it is the mastery of the language in a conversation, and the ability to translate the acquired knowledge into other concepts, which qualifies the student to be literate. Thus, Scott rationalizes, that there is no point in learning anything, if the students cannot apply the information in some sort of way.

In this conversation, Scott repeats what he had said much earlier *(see Conversation Excerpt # 4.1)* to the question I asked about the characteristic of a scientifically literate student, in general. He once again stressed the importance of appropriate vocabulary to converse, and the ability to apply the information in related contexts. He affirms that the student's interest in the topic, coupled with his extensive prior knowledge would provide a profitable fertile ground for any scientific literacy development *(see Conversation Excerpt # 4.12).*

4.5 Summary

This chapter entails Scott's views of scientific literacy. From my conversation with him, both, earlier, and during his teaching of the unit on Weather, three characteristics emerged as significantly important. They are: a definite interest in the subject, the vocabulary to support the student's knowledge, and willingness to explore and apply the information to another setting. All would agree with Scott's view that an interest in the subject is a defining factor in developing the students' scientific literacy. History recalls, how great scientific discoveries occurred as a result of one's keen interest in a specific subject. Usually, the topic, which a scientist or a team of scientists chooses to study, makes the difference. Since research involves a great amount of time and intellectual stamina, a deep interest in topic is essential to perform a remarkable job. A lethargic scientist will never end up in great discoveries. Likewise, a bored student will rarely become literate in any subject, unless he or she is motivated to take an interest in the subject. In this case, without an interest in science, a student is not going to develop the three notions of literacy: "what", "how", and "why" of science, which I introduced in the first chapter of this thesis.

Like Bruner (1986) and Lemke (1990), Scott emphasizes the significance of the vocabulary, in order to confidently participate in any scientific reasoning, arguments, and decision-makings. However, from our conversation, I infer that Scott places too much emphasis on learning the language of science. Also, like many teachers, he seems to misread the curriculum. *Manitoba Curriculum Framework of Outcomes* recommends the use of appropriate vocabulary in investigations (Manitoba Education and Training, 2000). This statement does not mean, however, that the students are expected to memorize the words in the curricular unit before hand. Scott's perception explains two issues in science education. Firstly, the strong emphasis on vocabulary as the only approach prevents many students from pursuing science in the future, because it does not present science as an intellectually stimulating discipline (Peters and Gega, 2002). Secondly, this approach can also, become a barrier in a science classroom, where not *all* students share a strong command of the language. This is especially true in many North American, inner city schools, which are filled with students from immigrant, non-English speaking families (Hammond, 2001; Hewson, Kahle, Scantlebury, & Davies, 2001).

The last characteristic of a scientifically literate student, according to Scott, is the willingness to explore and apply knowledge to other contexts. However, the scale of the application, which Scott presents, is not as grand as the one proposed by policy makers, scientists, and science educators, who advocate making connections among science, technology, society, and environment at large. Scott, on the other hand, narrows the scale down, to the ability of finding new applications to what have been learned in class. In other words, policy makers, scientists, and science educators associate such application of science, with a very popular trend in science education, known as STSE education. Scott, on the other hand, sees this scientific application, within the frame of the learning cycle.

Also, Scott and I talked about the importance of scientific literacy for Middle Years students. He views science as a way of thinking and strongly believes that it is important for the students to become scientifically literate to succeed in their future activities. According to Scott, science as a way of thinking, involves a step- by- step logical process that leads to the completion of specific tasks. He persists in saying that most scientists follow the same step-by-step process known as the scientific method, which has been around since it was proposed by Karl Pearson, in 1937. I argue, however, that this method is mostly applicable to those, who conduct laboratory experiments for their investigations (McComas, 1996).

Although Scott believes that the laboratory methodology is the approach taken by most scientists, he has a totally different perception of a scientists. He does not view a scientist, as someone carrying out experiment in the laboratory with a stack of esoteric equipments (Howe, 2002.) He knows that this is a stereotypical image, and he even urges people involved in the science education of young children, to "do their best to build a different image of what science is", as he does it in his grade five classroom.

We also discussed about how the unit on Weather plays a part in the development of scientific literacy in young children. According to Scott, in regards to the unit of Weather, a scientifically literate student displays two striking characteristics; Firstly, the student is eloquent in the vocabulary, to carry out meaningful conversations on the subject of weather, Secondly, the student has the ability to apply his or her acquired knowledge to any other contexts." Otherwise, there is no point in learning anything," says Scott.

Chapter 5

Scott Developing Scientific Literacy in a Unit on Weather

5.1 Introduction

In Chapter four, I discussed Scott's views on science literacy. Specifically, I presented Scott's ideas of a scientifically literate student and how he values scientific literacy for middle years' students. From the interviews I had with Scott, I inferred that he sees the following three striking characters in a scientifically literate student: a keen interest in the subject, an eloquent vocabulary building in the language of science, and willingness to explore and apply the learned facts to another setting. It was clearly evident that Scott strongly believed in the importance of scientific literacy for the Middle Years students to benefit future endeavors. As well, I realized that he was determined to eliminate the stereotype image of a scientist and present a contemporary type instead.

In this chapter, I describe the views of Scott, concerning scientists and scientific literacy and how they became evident in his teaching of the unit on Weather, using the CKCM. I concentrate on the first three phases of the model. For the Exploring and Categorizing phase, I present his approach of collecting the ideas of students' and their parents on predicting and measuring the weather. My comparisons of their views are recorded in Table 5.3 and 5.4 and they are discussed in more detail in the paragraphs following each of these two tables. I have also included a few representative student-parent interviews. In those interviews, worthwhile expressions are highlighted, in bold letters, and interpreted below the interviews. The transcript of an entire student-parent dialogue is located in Appendix C of this thesis.

For the Constructing and Negotiating phase, I have presented several representative lessons that best reflect the NOS leading to the development of scientific literacy of the students. Whenever possible, I have provided the interview or a conversation excerpt. And within each excerpt, I have highlighted pertinent expressions in bold letters and given their interpretation just below each excerpt.

For the Translating and Extending phase, I describe how Scott and his students apply science into a larger societal context. In other words, I point out how they make connections among science, technology, society, and environment (STSE). In Scott's classroom, these connections were made in two stages, which involved construction of a weather instrument and a study of floods, an important societal and environmental issue in Manitoba and other parts of the world.

5.2 Exploring and Categorizing Students' Ideas

The authors of the CKCM provide good guidelines for exploring children's conceptual ideas. They recommend the teachers to choose a simple, but related activity, and provide a conducive environment where everyone's ideas are respected, and sufficient time is given to understand their conceptions. They emphasize choosing activities that must reflect the key concepts of the unit. Keeping their recommendation in mind, we started our investigations on exploring students' ideas about the weather. We chose a demonstration that marked the beginning of the first component of our investigations entitled, Weather Forecasts: Different Ways of Predicting and Measuring Weather (see Table 3.3, in Chapter three for the Specific Learning Outcomes and corresponding lessons in this component.) At the beginning, we showed a short video clip, which featured a TV weather anchor, standing in front of a weather map, and explaining the upcoming weather. To find out the students' thoughts on the prediction and measuring of weather, Scott asked the students to write down their answer for the following two questions: 1) How do you think people predict weather? 2) How do you think people measure weather? He requests them to support their answers with drawings and reasoning. While the students got down to answer their questions, Scott walked around the class clarifying some of their questions. Once they completed answering the questions, he gave them an opportunity to share their ideas with the rest of the class. Meanwhile, he wrote down their ideas on the board. He made sure not to judge their understandings. Following is the conversation between Scott and the students during the exploration activity:

Conversation Excerpt # 5.1: Class Conversation

Scott: now is let's start off with our ideas about how we believe that people predict the weather. I'm gonna write them all down here on the poster so that we can get a nice big collection about what our classroom knows about predicting weather. Okay, yes Jane give me one.

Jane: ***That they think about it.***

Scott: Okay so they think about, so they think about. ***Okay well they think about weather now, weather what it's going to be like, or weather in the past.***

Student: In the past.

Scott: Okay, they think about it, okay, any other ideas? Okay, um Ian?

Ian: Um, that they predict weather by the weather in other places and drawing maps.

Scott: Okay so, by looking at the weather in other places and comparing it to us, okay, okay so we could say, by looking at weather, in other places, that's good, okay.

Zoe: I think they use a radar system.

Scott: A radar system, hmm, a radar system. ***Zoe, do you know what a radar system is?***

Zoe: Well sort of.

Scott: Oh sort of.

Zoe: They put like a satellite up there that gets signals that tells them stuff.

Scott: Okay so ***Zoe is talking about a satellite*** *that they put up into outer space that can, that can attract signals that tells them what things are like, could be. Chris?*

Chris: They use a certain type, a type of a map.

Scott: They use a certain type of map, okay so they use, why don't we say use special maps, special maps. Anything else, Charity?

Charity: Umm, They go outside to like see...

Scott: Okay so they go outside, they see what the weather's like now and then they can predict for the future.

Charity: Ya.

Scott: Okay, so why don't we say look at current weather conditions, so your example was, what was your example that you gave there Charity?

Charity: What for?

Scott: ***Well the example that you gave on your paper I was noticing?*** *You said they go outside and they look at what the weather conditions are like now, currently, right and they can predict what's going to happen in the future, so what was your example there?*

Charity: Hm...

Scott: Well what was the example you just gave right there.

Charity: Umm, that there are rain showers and that it's clouding, might mean that a storm will come.

Scott: Okay, so what Charity used for an example of that is that it might be cloudy outside, and so what do you predict might happen?

Student: A thunderstorm.

Scott: A thunderstorm or rain, exactly. So we can look at what's happening right now to predict what will happen in the future. Jessica.

Jessica: They use a satellite signal to like compare weather.

Scott: Okay so I'm gonna put a checkmark here, right beside that, satellite signals right, good idea. Peter .

Peter: I think that they use a signal outside.

Scott: Okay, so they might look for a signal outside, why don't we put another check mark beside satellites because that's the signals that they're looking for right, with satellites.

Student: If they look at the sky....

Scott: Okay, so they might look for a signal outside, why don't we put another check mark beside satellites because that's the signals that they're looking for right, with satellites.

Student: If they look at the sky....

Scott: Oh okay, so they might, so they might look at the sky, is there anything else you think they might look at?

Student: The ground.

Scott: What were you saying?

Student: The ground.

Scott: The ground okay, okay so the ground, that's ya that's possible look at the ground. And what else, what else with the ground?

Student: The trees.

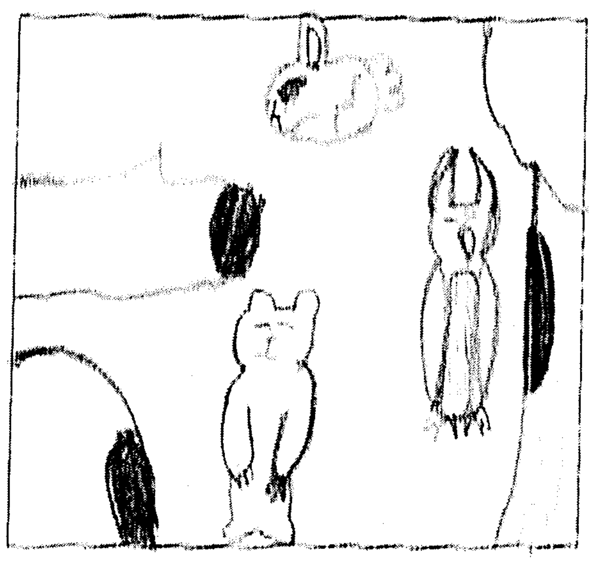
Scott: Trees or plants, right, trees plants, okay, could be a lot of different things that people look at to predict the weather. (Class Discussion, April 7, 2003).

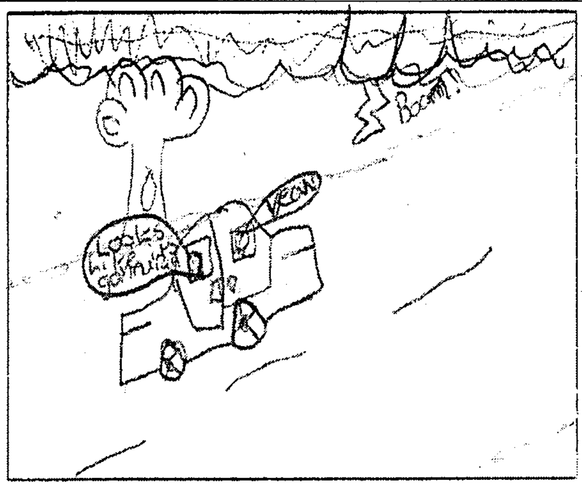
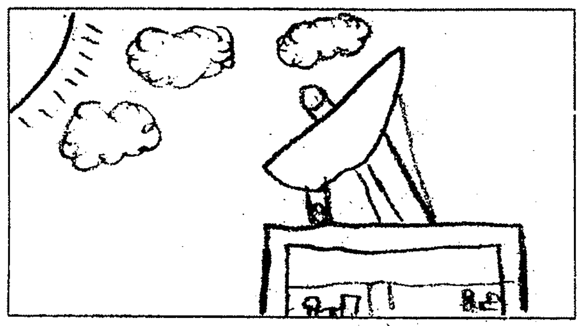
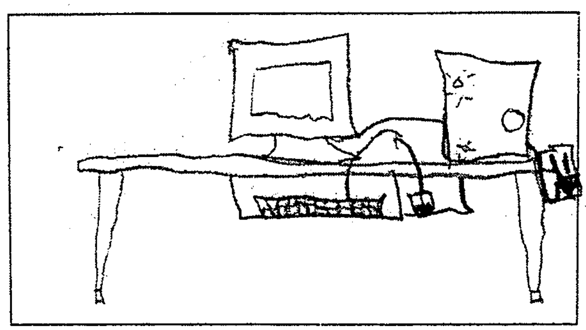
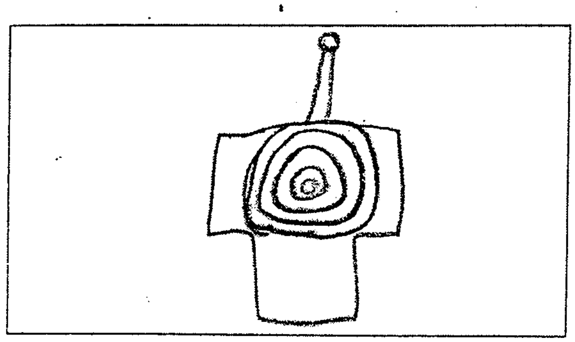
The above class discussion reveals how Scott follows the rules of Exploring and Categorizing, recommended by Ebenezer and Connor (1998). Firstly, he provides a positive and conducive environment for the children to freely express their ideas while he intently listens to every one of them. Secondly, he facilitates a discussion, where every student's view is respected. Finally, he makes sure that the class understands what each child is trying to say. For example, when Jane answers, "they think about it," Scott asks her to be more specific. He wants to know whether she meant, the people's prediction of weather now, in the future or in the past. It is interesting how he handles Zoe's answer. When Zoe talks about a radar system, Scott tries to find out, if she really knows what a radar system is, and then slowly helps her and the class to understand that Zoe was really talking about satellites that are placed in the outer space to attract the weather signals. Through his conversation with Charity, he teaches the students that one could predict the upcoming weather by just observing the natural environment. He, then, ends up the discussion by saying, "there could be a lot of different things that people look at, to predict the weather." It is commendable that he does not try to impose judgment on any of the ideas shared by the students that day.

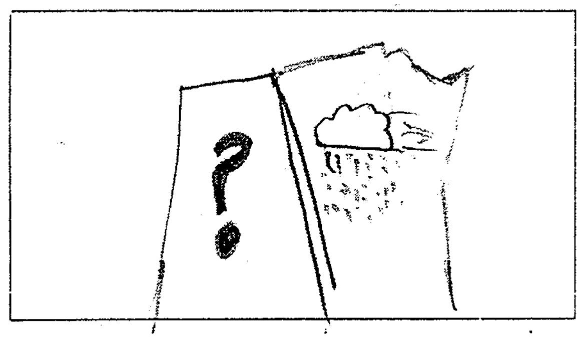
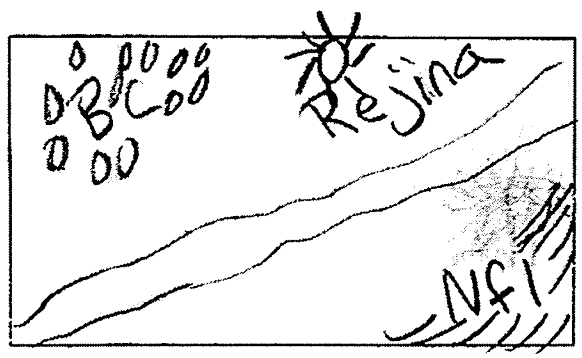
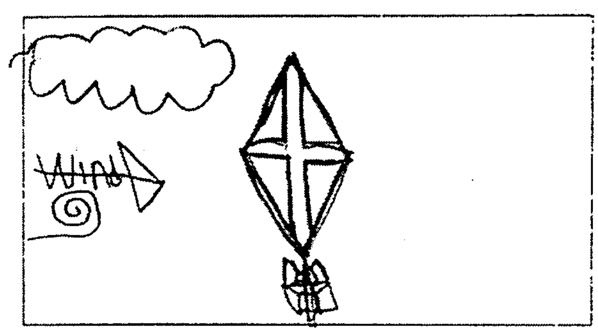
Soon after the discussion, I gathered both the oral and written ideas and developed descriptive categories using Phenomenography, described in Chapter three. Subsequently, I classified students' ideas on predicting the weather into four main groups *Traditional Knowledge, Technological Advances, Maps, and Toys.*

Table 5.1 presents a list of different teacher-made categories, corresponding to the Specific Learning Outcomes from the *Manitoba Curriculum Framework of Outcomes*. Also provided in this table are examples of students' ideas within each category, the number of students sharing similar ideas, and the students' representative drawings.

Table 5.1 Students' ideas about predicting weather.

PREDICTING WEATHER			
Teacher-made category	Curricular ideas	Representative students' ideas and # of students holding similar ideas (in brackets)	Students' representative drawings
TRADITIONAL KNOWLEDGE	5-4-10 Investigate various ways of predicting weather, and evaluate their usefulness. <u>Example:</u> folk and traditional knowledge.	They look at the animals to see if bears and stuff are hibernating (2).	

	Example: observations of the natural environment…	1. I look at the clouds and know how much rain we will get (5).	
	5-4-12 Describe examples of technological advances that have enabled humans to deepen their scientific understanding of weather and improve the accuracy of weather predictions. Example: satellites collect data that scientists analyze to increase understanding of global weather patterns.	1. They use a big and powerful satellite system to predict weather (8). 2. They use computers (3). 3. They use radar (3).	  

	<u>Example</u> computerized models predict weather…	2. They compare the weather to other places and draw a model (2).	
MAPS		1. I think some type of map they use (1).	
TOYS		1. I think that they fly a kite to predict how much wind there is (3).	

As shown in Table 5.1, Traditional Knowledge corresponds to the 5-4-10 Specific Learning Outcome, which states that the students will adopt various ways to predict the weather and to evaluate their usefulness. The curriculum foresees students to predict the weather in the following three ways: 1) Weather-related Sayings, 2) Folk and Traditional

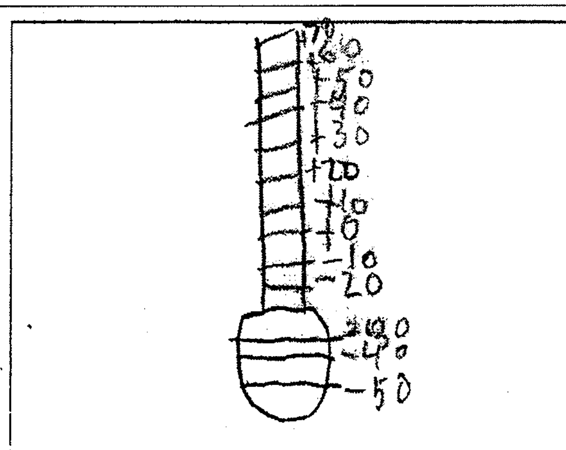
Knowledge, and 3) Observations of the Natural Environment. Nevertheless, it is found that only two students derived his idea from traditional knowledge, and five others based theirs upon the observation of the natural environment. Those who relied on the latter seemed to be more specific in their answers. For example, Sammy claimed that by looking at the clouds, he could guess how much it would rain that day. And Charity went on to say, "If there is a rain shower, and it is cloudy, it might mean that a storm will come." The rest of students were more general in their answers.

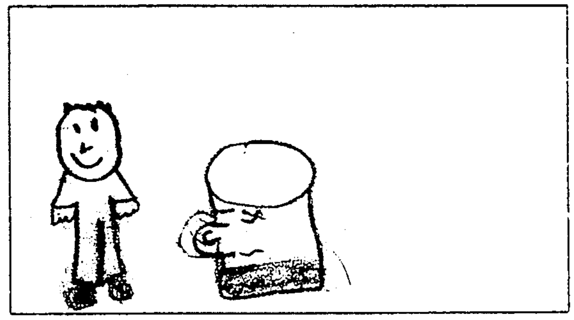
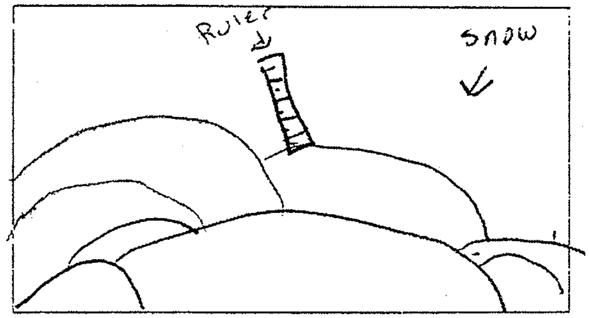
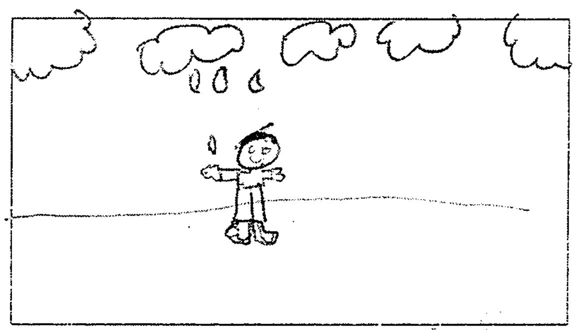
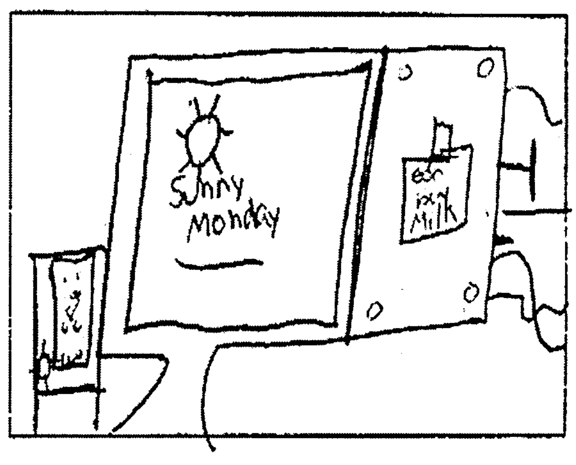
My second category, Technological Advances, corresponds to the 5-4-12 Specific Learning Outcome. This outcome recommends the study of the technological advances, which have enabled the people to deepen their scientific understanding of weather and thereby improve the accuracy in predicting the weather. The curriculum specifically recommends the satellites and the computerized models. Eight of our students thought that satellites provide useful information in predicting the weather, and two other students' ideas were related to the computerized models. And, there were also others, who mentioned about the radar and computers.

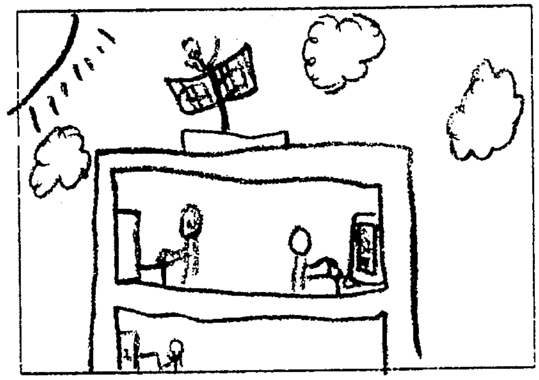
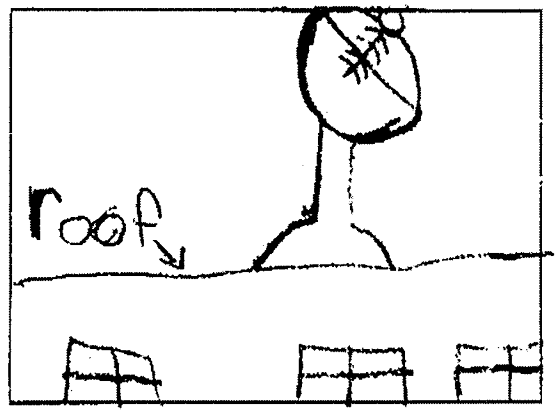
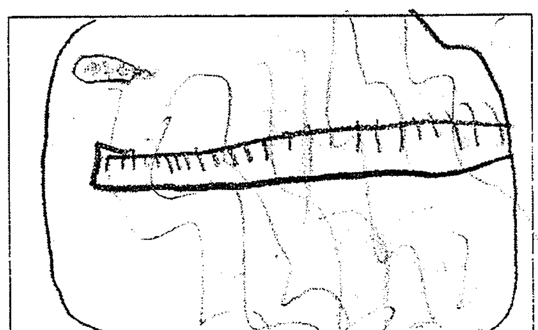
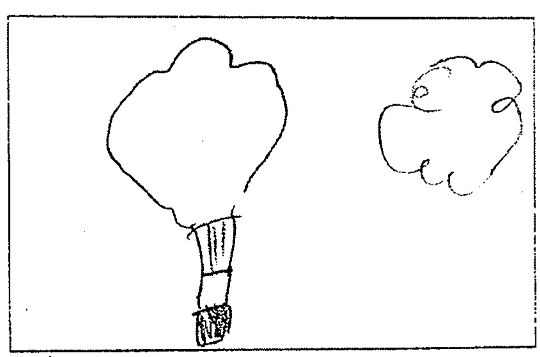
Only one student came up with an idea, which fell into my third category - Maps, which in fact does not have a direct parallel in the curriculum. And, my last category - Toys, also does not have a corresponding Specific Learning Outcome in the *Manitoba Curriculum Framework of Outcomes*. Under this category, I wrote down the ideas of Emillio, Charity, and Daniel. Emillio drew a kite, saying that "people fly kites to predict how windy the weather is," while Charity drew a picture of her holding a balloon, and wrote down, "If her balloon flies all over, that will mean that it is windy." And, Daniel drew something that resembled a toy and wrote that "people use mechanical toys to find out how windy the day is."

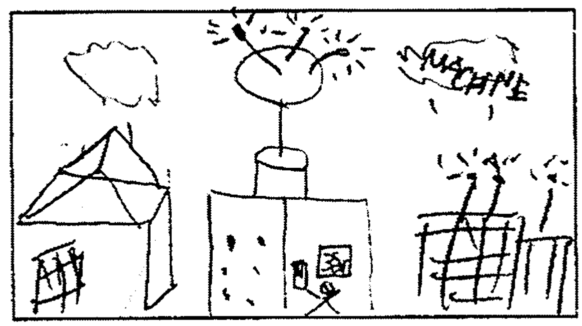
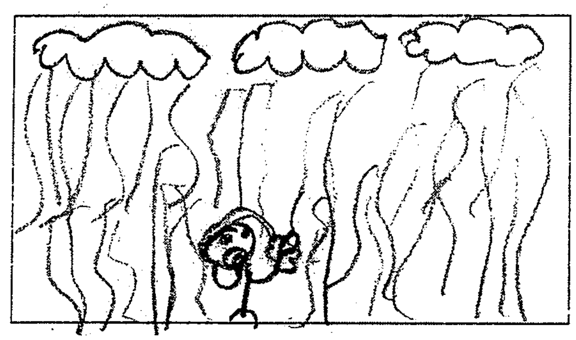
Table 5.2 categorizes the students' ideas about measuring weather. It presents a list of different teacher-made categories, corresponding Specific Learning Outcomes from the *Manitoba Curriculum Framework of Outcomes*, examples of students' ideas within the category as well as the number of students holding similar ideas, and students' representative drawings.

Table 5.2 Students' ideas about measuring weather.

MEASURING WEATHER			
Teacher-made category	Curricul ar Ideas	Representat ive students' ideas and # of students holding similar ideas	Students' representative drawings
INSTRUMENTS	5-4-05 Use the design process to construct a weather instrument	Standard Instruments: 1. They use a big thermometer (4).	

	5-4-06 Observe and measure local weather conditions over a period of time. Using student-constructed or standard instruments, and record, and analyze these data.	<u>No name</u> <u>Instruments:</u> 1. I think that people have measuring cups (1). 2. People can measure the <u>snow by using a ruler</u> (1). 3. <u>A bucket with a ruler</u> (1).	  
TECHNOLOGICAL ADVANCES	5-4-12 Describe examples of technological advances that have enabled humans to deepen their scientific	1. I think that they use a <u>computer</u> (1).	

	understanding of weather and improve the accuracy of weather predictions.	2. They might have used computers connected to a radar system to measure weather (1).	
		3. Big satellite and that is how they know that it is going to snow (1)	
		4. I think that they have a radar (1)	
		5. They take um a big balloon and it goes up to the sky and after touching the weather it will come down (1).	

		6. I saw people using a special machine (1).	
SENSING THE ENVIRONMENT	**None**	People can feel how cold it is (3).	

As shown in Table 5.2, I grouped students' ideas about measuring weather into three major categories: 1) Instruments, 2) Technological Advances 3) Sensing the Environment. The first category - Instruments, corresponds to two Specific Learning Outcomes from the *Manitoba Curriculum Framework of Outcomes*. The 5-4-05 Specific Learning Outcome recommends using the design process to construct a weather instrument. This outcome is closely related to the next Specific Learning Outcome, 5-4-06, which requires the students to observe and measure local weather conditions over a long period of time. As shown in the above table, four of our students were quite familiar with the thermometer, a standard instrument. They were also accustomed to measuring devices like a ruler and measuring cups. I have labeled these devices as no-name instruments, (see third column of Table 5.2).

The second of my categories - Technological Advances, corresponds to the 5-4-12 Specific Learning Outcome. This learning outcome, recommends studying the examples of technological advances that have enabled people to deepen their scientific understanding of weather. Though, several technological advances were mentioned by the students, the computer stood out as the most popular one. It is also fascinating how the children spontaneously added further information. For example, Rose talked about a computer connected to a radar system, Steven came up with a radar system, whereas Peter spoke of a weather balloon, and Daniel, about a special machine.

My third category - Sensing the Environment, was represented by three students. Even though, this category does not closely link to the corresponding Specific Learning Outcome, there is an outcome that recommends the observations of the natural environment to predict weather. Our students' comments, however, were along the lines of sensing, rather then predicting the environment.

While categorizing the children's ideas, I came to realize two things. First, I came to understand that not everyone could see the difference between the two questions we asked. As a result, I ended up with similar categories for both predicting and measuring weather. For example, Matthew thought that computers were used to predict weather, while Rose believed that they are used to measure weather. Yolanta claimed that satellites are used to measure weather, while Jessica illustrated them for predicting weather.

Consequently, I included the same Specific Learning Outcome (5-4-12) in Table 5.1 and 5.2. Also, I noticed that some students only concentrated on weather predictions and did not attempt to give any answers for weather measurements. Consequently, the number of students responding to the fist question (Table. 5.1). does not correspond to the number of students responding to the second question (Table 5.2).

Secondly, I came to realize that we need to allow sufficient time to process and interpret the students' ideas. The importance of doing so became evident when I talked to Dorothy after our exploration class. In class, Dorothy wrote that she does not really know how people measure the weather, but she could guess, "someone feels a drop of rain on the body and finds out." To clarify her written statement, I interviewed her after class. Consider the following conversation:

Conversation Excerpt # 5.2 Student-Researcher Conversation

Beata: And the other question was – how do you think people measure weather?

Dorothy: I think they take like – ***if they see a raindrop and they go out there and get a raindrop and then they like examine it.***

Beata: Uh hm, so they collect the raindrop, okay, and how will they examine it?

Dorothy: Uhm, they check ***and see stuff in the raindrops if it's going to rain or not, and they would probably just use it to find out if it's going to rain or not, like this.***

Beata: How would they collect that raindrop, like how would they catch it?

Dorothy: They could probably put some buckets outside and then when it's raining ***the water would go into a bucket.***

Beata: And then they will take that water and what will they do with it.

Dorothy: They would just examine it and see if it's going to rain or uhm, how it's going to start to rain I think.

Beata: How will they examine it?

Dorothy: They would just... I don't know, they would just...

Beata: What do you think?

Dorothy: I don't know, just to see if there is any stuff in it that will – that – how rain ***is – how much rain is going to – how much rain will be made.***

Beata: From that collection which is already in the bucket?

Dorothy: Ya.

Beata: Okay, good, so will they have a measuring tool there?

Dorothy: Ya, something like a ruler?

Beata: Good. Anything else?

Dorothy: No.

Beata: And how did you know about this?

Dorothy: I just thought that maybe they would do that, so I just wrote it down.

Beata: Oh, okay, very good. And who are they? You said, "I just thought that they would do that." ***Who are they?*** *Who are the people who predict weather and measure weather?*

Dorothy: I don't know, ***probably scientists.***

Beata: Okay. Good, very good. Thanks. (Student-Researcher Conversation, April 7, 2003).

When I first looked at Dorothy's work, both her drawing and written explanation, I wanted to place her written statement in the Sensing the Environment category, because of her statement, "people feel rain on their body." When I talked to her after class, she said that "if they see a raindrop and they go out there, and get a raindrop and then they like to examine it." She was not clear, however, how would these people measure the amount of rain. So, I asked her, how she expects them to collect the raindrop? And, her response was "probably put some buckets outside and then when it's raining the water would go into a bucket." Later in our conversation, she mentions that there is "something like a ruler" in the bucket to measure the amount of rain. After this comment, I decided to place Dorothy's idea in the Instrument rather than Sense the Environment category. This situation illustrates that it is important that teachers take time to analyze and make sense of students' ideas.

5.2.1 Exploring and Categorizing Parents' Ideas

To enrich our understandings on how people predict and measure weather, we invited our students' parents to participate in the study. Furthermore, since one of the characteristics of the NOS points out that science is socially and culturally embedded, we reasoned that by incorporating parents' ideas into our study we would be able to illustrate this feature of the NOS. We asked the children to interview their parents, and tape-record their conversations. They were told to ask the two questions, which Scott asked them in our exploration class: 1) How do you think people predict weather? 2) How do you think people measure weather? Once they have interviewed the parents, the students were told to summarize their parents' ideas in a written format. All of the conversations are transcribed verbatim, and all of the child-parent interview transcripts are included in Appendix C at the end of this thesis. Out of the 19 conversations obtained, 16 were recorded between the students and their parents, and three were between the students and their siblings. In the latter case, because the parents were unavailable, the students ended up interviewing their siblings. The following conversation between Sammy and his mother is an excellent example of parental views about how people predict and measure the weather.

Conversation Excerpt # 5.3 Sammy interviewing his mother

Sammy: How do people predict weather?

Mother: I really do not like being recorded here but, for you Sammy I will do it and I will give it my best shot. People predict weather in ***many different ways****. When I was a little girl growing up on the farm in Saskatchewan my parents made us look at the weather. My mother for example looked at the* ***clouds,*** *if they were certain shape, then the weather would be sunny and hot. These clouds were usually fluffy and white looking. If they were sort of rainbows on each side of the sun, they were called sun dogs and in the winter they would mean a very cold weather. If the* ***animals*** *were seen storing away food, it would mean that it will be a very early winter. In the spring if the birds returned earlier, they everyone knew that the spring is just around the corner. Other people who suffer from arthritis can predict the rain and snow by the* ***pain and discomfort in their joints****. And, people who predict the weather for living are called the* ***meteorologists****. They use* ***computers and other high-tech equipment*** *and certain types of* ***weather maps to predict*** *storms. Weather can change from hour to hour depending on where you live, no one can accurately predict weather all the time. Today we have a prediction at our finger tips by* ***going on line*** *or watching a* ***weather channel,*** *we can get it in the matter of seconds. Technology has come a long way since I was a little girl.*

Sammy: And how do you measure the weather?

Mother: In terms of measuring the weather, people can use a different types a gages. For example, ***a yard stick*** *could be stack into the snow to measure the amount of snow fall. An* ***anemometer could be used to measure the wind velocity****, some farmers have a* ***mill that tells them the wind direction.*** *There are* ***thermometers*** *to measure how hot it is. Almost every house has one inside and out. Weather stations use* ***barometers*** *to measure the* ***barometric pressure*** *in the air. There are* ***certain figurines that change colors*** *for rain, sun, but they are not very reliable, etc.* (Student-Parent Interview, April 10, 2003).

Like many parents, Sammy's mother mentions that she does not like being recorded but, for Sammy she is giving it her best shot. First, she says that there are many different ways of predicting weather. And, like the grade five curriculum, she separates these different ways of predicting weather into traditional and scientific. To give an example of the traditional ways of knowing, she recalls growing up on the farm and observing the natural environment. She remembers foretelling the weather by certain shapes of clouds. The fluffy and white ones were bringing sunny and hot weather. The "sun dogs," on the other hand, were an indicator of a very cold weather. Looking at the clouds seems to be a very common way of predicting the weather, because it was mentioned by many parents. None of the parents, however, were as specific as Sam's mother. Some of the parents, like Dorothy's mother, for example, remembered that there were certain types of clouds that bring more rain than others. Other parents, for instance Jessica's mother, just mentioned that they go outside and look at "look at the clouds and if they look bad there is gonna snow or something, depending on the color." Yet, other parents, like Anthony's mom go outside and feel and observe the weather, and "if the day is windy and cloudy, we can expect to have a thunderstorm." Contrary, to Anthony's mom, Jessica's parent had a different prediction for storms. She thought that when it "becomes really, really calm where everything seems to be quiet, no wind, there is gonna be a storm."

Sammy's mother also talks about certain animal's behavior that is an indicator of a change is weather. She says that "if the animals were seen storing away food, it would mean that it will be a very early winter." She is not the only parent who mentions animals. Jessica's mother who also grew up on the farm said that "when the cows all huddle together there is gonna be a storm." In the above excerpt, Sam's mother talks about the fact that "people who suffer from arthritis can predict the rain and snow by the pain and discomfort in their joints." Tim's mother and Dorothy's mother also mentioned pain in the joints. Timothy's mother specifically told his son that his grandpa, who actually has arthritis and suffers from such pain tends to say that "his bones are cold," when it is gloomy and wet outside.

To give an example of the professional way of predicting weather, Sam's mother talks about meteorologists. According to her, meteorologists "use computers and other high-tech equipment and certain types of weather maps." The high-tech equipment she mentions might be a satellite or radar, which were also mentioned by other parents. Furthermore, she says that "technology has come a long way since I was a little girl" and "today we have a prediction at our finger tips by going on line or watching a weather channel." The Internet was not mentioned by anybody else, but, many parents watch TV, "which has the predictions ready for them". These predictions are done by professionals, who, as Jessica's mother put it, "can see the direction of the wind, the clouds and the highs and the lows." Sam's mother also explains that no one can accurately predict weather all the time.

In terms of measuring weather, Sam's mother also separates the many different possibilities into more traditional ones, that she probably remembers from the farm, and more "sophisticated ones," used by professionals. She says, for example, that people can stick a yard stick into the snow to measure the amount of snow fall. Or, people can use anemometer to measure the wind velocity and barometers to measure the barometric pressure in the air. The same measuring "gadgets," and a few other ones were also mentioned by other parents. The most common measuring instruments mentioned by the parents were thermometer, barometer, and rain bucket.

5.2.2 Comparison of Students' and Parents' Ideas

Table 5.3 compares students and parent's ideas about predicting the weather. It presents a list of different teacher-made categories, corresponding Specific Learning Outcomes from the *Manitoba Curriculum Framework of Outcomes*, examples of best students' ideas within the category as well as number of students holding similar ideas, and corresponding parents' ideas as well as number of parents holding similar ideas.

Table 5.3 Comparison of students' and parents' ideas about predicting weather.

Teacher-made category	Curricular ideas	Representative students' ideas and # of students holding similar ideas (in brackets)	Representative parents' ideas and # of parents holding similar ideas (in brackets)
TRADITIONAL KNOWLEDGE	5-4-10 Investigate various ways of predicting weather, and evaluate their usefulness. Example: weather-related sayings,	**None**	Red sky at night sailors delight, red sky in the morning sailors take warning (3)
	Example: folk and traditional knowledge.	They look at the animals to see if bears and stuff are hibernating (2).	1. There is a lot of old wise tales where like for instance growing up on the farm when the cows all huddle together there is gonna be a storm (2). 2. If bones ache, it means it is going to rain or there is going to be a bad weather. The older the people get the worst aches in their joints (3).

	Example: observations of the natural environment…	I look at the clouds and know if it will rain (5).	1.My mother for example looked at the clouds, if they were certain shape, then the weather would be sunny and hot. These clouds were usually fluffy and white looking. If they were sort of rainbows on each side of the sun, they were called sun dogs and in the winter they would mean a very cold weather (9). 2. They can feel that the rain is coming (1).
TECHNOLOGICAL ADVANCES	5-4-12 Describe examples of technological advances that have enabled humans to deepen their scientific understanding of weather and improve the accuracy of weather predictions. Example: satellites collect data that scientists analyze to increase understanding of global weather patterns.	1. They use a big and powerful satellite system to predict weather (8). 2. They use computers (3). 3. They use radar (3).	1.They use the satellite (2). 2.Computer maps. 3. Today we have a prediction at our finger tips by going on line or watching a weather channel. 4. They use the radar.

	Example computerized models predict weather…	2. They compare the weather to other places and draw a model (2).	1. They use computers and other high-tech equipment and certain types of weather maps to predict storms (5). 2. Review the weather of the past (1).
MAPS	**None**	1. I think some type of map they use (1).	**None**
TOYS	**None**	1. I think that they fly a kite to predict how much wind there is.	**None**
AIR MASSES	5-4-04 Recognize that warm and cold air masses are important components of weather, and describe what happens when these air masses meet along a front. Include: in a cold front the cold air mass slides under a warm air mass, pushing the warm air upwards; in a warm front the warm moist air slides up over a cold air mass.	**None**	1. They can see a weather front coming from different country or different province. They can kind of predict that it will be coming this way or something like that.

The most obvious difference between the students' and parents' ideas about predicting weather was the parents' reliance on the "old wise tales" passed down from one generation to the other. One example of these "old wise tales" mentioned by the parents, but unknown to their children is the well-known weather-related saying, "Red sky at night, sailors delight; red sky in the morning, sailors take warning." This folk tale saying was mentioned by Tim's mother, who explained, "when there is a red sky at night sailor's delight, means that it is going to be very pleasant the next day or days after. And when the sky is red first thing in the morning means that rough weather is on the way.

Many of the parents associated animals' behavioral pattern or people's physical ailments with the change of weather. Kathy and Isabella were the only two student who mentioned about the animal behavior. Kathy said, "we can look at the animals to see if bears and stuff are hibernating." And, Isabella mentioned that if "trees loose leaves, winter is coming." Their ideas, however, relates more to the changes in the seasons, rather than changes in the weather.

As shown in Table 5.3, both students and parents believed in observing the natural environment for the prediction of the weather. But the statements of the students were found to be more general in comparison to those of their parents. While some parents were general in their statements like the students, others were more specific in their explanation, like mentioning the shape and color of the clouds, when it came to the observation of natural phenomena. Table 5.3 reveals that none of the parents included any toys in their predictions of the weather. On the other hand, none of the students associated the prediction of weather with cold and warm air masses.

While transcribing the student-parent interviews, I noticed that the students' ideas on predicting the weather gradually changed as the study progressed. At the beginning of our study, the students seemed unaware of the traditional practices like animal folklore or arthritic pain in damp weather. In fact, they were surprised when they came to know about them while they interviewed their parents. Consider the following conversation between Dorothy and her mother:

Conversation Excerpt # 5.4 Dorothy interviewing her mother

Dorothy: How do you think people predict weather?

Mother: By the ***aches in their bones****. If their bones ache it means it is going to rain or there is going to be a bad weather. The older the people get the worst aches in their joints.*

Dorothy: ***I do not know what you are talking about****. But,...I, we do not know about that. Like can you make it better so I can understand you?*

Mother: O well that is how older people predict weather if their joints are hurting.

Dorothy: No how people for ***news like news*** *people how do they know if it is gonna rain or not.*

Mother: Ooooo....O.K., O.K. I get it now. They have a weather channel where they go and look on the map and they see different weather patterns they see the wind, they see different patterns to winds and weather, and this is how they are able to tell what kind of weather we are having today. (Student-Parent Conversation, April 7, 2003).

In this conversation, Dorothy sounds surprised, when her mother tells about elderly people experiencing joint pains during damp and bad weather. She in fact, tells her mother that she could not understand any such things. Equally surprised by Dorothy's statement, her mother replies, "oh, well that is how older people predict weather if their joints are hurting." She gets it only after Dorothy directs her to talk about how the TV people know that it will be raining.

Table 5.4 compares the ideas of students and parents regarding the measurement of weather. It presents a list of different teacher-made categories and corresponding Specific Learning Outcomes from the *Manitoba Curriculum Framework of Outcomes*. Also linked are examples of students' ideas within the category, the number of students holding similar ideas, corresponding parents' ideas, and the number of parents holding similar ideas.

Table 5.4 Comparison of students' and parents' ideas about measuring weather.

Teacher-made category	Curricular ideas	Representative students' ideas and # of students holding similar ideas (in brackets)	Representative parents' ideas and # of parents holding similar ideas (in brackets)
INSTRUMENTS	5-4-05 Use the design process to construct a weather instrument. 5-4-06 Observe and measure local weather conditions over a period of time. Using student-constructed or standard instruments, and record, and analyze these data.	Standard Instruments: 1. They use a big thermometer (4). No name Instruments: 1. I think that people have measuring cups (1). 2. People can measure the snow by using a ruler (1).	Standard Instruments: 1. There are thermometers to measure how hot it is. Almost every house has one inside and out (12). 2.Weather stations use barometers to measure the barometric pressure in the air (5).

		3. A bucket with a ruler (1).	3. An anemometer could be used to measure the wind velocity (3). No name Instruments: 4. Farmers have a mill that tells them the wind direction (1). 5. They look outside and see how much rain was in a bucket (7). 6. Something like a fan (1). 7. There are certain figurines that change colors for rain, sun, but they are not very reliable (1).
TECHNOLOGICAL ADVANCES	5-4-12 Describe examples of technological advances that have enabled humans to deepen their scientific understanding of weather and improve the accuracy of weather predictions.	1. I think that they use a computer (1). 2. They might have used computers connected to a radar system to measure weather (1). 2. Big satellite and that is how they know that it is going to snow (1) 3. I think that they have a radar (1)	1. It is computer based now and the special instrument is sending it to the computer (1). 2. People measure the weather by sending the balloons up and weather station which measures the humidity, wind speed and precipitation (1).

		4. They take um a big balloon and it goes up to the sky and after touching the weather it will come down (1). 6. I saw people using a special machine (1).	
SENSING THE ENVIRONMENT	**None**	People can feel how cold it is (3).	**None**

It is noted that both students and their parents had similar ideas in regards to measuring the weather. As seen in Table 5.4, most of them spoke of standard instruments as measuring devices. The only difference being, the students could only name the thermometer, while the parents could come up with other gadgets like barometers and anemometers. Also, you could note that both the students and parents spoke of measuring devices, which I labeled as No Name Instruments. Here, the students listed a ruler to measure the snow, a bucket with a ruler and the measuring cups, whereas the parents mostly talked about windmill, buckets, changing color of figurines and fan like gadgets.

Only two parents had ideas, which corresponded to the second category of Technological Advances. Bonny's mother talked about the weather balloons and Emillio's mother mentioned about computer based instruments. In contrast, more students came up with the examples of technical equipments than the adults. Also, three students talked about sensing the environment, while none of the parents mentioned about anything under this category.

The student-parent conversations might have had a different tone, if all of them occurred at the same time. But, because I only had two tape recorders, some of the students interviewed their parents at the beginning of our study, while others conducted their interviews as the study was well underway. Consequently, the students in the second group had a better idea about the various technical instruments used for measuring the weather. Jessica, for example, interviewed her mother after we have already studied about the thermometer, barometer, rain gauge, wind vane, and anemometer. Consider the following conversation:

Conversation Excerpt # 5.5 Jessica interviewing her mother

Jessica: Mom, how do you think people predict weather?

Mother: Well, I think people predict weather by ...well depends who it is. ***There is a lot of old wise tales where like for instance growing up on the farm when the cows all huddle together there is gonna be a storm.*** *It can become really, really calm where everything seems to be quiet, no wind or whatever and there is gonna be a storm. I just look at the clouds and if they look bad there is gonna snow or something depending on the color of the cloud and everything.* ***There is your meteorologists they do all their satellite images, and that is how they predict it. They can see the direction of the wind, the clouds and the highs and the lows.*** *They know what they are looking at, I do not, and the weather channel predicts it for me. So that is all I have to say about that one.*

Jessica: Well, how do you think people measure weather?

Mother: They look outside and see how ***much rain was in a bucket.*** *I do not know.*

Jessica: ***That is exactly it, the rain gauge.***

Mother: Look I do not know that is how I measure it. Look outside the next day and see how much did it snow. It snowed four inches. ***I do not know how they, they have their special equipment to measure it.***

Jessica: ***Instruments.***

Mother: Be technical.

Jessica: What that is what they are called instruments.

Mother: O.K. What else do you need to know.

Jessica: That is it.

Mother: O.K. we are done I do not like being recorded here.

In this conversation, we note that Jessica gets impatient with her mother's answers, which being mostly based on folktales. She tries to tell her mother about the various weather measuring instruments and also goes onto correct her mother, when she called the rain gauge as a rain bucket. After interviewing her mother, Jessica told me," her mother did not know anything." Her statement only revealed how Jessica perceived the traditional practices of measuring the weather, such as observing animals' behavioral patterns. She seemed to trust the modernized technical instruments rather than her mother's traditional practice. Her mother's unfamiliarity with the modern techniques also could have contributed to Jessica's perception. However, Jessica wasn't the only student, who tried to incorporate technical names into the conversations with their parents. Our little Filipino boy, Emillio, really excelled as a young teacher, when he interviewed his mother.

Conversation Excerpt # 5.6 Emillio interviewing his mother

Emillio: How do people predict weather?

Mother: Some ***people can smell that the rain is coming?***

Emillio: Like people can sense the moisture in the air, you mean.

Mother: And they can also predict if it is going to be a long shower or not. And does not rain in one spot. Sometimes it rains in different spots, especially here in Manitoba.

Emillio: Ya. Do you know how people measure weather?

Mother: Just like what I told you. Sometimes they use these ***practical items****, like a* ***bucket****. They put it outside and measure.*

Emillio: ***That is called the rain gauge mom.***

Mother: Yes, the rain gauge. And, they will use some kind of wind.

Emillio: That is called anemometer mom.

Mother: Something like ***a fan****. And they put them up on the trees and stuff.*

Emillio: That is called the weather wane.

Mother: And they see the horizon, and they can ***only predict not be very sure****. Like they have a special* ***gadget*** *not even in the city, but, also on the outskirts.*

Emillio: So what you are saying is that they use a special kind of instrument, like a thermometer.

Mother: I do not know the names of those things.

Emillio: Ya, I understand, I know some. So what you are saying is that the meteorologists predict it by using computer.

Mother: Ya, it is ***computer*** *based now and the special instrument is sending it to the computer.*

Emillio: So you are saying that meteorologists measure weather with different instruments.

Mother: Yes, even as simple as the weather wane or buckets to put outside, maybe three or four of them in different areas and maybe the bucket that has more water will have more rain in the area. Or the one that has nothing at all must be sunny. So ***I think that is my generation's knowledge.***

Emillio: (Laughs), yes mom. Thank you.

In this conversation, Emillio's mother points out that some people can even smell the rain coming. To clarify her answers, Emillio enquires whether she meant people sensing the moisture in the air. Later on in the conversation, his mother mentions about "practical items, like a bucket," which people use for measuring the weather. By this time, Emillio had already studied about the different kinds of weather measuring devices in class, and so he corrects his mother saying "that is called the rain gauge mom." As the conversation continues, his mother also mentions about people using "something like a fan, and they put them up on the trees and stuff." And Emillio's response is, "that is called the weather wane." Evidently, Emillio sounds desperate to hear the names of the instruments, which meteorologists use for measuring the weather. I guess, he wants his mother to say the "the right thing." So, he tries to put the words in her mouth by saying, "meteorologists measure weather with different instruments." She, on the other hand, presents her "generation's knowledge" that those instruments could be "even as simple as the weather wane or buckets to put outside, maybe three or four of them in different areas and maybe the bucket that has more water will have more rain in the area. Or the one that has nothing at all must be sunny."

Students' conversations with their parents (Dorothy's, Jessica's Emillio's) provide evidence for gradual development of their understanding of the material. Hence, their scientific literacy development.

5.3 Constructing and Negotiating

The Constructing and Negotiating phase of the CKCM involves constructing meaning using students' ideas in negotiating curricular ideas (Ebenezer & Connor, 1998). Thus, students' conceptions that were gathered in the Exploring and Categorizing phase are the bases for the lessons in this phase. In this chapter, in sections 5.3.1 – 5.3.8, I present relevant lessons that were planned to construct and negotiate students' knowledge within the first component of the curriculum. I selected these particular lessons, because they best reflect the contemporary character of science. To see the titles of the other constructing and negotiating lessons, refer to Table 3.3, in Chapter three.

5.3.1 Weather-Related Sayings

The *Manitoba Curriculum Framework of Outcomes* recommends the students to explore various ways of predicting the weather and evaluating their usefulness (SPO, 5-4-10). One such example mentioned in the curriculum, is the study of the weather-related sayings. The other examples include traditional knowledge, folk knowledge, observations of the natural environment. None of the students made any direct reference to the traditional ways of predicting weather. However, the students' parents shared a few of these "old wise tales" with us. For example, when Timothy asked his parents how people predict weather, his mother recited the common weather-related sayings, "Red sky at night sailor's delight, red sky in the morning sailors take warning." She also tried to explain the meaning of the saying. Other parents talked about looking at the sky and the clouds as a way of predicting the upcoming weather. So, we decided to start our investigations from the study based on the weather-related sayings.

As a homework assignment, we requested the students to inquire about weather-related sayings. They were required to write down any weather-related sayings, they already knew or to find out about them from their parents, siblings, and relatives. To make sure that the students understood the assignment, Scott gave them an example of the following saying: "In like a lion out like a lamb," and discussed the meaning of this saying with the students. Together they decided that it means that it "it is raining hard and then it turns out to be really nice." The students came up with the following weather-related sayings: *April showers bring May flowers; It is raining buckets; It is raining cats and dogs; Red sky at night sailors delight, red sky in the morning sailors take warning.* At first, they shared their findings with the rest of the students in his/her group, and then participated in a class discussion, which Scott had encouraged them to do.

In this class, for the first time, I noticed Scott's openness and non-dogmatic approach to teaching science in this class. Consider the following conversation in regard to the weather-related saying, Red sky at night sailors delight red sky in the morning sailors take warning:

Conversation Excerpt # 5.7 Class discussion

Scott: *Is this weather saying* ***accurate****, can we* ***trust*** *this all the time? What do you think* ***Hanna, can we trust it to be an accurate prediction of our weather?***

Hanna: No.

Scott: Shane?

Shane: Yes.

Scott: Ya, Emillio?

Emillio: Maybe.

Scott: No, ya and maybe. I have got three different answers here. ***Anybody wants to give me an answer with an explanation.*** *Can we trust this though? Is this going to give us the* ***right answer all the time?*** ***Is it going to predict the weather for us, Joseph?***

Joseph: No.

Jane: I think it will.

Scott: You think it will. So every time there is a red sky in the morning then it is sailors warning.

Jane: No that means sometimes but not always.

Scott: So, accurate would mean that it is right every time. And you think that it is not accurate, right Jane.

Jane: For example sometimes, you can have red shy in the morning and you can have a good day.

Scott: Ya, ya. That is a good response. So what I am getting from you guys is that ***sometimes it could be right and sometimes it could be wrong.*** *Is that what you were saying Emillio? Is that what you meant by maybe? So it could be right, it could be wrong. So, is it accurate. Would it tell us the right thing all the time, will it predict it properly all the time.*

Students: No, No.

Jane: Sometimes people say that when it is ***thundering God is bowling.***

Scott: Right God is bowling, like playing the bowling game.

Jane: And when it is ***raining angels are crying.***

Scott: Hm, interesting ***it could be true, it could be untrue we do not know.*** *But, hang on though. From what you have learned in science in the water cycle and precipitation* ***could we say that we know better than that.***

Nick: Ya.

Scott: When it is raining angels are crying, hm. We can say that it is untrue because we do not know. ***But, looking at the science of the water cycle, Ian what would you pick. Would you pick that it is science that makes it rain or would you pick that it is angels crying that makes the rain?***

Ian: Science.

Scott: You would pick science, Nick?

Nick: The water cycle.

Scott: We can not say that one way or the other is the truth because ***no one will ever know for sure if the angels are crying or if they even exist.*** *We do not know that for sure. That is the thing, we can not know for sure, can we?* (Class Discussion, April 8, 2003).

The above conversation reveals how Scott negotiates knowledge with his students. Scott does not act as the knowledge authority, a position highly criticized by science educators (Aguirere, Haggerty, & Linder, 1990; Duschl, 1994). On the other hand, he acts as a negotiator of knowledge, a position highly valued by science educators (Ebenezer & Connor, 1998; Hodson, 1993). Note he throws a question at the students, and then seeks an answer from several students. Specifically he asks: "Is this weather saying accurate? Can we trust this all the time?" He then asks Hanna, Shane, and Emillio for their opinions. Not too satisfied with their one-word answers, he then persuades the class to come up with some explanatory answers. "I think, it will," answers Jane, meaning that the saying is an accurate prediction of the upcoming weather. After Jane's response, Scott reiterates "...every time there is a red sky in the morning then it is sailors warning." At this point, Jane retreats by saying, " it means sometimes, but not always." Scott then tries to convince her that if the saying is accurate, it would be right every time.

Jane grasps the idea and responds by saying that "sometimes, you can have red shy in the morning and you can have a good day." After negotiating with Jane, Scott asks the class whether they think, the saying is accurate. Since they have listened to his conversation with Jane, they unanimously agree that the saying is not accurate.

Jane brings up two other examples, which Scott needs to address. She claims that if it is thundering - God is bowling, and if it is raining - the angels are crying. This is something Scott has not expected. So, he keeps quiet for a while and then he says, "Hm, interesting it could be true, it could be untrue we do not know." Although Scott admits that no one is quite certain about the saying, whether it is true or not, he asks the class to recall what they have studied on the water cycle. Thus, he encourages the students to look at the science of the water cycle and make their decisions on the basis of what they have learned in the past in the science class. By saying that "we know better than that" and asking the students to consider the previous study, Scott proclaims that crying angels do not cause the rain. He doesn't, however, give his students a definite answer. On the other hand, he allows room for them to have their own interpretations. He ends this conversation by stating that "we do not know that for sure." Though he claims that there is not any truth in any of the weather saying, he doesn't say that they are incorrect either. Thus, Scott presents a very broad view, which covers both intuition and uncertainty.

5.3.2 Folklore

We next organized a class on folklore to investigate the various ways of predicting the weather. This lesson closely reflects Kathy's and Isabella's ideas. Kathy, who loved animals, believed that people "look at the animals to see if bears and stuff are hibernating." Isabella, on the other hand, said that people look at trees, and if they loose leaves, it means that winter is coming. This lesson also incorporated the ideas of other students, who believed that people predict weather by observing the natural environment such as the type of clouds, color of the sky, or just "being outside and looking." This study also included the traditional knowledge shared by some parents. Jessica's mother, for example, told us that there are certain types of clouds that produce more rain than the other types. Sammy's mother shared that, on the farm, "if the animals were seen storing away food, it would mean that it will be a very early winter" or "in the spring if the birds returned earlier, they everyone knew that the spring is just around the corner."

In this class, we had the students circulate among five stations that highlighted how some people analyze the behavior of plants and animals as well as the color of the sky to predict the weather. Each of the five stations had a set-up and a description of the activity and/or observation to do. And, in three of the stations, there was an adult assisting the students. The first station dealt with plant folklore, and I was present at that station to show the students how some people use plants to predict the weather. I told them that many trees show the underside of their leaves when the air is humid because the moisture softens their leaf stalks, which then bend. I also mentioned that it has also been reported that dandelions open their flowers only when the air is dry. In moist air, they remain closed. It is because dry air means fine weather, so by responding to relative humidity these plants give an indication of the weather to expect over the next few hours (Allaby, 1995). I had onions at the station and I showed them that some people believe that there will be a hard winter if onions grow thick outer skins (Allaby, 1995). Having onions at the station encouraged me to tell the students about an experiment that my grandmother used to perform to foretell the weather. Every year, on Christmas Eve, before supper, she separated the storage leaves of an onion to get 12 more or less even wedges. Each wedge represented one month of the next year. Then, she put an even amount of salt, a pinch or so, into each of the onion boats and left them standing around a home made loaf of bred till the end of the supper. After supper, she examined the appearance of the salt and used that to foretell the weather for the upcoming year. If all of the salt dissolved and there was water in the onion boat, she predicted that it will be a rainy month. If, on the other hand, the salt did not melt, she believed that this particular month will be dry. For us – kids, there was something magical about it and, at that time, it also seemed important. One of the older grand kids had to write down all of her predictions for the future reference throughout the year. My grandma was mostly interested in the summer months because she lived on the farm and wanted to know what the weather will be like during the harvest months.

The second station/table was a research table with weather-related books. At the third station, students were learning how some people analyze the color of the sky to predict weather. Sky signs are usually more accurate than plant and animal behavior in terms of predicting the weather (Allaby, 1995). Some are even mentioned in the Bible: *When it is evening, it will be fair weather for the sky is red. And in the morning, it will be foul weather today: for the sky is red* (Matthew 16, 2-3). Scott was positioned at this station and he talked about some of the sky signs, such as a rainbow, for example. The morning rainbow in the west means that the shower is approaching. The rainbow at sunset in the east means that the shower is moving away and bringing fair weather. A ring or halo around the moon is often followed by rain. The halo is caused by the refraction of light by ice crystals in high-level clouds. These clouds often arrive ahead of a vigorous depression. The bigger the halo, the sooner it will rain.

Station four was allocated for the animal folklore, and Scott's teaching assistant Grace, was in charge of the station. Allaby (1995) reported that some people believe that the behavior of certain animals change due to changes in weather. Some parents affirmed his statement during the interview. For example, Jssica's mother, who grew up in a farm, mentioned that she believed in folktales such as," if cows huddle together there is gonna be a storm. It can become really, really calm where everything seems to be quiet, no wind or whatever and there is gonna be a storm." We wanted the students to understand that animals could respond to changing atmospheric conditions by simply reacting to the feel of the air around them. In no way, one could infer that the behavioral pattern of the animals could foretell the weather. For example, bees navigated by the sun, stay within their hives on cloudy days. They also do not fly against the wind stronger than 25km/h. It is believed that the house crickets chirp when the rain is approaching. The reason might be that the chirping is caused by the change of temperature. Field mice are noted to enter house for shelter before rain, and house mice are supposed to warn about the change of weather, by squeaking and running around the house. As a general rule, hot weather, can make large animals uncomfortable and static electricity makes some small animals restless Allaby (1995).

The fifth station was at the computer table, where the students could find information about the weather instruments that they were just about to create in their next class.

To understand what our students were thinking about plant and animal folklore as well as the sky signs in foretelling the weather, Scott gave them an opportunity to first debate with their peers and then to write down which ones out of all the folklore that they have seen, they believed to be true, and which ones they believed to be false. Scott, however, clarified that he is not suggesting that any of them are true or that any of them are false. He pointed out that *he does not know it himself*, and that he wants students' opinion. He also emphasized that because we "*do not know if these things are true or no, in the near future, we will be going on a field trip to the Environment Canada Weather Office*." He explained that in the office, the students will have a chance to talk to meteorologists and learn how scientists predict and measure the weather. Scott also suggested that after the filed trip to the weather office, we will be able to make our own minds, which meant that we will be able to compare folklore with the scientific ways of predicting the weather and then "*decide which one is more accurate, because right now we are not too sure. We think maybe it might be o.k. Maybe it might not be. But, after we go to the weather office, we will be able to make our own mind.*"

Throughout this class on folklore, Scott once again displayed the openness to students' opinions. Never did he attempt to impose any view on his students. Neither did he suggest that the students would get a chance to see a more accurate way of predicting the weather at the weather office. Instead, he told them that after the field trip to the weather office, "we will be able to make up our own mind."

5.3.3 Aboriginal Story

For our next class, Scott and I decided to incorporate Aboriginal views into our investigations. We chose Aboriginal perspective, because it has been reported that the traditional education prefers a curriculum of exclusion, meaning that it is mainly based in Western, middle/upper-class, White males' way of knowing (Atwater, 2000; Kyle, 1998). Thus, students that are not of western European ancestry are deprived of knowing about their culture and what their ancestors contributed to the society individually (Bryan, 1996). Furthermore, children who immigrated from countries like Africa, Asia, South America, as well as North American children have to deal with the conflicting beliefs of their family, and those they study in the science class. As recommended by Bryant (1996), we decided to have our lessons to reflect the cultural diversity of the school's population. As I have already mentioned in chapter three, the Prairie View School had a significant population of Aboriginal students, and thus it seemed logical to include native wisdom into our study of predicting the weather. Further, we felt that it was our responsibility to educate all the children from a national point of view.

I invited an aboriginal storyteller, Mr. Birdie (pseudonym) to our class, and he told us how his people predict weather by looking at the natural environment, which was in synchrony with the 5-4-10, Specific Learning Outcome and the preceding class on folklore. At first, Mr. Birdie, in his calm voice, told us one of the aboriginal legends, and grabbed the attention of the students. This legend could be read in Appendix D of this thesis. Fascinated by the legend, the students could not wait to ask him questions. Daniel wanted to know whether the Aboriginal legends were true, and Mr. Birdie replied, "only some parts are true and the rest is made up to make kids chuckle." Daniel's question, prompted Mr. Birdie to explain that in his culture, young people acquire knowledge by listening to the elders. And, he did that all the time when he was growing up, because they "...did not have the radio, TV, or music, that was the only way of learning," he said. And, he added that their "only entertainment was to listen to their grandparents." Now he uses the knowledge he gained from his elders to tell stories, but sometimes his stories put the kids to sleep, he jokingly said. I could see that because his calm and tender voice almost put me to sleep that day.

Mr. Birdie also talked about the four seasons he encounters at his place, way up north where the winters are longer and colder. There, the summer starts in the middle of May. In June the willows start budding, and the grass turns green. In July, the geese start changing feathers but they do not start to fly yet. They just walk, Mr. Birdie said. The geese start flying in August and by September they fly down South. Soon, the leaves change color, and it starts getting cold. By looking at these signs in the nature, the aboriginal people get to know that the season is changing. By the middle of October it begins to snow and freeze, and the winter begins. December, January and February are the coldest months. It starts to get warmer by April or May, and soon, the season start to change again, like a cycle.

Mr. Birdie explained that the Native People of the North are able to identify the season of the year simply by listening to the sounds of nature and observing the plants and animals. He said that they could detect the change in weather by merely observing certain signs in the nature. For example, if they see the bears waking up from hibernation, they know that it is the middle of winter. Because the eagles come back from the south in March, they call the month-Eagle Month. Likewise, April is called the month of the Canada geese, because the geese return from the south in April. In June, the snow starts melting, flowers are in bloom, and all the other birds are back from the south. During this month, robins begin to sing, and the frogs begin to croak, and the weather becomes warm and balmy. By July, everything looks green and the berries begin to ripen.

Mr. Birdie also told us that there are a lot of signs by which his people forecast the weather. For example, if they see the ski dog stands up and wiggle his body three times on a calm winter night, they would assume that it is going to be snowing the next day. In May, if they hear the frogs sing, and all of the sudden they stop singing, and a bull frog starts to make a "row-row " sound, then they would know that the weather is going to be cold. Also, when they see the willows droop, they know it is going to be cold... Mr. Birdie also made references to the abiotic factors, such as clouds and sky. For example, if the sky is very red almost purple red in the morning, just before the sun rises, it means that it is going to rain during the day. But, if it clears up all of the sudden, it means that it is going to rain first, and then it is going to turn pleasant. If they see the sun during the day, and also a little bit of cloud followed by a ring, it means that it will rain during the day and it will be slightly cold too. If the sun is red, it is going to be a warm morning, and if it turns very yellow, it means that it will be cold the next day. He mentioned that the elders are knowledgeable in interpreting all such signs. And his parents taught him and his siblings, how to do the same. He said that his parents woke them up before sunrise and took them for hunting. It was emphasized to them that they go hunting at early dawn, because when the sun start to rise, every animal stops moving for about two minutes and they become an easy prey during that time.

Although we were not sure about the topic of Mr. Birdie's presentation, it surely added an extra flavor to our investigations. His stories approved another way of seeing things, and brought more credibility to our study on weather-related sayings and folktales. Furthermore, his presentation embraced both students' and parents' ideas about predicting weather. Mr. Birdie emphasized that by listening and observing the signs of the environment, one could predict the weather and have a good sense of the changes in the seasons.

5.3.4 Field Trip to the Weather Office

After Mr. Birdie's visit, we got ready to plan out our field trip to the weather office. This field trip surely helped the students to learn about the technological advances that have enabled people to enhance their scientific understanding of weather, and improve the accuracy of weather predictions. Furthermore, this field trip improved students' understanding about the variety of equipments used by professionals to predict, measure, and share the information about weather. Additionally, the presentation given by a meteorologist related to the many ideas about weather put forward by both parents and students during the Exploring and Categorizing phase of the model. Thus, the field trip enhanced and clarified the ideas shared both by the students and parents.

The students enthusiastically participated in planning of the field trip, by writing down all they want to see and ask at the weather office. Scott asked the students to write down the questions individually at first, and then to share the questions with their group and finally to choose the best three questions to be asked at the weather office. And following are the questions the students chose to ask: Why is rain and snow always cold? Why is the world twirling in the twister? Are they experts who travel and take videos of tornadoes? Do tornadoes go over water? How are tornadoes made? Do you use some sort of maps? How do you know how much rain will fall? Why is the sky blue? Why there is a tornado? How fast the wind goes in a tornado? Do you believe in folklore? How do you keep up with everything?

The idea of incorporating questions into science teaching and learning is in line with the reform documents, such as the *National Science Education Standards* (NRC, 1996) that promote inquiry as the central strategy for teaching science. The Standards suggest that students in K-12 science classrooms develop "both abilities necessary to do scientific inquiry" and "understandings of scientific inquiry" (NRC, 1996, p.121). And, according to the *Standards,* abilities to do scientific inquiry include, among other things, identifying and questioning. Science educators agree that posing questions is an important aspect of inquiry. For example, Eielson, Gordon and Pea (1999, p. 393) state that inquiry is "driven by questions generated by learners." Taking their lead from reform documents and research articles, textbooks designed for science teacher education, contain information on inquiry. Although the authors of these textbooks define inquiry in different ways, they all seem to agree that providing opportunities for the students to ask questions is an important aspect of inquiry-based teaching (Howe, 2002; Martin, Sexton & Gerlovich, 2001; Peters & Gega, 2002; among others). These authors suggest that the students conduct inquiries based on their own questions. In our case, the students proposed questions, but they did not do any further inquiries to find answers for their own questions. These questions were answered for them at the Environment Canada Weather Office. Nevertheless, formulating these questions might have motivated them to learn based on their ideas.

Although I welcomed the idea of giving the students the opportunity to first prepare and then to ask the questions at the weather office, I doubted their ability to do so. Firstly, I thought that their questions might be irrelevant, because they didn't get any help from us in the wording or the content of those questions. And, secondly, I could not visualize the mechanics of asking so many questions per group. Although, each group selected a student to ask their questions, I was rather nervous about them getting shy, scared or overwhelmed by the questioning process. Scott, on the other hand was quite confident of his students' competence in handling the questions well. I indeed was wrong in this matter. To my surprise, they not only came up with very good questions, they excelled in asking them in a very professional manner. Their performance indicated that the students were capable of learning and evaluating what is presented to them. This matter is discussed in more detail later in this chapter.

Once we arrived at the Environment Canada, we were greeted by a meteorologist - Mr. Jason Anderson (pseudonym), who is well known in the city, since he is often interviewed by the local media. Later, we listened to his presentation inside the conference room, especially designed to accommodate school field trips. The presentation was then followed by a question and answer period, and soon after that, the students had a chance to meet with other meteorologists. Mr. Anderson started his presentation by asking if we have any questions about tornadoes. This, of course, led to a lengthy discussion on tornadoes. I found the talk on tornadoes very valuable. For example, Mr. Anderson questioned the students what needed to be done, when a tornado comes, and Isabella at once replied that we need to stay down. Mr. Anderson agreed that it was a very good idea as long as we stay inside a house. Then he asked what they needed to do, if they are caught outside in a campground. "Go to the ground," answered Rose. "Yup, that is a good idea or lie down in a ditch" - responded Mr. Anderson. And, then he added that if they are in a place where there are tall trees and bushes, they should hide in these bushes to stop materials from hitting us. Later, he asked what they would do if they were in school. Timothy said that he would go downstairs, but Mr. Anderson wanted him to be more specific. So other students came up with hiding places like, corner, closet, janitor's room, etc. "Can you go in any corner of an auditorium, for example?"- asked Mr. Anderson. "No" - replied Shane. Pleased with his response, the meteorologist explained that if possible, they should look for a small room where there is lots of protection, such as closets, hallways and washrooms, as long as there are no windows and cleaning materials.

Another important thing that occurred during the conversation was Mr. Anderson admitting the fact that even the meteorologists do not exactly know how and why tornadoes happen. His admission supports what Scott had said of the scientist as someone, who does not always know the answer for everything (presented later in this chapter.) During the conversation about tornadoes, Nick asked Mr. Anderson to explain how tornadoes occur. So, Mr. Anderson, in a very plain and simple language, described its occurring as follows: *"A thunderstorm first grabs the winds, twists them into a twister, and then makes the twister spin faster and faster, like the movements of a figure skater. Just like the figure skater, who pulls her hands in and spins faster, the tornado pulls up the air and stretches it out until it spins faster and faster."* However, Mr. Anderson admitted that the meteorologists "do not know the exact answer to this question." He continued, "after studying and chasing tornadoes, scientists only have part of the explanation." Then, Joseph wanted to know why tornadoes take place, and Mr. Anderson's response was that they occur, when there are different directions of the wind at various layers of the atmosphere, which are then pulled in by the thunderstorm. However, he concluded that "we do not know exactly."

There was one more situation when Mr. Anderson couldn't give a definite answer. When Kathy asked him, how the scientists know how much rain will fall, Mr. Anderson explained that they can either use a map generated by the computer or watch what is happening in other places to predict what kind of weather system will be moving in their direction. But, Mr. Anderson said that forecasting the amounts of rain, especially in the summer, is very hard and forecasters usually can't estimate how many inches of rain will come out of a thunderstorm, "so it is not cut and dry and sometimes they can only give an approximate number."

Mr. Anderson patiently answered all of the tornado questions, but when the students started asking about tornado related movies, such as *Twister,* he cleverly directed the conversation toward forecast writing. At first, he asked the students whether they know, how and where the meteorologists get their information to write the forecast. When Daniel answered they think about it, Mr. Anderson responded by saying, "thinking is good, but it is not good enough to write the forecast." He looked pleased, though, when Shane mentioned about the radar and soon he went on to explain how the radar works like a flashlight. He used simple analogy for them to understand better. It sends out radio waves, just like microwaves in a microwave oven and then these waves bounce off or reflect from the snow and rain to come back to the radar. In turn, the meteorologists make pictures out of the images that return to the radar. Mr. Anderson also told us that the pictures could be animated or composed into a little movie to see how the conditions change over time.

Later, Mr. Anderson showed us a computer image depicting a forest with short trees and asked us to figure out from which part of the country the picture had come. He gave us just one clue, saying that the forest, although very short is very old. Since no one except Timothy tried to answer, Mr. Anderson started giving us more clues. For example, he pointed out that there was snow on the ground, for which Daniel responded by saying that "he had seen such a forest in Winnipeg." Zoe guessed it to be a forest in Ontario. But neither of them was correct. Since the rest of the class was clueless, Jason told us that the image was taken from the Northwest Territories. But, Mr. Anderson didn't seem pleased with our performance. He told us that scientists look into various clues, and that if the "students want to become scientists, they need to look for clues." His comment reinforced another perspective of scientific work. It taught the students that scientists need to be analytical, and on the look out for clues.

The next instrument that Mr. Anderson described to us was a big weather balloon, which when fully inflated, is about the size of a big room, like the conference room we were in. He, then, showed us a special device that is attached to the balloon to measure humidity, temperature and pressure. Such balloons are released to upper atmosphere, which is about 25 kilometers high, from about 1.000 weather stations around the world. For example, the balloon is sent from The Pas and Churchill, Edmonton, and sometimes from Winnipeg, usually from the roof of the weather office. Those balloons send readings by radio to the weather station. Jason also told us that the balloons could be followed with a tracing device, so the meteorologists know how they move. The students were eager to know how the meteorologists get the balloons down. Mr. Anderson clarified that when the balloons ascend above 25 kilometers, they expand, and soon they burst and fall down. There is a little note on each of the balloons saying, 'this is a weather balloon and whoever finds it is welcome to keep them.' Mr. Anderson also showed us a few other instruments, located at the weather station outside of the weather office, and he suggested us to stop by the weather station on our way out. He also described how these instruments are used to measure the local weather conditions on the ground, such as temperature, humidity, wind speed, wind direction, and precipitation.

Mr. Anderson also talked about "one of the biggest things used by meteorologists- the computers" and showed us a weather map created by the computer on the morning of that day. He explained that all of the data gathered by all of the instruments are put into the computer, and the computer then calculates what will happen in the future. In other words, the computer is making a prediction of what the weather is going to look like in the future. Emillio wanted to know whether the computers are always reliable, and Jason responded by saying that you can't fully rely on the results of the computer, because they can be incorrect at times. As such the forecasters often use their knowledge as well as the information from other reliable sources to accurately predict the weather.

The time to ask the questions that we have framed at school finally came. I particularly liked the three questions put forth by the groups of Nick, Jessica, and Matthew. Nick asked if Mr. Anderson believes in folklore. I taught that this was an excellent question to be asked at this point of our inquiry about the weather, especially because we have just studied about folklore. Furthermore, it was obvious that the students were looking for more answers, which had not been provided by Scott. The students still struggled with the choice between the scientific and traditional methods of knowing. Scott had not told them that one way of predicting the weather is more accurate than the other, or that the scientific way of predicting is found to be right, while the rest, we have studied were wrong. Even Mr. Anderson could not give us any definite answers. According to him," scientists only have part of the explanation." And he also implied that many of the folklore are found to be right.

To support his point, Mr. Anderson used the same weather-related saying that we studied in class: "Red sky at night sailors delight,...." More importantly, he explained why we have the red sky at night. He pointed out that red sky at night, means that the weather system is moving away. And, when the weather system is leaving, the clouds are leaving as well, thus the sky is gradually clearing, and the sun is shinning into the clouds turning them red. In the morning, on the other hand, the weather system is coming towards us and the red sky would indicate clouds coming towards us. Mr. Anderson added that this phenomenon could be traced back to 2000 BC where we can find out that the Babylonians actually had similar folklore. The Babylonians apparently did not say red sky at night, instead they used to say something that sounds like, "When the sky is glowing red, the gods will look favorably on the day or something like that, the same sort of thing."

Jessica's question was also related to our study of folklore. She asked Mr. Anderson if he believes in Wee Willie- the ground hog. She brought it up because we talked about Wee Willie in our first class on the weather-related sayings. During that class, Scott had told the students that if this animal comes out of his hole on Ground Hog Day, which is February 2nd and sees his shadow, he gets scared and goes back into his hole. If this happens, people say that we are going to have six more weeks of winter. And, if he comes out and does not see his shadow and gets scared and goes back in that we are going to have an early spring. Mr. Anderson responded to Jessica's question by saying that it "depends on where we live." Apparently, in Alberta he is only right about

30% of the time but in Ontario he is right about 55% of the time because Ontario gets more of a cloudy weather.

Matthew asked another interesting question. He asked Mr. Anderson, how he manages to keep up with everything, and Mr. Anderson replied that he and the other staff members "often take courses and that they are always studying stuff." He also suggested that "it is hard to keep up with everything because there is so much new stuff coming in all the time." This comment, which related to the professional development, added yet another angle about scientist's work, something that the students would not have realized if they had not heard it from Mr. Anderson.

Next, we went to see the forecasters at work in the weather office. Up to this point, we were inside the conference room. Because we were allowed to spend only a few minutes in the office, we did not really have a chance to talk to anybody there. Already we have taken 1.5hours of Mr. Anderson's time, and as such we understood why we were not allowed to talk to other meteorologists at the office. Jason briefly told us how things work at the place. He introduced Sarah (pseudonym) and Michael (pseudonym) and said that they are responsible for writing the forecast. Then, he directed our attention to the number of computers with display screens, bringing in information that is updated every minute, and how the data are finally converted into a voice. It is this voice that is heard when people phone the weather office for information or when they listen to the weather radio.

5.3.5 Teacher Reiteration of Mr. Anderson's Talk

Because Mr. Anderson gave students an incredible amount of information, Scott felt that it was necessary to follow up on the field trip, making sure that the students clearly understood how meteorologists predict and measure the weather, and more importantly what is involved in writing the weather forecast. Considering that to be a great idea, I let Scott plan the entire lesson. The book, he used is *Weather Forecasting* by Gail Gibbons, which outlines the life of a meteorologist in an interestingly illustrated story format. Instead of reading out the story to the class, Scott used the book to show how certain weather instruments look like. Scott told me that he particularly liked the book, because the major meteorologist depicted in the book was a female. His comment indicated that he is trying to teach according to the principles of multicultural science education. This type of education requires the teachers to look for appropriate resources, which would promote science education of *all* students regardless of their sex and ethnic background (CMEC, 1997; NRC, 1991; NSTA, 1991). By choosing this particular book, Scott declared that female students have equal opportunities to do well in science as well as pursuing careers in scientific field in the future.

In a calm and quiet environment, Scott gathered the students to sit on the carpet at the front of the class and told them that he wanted to summarize all that they learned on the field trip. "Just to make sure that you got everything," were his exact words. Consider the following conversation:

Conversation Excerpt # 5.8 Class discussion

Scott: ***Can anyone remind me who the meteorologist is and what they do?*** *Who is it and what do they do. Who can explain to me who that is and what they do?, Shawn, could you tell me who it is?*

Nick: How to predict and measure weather.

Scott: How to predict and measure weather, good. ***So, are they just a regular person like me and Zoe?*** *Is Zoe a meteorologist because she likes to predict weather?*

Students: No.

Scott: What is special about them? They are what kind of person? Peter?

Peter: They know how to use a thermometer.

Scott: O.K. So Peter if you take a thermometer outside, you are a meteorologist?

Students: Ha, ha ha.

Scott: ***What makes them special, why are they meteorologists****? Chantel?*

Chantel: ***They are scientists.***

Scott: They are scientists, right. So we are training right now through our learning to become scientists to think about these things how a scientist would. ***That what science is all about: learning how to become a better scientist.*** *Now, we have focused a lot, at the very beginning we asked you guys to write your ideas about two things. Nick mentioned them just a second ago. There were two things we wanted you to concentrate on. Something weather, something weather. Give me one of them please, Jessie?*

In this excerpt, Scott asks the students to remind him who meteorologists are, and what they usually do. Nick replies to Scott's question by saying that meteorologists are people who predict weather. This is not the answer Scott is looking for. So, he sarcastically asks if Zoe, one of the students, is a meteorologist because she likes to predict the weather. Then, Peter replies that meteorologists are people who know how to use a thermometer. Scott is not satisfied with Peter's answer either and tells him that we have studied in class how to use thermometers but, it does not make any of us a meteorologist. In other words, he wants to know what sets them apart from other people. Finally Chantel comes up with the answer he is waiting for. She says that meteorologists are scientists. At this point, Scott tells the students "through our weather training, we are learning to become scientists and to think about weather how a scientist would." He also comments that," science is about learning how to become a better scientist."

Next, Scott chooses to talk about what scientists, specifically meteorologists do. So he first asks the students to tell him, what they think the meteorologists usually do. Because we put so much emphasis on predicting and measuring weather, it is not surprising that the students tell him that meteorologists measure the weather. Consider the following conversation:

Conversation Excerpt # 5.9 Class discussion

Scott: *O.K. What do meteorologists do?*

Peter: *They predict the weather.*

Scott: *O.K. one of them was predicting and what was the other one?*

Tim: *Measure.*

Scott: *So right now, we have looked at how people measure the weather. What are some of the instruments that we looked at that people use to measure the weather. I love the hand that I am getting up in the air. It really shows good participation. Give me one, please, Zoe?*

Zoe: *A rain gauge.*

Scott: *Good.*

Dorothy: A thermometer.

Scott: Thermometer, for temperature, right.

Student: Barometer, Sammy?

Sammy: Anemometer

Scott: Good.

Shane: Did anybody say thermometer

Scott: Someone already said that. Do you have something else?

Danny: weather balloon

Scott: Sure, we can use balloons. Think about the rooster, Zoe?

Zoe: Something.

Scott: Something, something.

Zoe: Something that starts with a "V".

Scott: a "v", ya. Peter?

Peter: A wind mill.

Scott: Not a wind mill but a wind vane, an wind vane that turns with a wind. So those are the things that people use to measure weather. One more still, Emillio?

Emillio: Stevenson screen.

Scott: Stevenson screen. Does it measure the weather?

Students: No, it protects.

Scott: It protects something. What does it protect?

Student: Thermometer.

Scott: Ya right. And I think in some instances an instrument that measures humidity. Right, but we are not going to cover it right now. We will just stick to the ones we have done already. What else?

Nick: A balloon.

Scott: The big balloon. ***Who was that who was talking about the big balloon*** *earlier about two weeks ago when we were exploring our ideas. Was that you Peter talking about the big balloon that they send up. So, there you go. Peter's prediction was confirmed they do use a big balloon to measure it.*

In this conversation, Scott and the students list the instruments that they have learned about, and seen on their field trip to the weather office. This information will be used later on, when the students construct their own weather instruments and learn how to use them to measure the weather for a period of time. Also, the purpose of this conversation, I think, was to once again reinforce students' ideas that were proposed during the exploration activity. For example, at the end of this conversation, Nick remembers that scientists use a weather balloon. Scott agrees, and tries to recall the student who talked about big balloon during the exploratory activity two weeks earlier. Then, Scott remembers that it was Peter, who mentioned about the balloons and he affirms Peter that his answer was correct.

The next point on Scott's agenda was to reinforce how meteorologists predict weather. Consider the following conversation.

Conversation Excerpt # 5.10 Class discussion

Scott: So, have ewe done a lot of work on how we measure. So, now I want you teach you guys directly on how we predict and forecast weather. How scientists do that. You saw a lot of it on Thursday when we went on a field trip. What of things do the scientists or did Mr. Anderson said that they use. ***And remember these are things that students in our classroom said,*** *O.K. Charity?*

Charity: I do not remember.

Scott: What do they use to predict weather in the future though? What kind of things did he talked about Tim?

Tim: I forgot.

Scott: You forgot. Remember they use certain instruments to predict what is gonna happen?

Nick: They use ***radar.***

Shane: That ***beam thing****.*

Scott: That beam thing. Are you talking about the laser that bounces and comes back? ***That is radar****. It sends a beam and it comes back and tells you what it looks like, Hanna?*

Hanna: A map.

Scott: Right, they use weather maps. I am going to put weather maps, which are different from the normal maps. Remember the maps he gave us. Does they look like your average, everyday maps?

Students: No, not really.

Scott: No, Zoe.

Zoe: They use those maps, they look at them and compare.

Scott: So that is how they use the weather maps, the temperatures on other days, and other places. So, here what they do with the weather maps is they would look at the weather here in Manitoba and they might look at the weather in Sasch. If it is really hot here in Regina and it is kind of cold here in Winnipeg and the weather system is moving this way. What kind of weather can we expect for tomorrow?

Tim: Warm.

Scott: Warmer weather, right. If it is hot here and cooler here, well the air systems are bringing us the hotter weather for tomorrow. So this is how they use maps and locations for other places and temperatures is there to predict what we are going to have the next time around. Does everyone pretty much understand that? Is there another one that we use?

Alek: ***Satellites.***

Scott: And how do those work? Does anybody remember what he said how satellites work? What do satellites do for us. Remember satellites are way, way up. Let me draw it for you. ***And where is that satellite if you know?***

Rose: Up in the air.

Scott: Way, way up there, we do not have satellites 10 feet above the ground. What is the point?

Shane : We do have dishes.

Scott: A, you are talking about satellite dishes. Very clever Shawn, very clever. But, what do you think those dishes communicate with?

Students: Right here.

Scott: That is right, they communicate with these ones to direct the signals back and forth.. Right they capture the signal that is coming from outer space and that is how you can communicate around the world with no power lines. So for now these satellites here are up in the space. I will draw a few stars around just so you know. ***But, what does the satellite do for us****. We know it is in space, we know it is a piece of machinery. What does it do for the scientist? How do scientists use it to predict the weather? Peter?*

Peter: ***Like telling what the weather is going to be like.***

Scott: O.K. satellite. Hallo, satellite what the weather is going to be like tomorrow.

Students; Ha, ha, ha.

Scott: Hi there Peter. This is satellite speaking. I am gonna to tell you that tomorrow is going to be plus 10. How does it tell us? What does it do? What does the satellite do? It does not tell us anything. We look at something and it gives us information, but what does it give to us.

Dorothy: It lets us communicate.

Scott: Yes, it lets us communicate with each other. But, what does it do for weather, though? Kathy?

Daniel: It sends that signal thing.

Scott: So we take a signal from the satellite, Travis?

Tim: ***It takes pictures, it draws something like a map.***

Scott: ***That is what I was looking for.*** *Thank you. It takes pictures from outer space looking down and from looking at those pictures over time. Remember how he showed us on the computer that you can click on a button and it would show you each one and how the weather system was moving. All the pictures that they took fro the satellite. He was saying this one was taken then this one was taken, then this one, then this one and this one. And when you put them all together?*

Ian: You have a map.

Scott: It becomes a map and it shows you how the weather is moving, right across the same piece of land. O.K. So that is how satellites work and that is how we can tell remember this here. Ok. So are the weather maps and satellites use together?

Students: Ya, no.

Scott: ***They are used together because here you can say on the satellite, the satellite showed us that this weather system is moving this way and then this is how we get this right here, we draw it on a weather map saying*** *O.K. That system is moving that way and it used to be hot here so hot weather is coming towards Winnipeg. Pretty neat how they use that, right. Is there anything else that we use?*

This conversation emphasizes that it was a great idea to go through all the information gathered on the field trip. When Scott first asks the students, what kind of instruments the meteorologists use to predict weather, two students admit that they do not remember. And, Shane talks about a "beam thing", which Scott identifies to be a radar. Then, they start talking about how weather maps are used to predict the upcoming weather. When Alek mentions about the satellites, Scott wants to know how they work and where they are located. Peter's answer that they are "like telling what the weather is going to be like," does not satisfy Scott. He wants him to be more specific, so in a cynical manner, he says, "O, hi there Peter. This is satellite speaking. I am gonna tell you that tomorrow is going to be plus 10." Finally, Timothy comes up with the expected answer by saying, "it takes pictures, it draws something like a map and those pictures can be seen on the computer." And Ian adds that a map is charted when all the pictures are put together. Satisfied with the answers, Scott points out that both the satellites and weather maps are used together for forecasting the weather. While the satellites show the movements of the weather system, the map displays their positions.

In this class, Scott also explained how computers are used to predict the weather. He talked about computers in relation to the radar. Specifically, he explained how the radar sends the laser beam up and the signal is then sent back with certain data such as information about the clouds. During the conversation, Peter had a great question. He wanted to know what happens if laser beam does not hit anything. Consider the following conversation:

Conversation Excerpt # 5.11 Class discussion

Peter: What happens to the radar when it is send up and there is nothing.

Scott: Good question. Did you guys hear that. Joey. Did you hear that. Can you repeat the question for me. Peter asked a question about radar, do you know what it was? What was the question Shane?

Shane: What would happen if it got shot on the air and there are no clouds, would it hit something, would it turn around, what would happen to it?

Scott: ***Remember, when Mr. Anderson was talking about radar and he said that it will tell you if it is really cloudy, if it is raining high up in the air because sometimes it is raining and we do not get it till later on because it takes time to fall and so they can actually tell us that it is going to rain in about an hour.*** *They could tell us that. If there is no clouds at all in the sky, what did he say? It is a clear day, right. What did he say that they* *often see on the radar, the radar always picks up all of these little things in the summer time, ok, Dorothy?*

Dorothy: Mosquitoes.

Scott: Right, it makes it look like big clouds but it is just a big cloud of mosquitoes. So he said that sometimes it can hit other things. And you know my guess would be Peter is that whenever they send up a laser beam, it always hits something.

Scott: (continues): And you know Peter my ***guess*** *would be, now I can not tell you Peter for sure because I am not a meteorologist and I do not know for sure. But, my* ***educated guess would be*** *that if it sends up a laser beam, Peter and it does not hit anything it does not come back and so the computer says o completely clear day, right. It did not hit anything so it does not send any message back so what the screen is going to look like on the radar system?*

In this conversation, Scott tells Peter that he does not know for sure what happens when the laser beam does not hit anything. But he said, his educated guess would be that if the laser beam does not hit anything and thus does not come back, the computer, possibly predicts a clear day. Scott's choice of words, such as, 'educated guess' was purposeful. He used the same words in other situations, when he was referring to scientist's work. Johan Stern, a TV weather anchor, who later visited our classroom, also used the same wording. Even Jason Anderson at the weather office, also told us that the forecasters can not always rely on computers, and as such sometimes they must use their knowledge and information from other sources to write the weather forecast.

Scott also asked the students if they remembered seeing the lady meteorologist in the weather office. He was referring to Sarah. Consider the following conversation:

Conversation Excerpt # 5.12 Class discussion

Scott: We are going to go back right away and we actually have 15 minutes. I just used the book. Actually maybe I will show you another picture before we go back. Do you remember seeing the ***lady in the office there?*** *She is a meteorologist and what she was doing, you noticed how they had three different computers in front of them. Actually they had four screens in front of each of them, right.*

Student: And they had a big T.V.

Scott: And they had a big T.V. right. So, and you are right because they make that information that goes on T.V.... So, with all this information that she has what will she do with that? First she types it up on the computer and she sends it to probably a computer web site, right and that web site is what tells us on our computer what the weather is like. When we get a forecast on a computer or T.V., right the T.V. you were watching the forecast on Jessie. Remember the environment Canada, the red and green or the have the blue and green and it switches colors once in a while. That environment Canada, they put the information in for that all the time. So, here and the other thing is she is recording her voice and she will probably send that out to all the radio stations around here and then they will play that on the radio and that is where the weather comes from on the radio. So, meteorologist job is really two things, or three things to measure the weather, to predict the weather, and to...

Students: ***Share.***

Scott: To share the weather with us, yes you are right.

This conversation took place at the end of the class, and I thought it was an excellent move of Scott's to summarize all that is required for forecasting the weather. Scott explains to the class that the *lady meteorologist*, whom they saw at the weather office, works amidst computers and a big TV, so that she could use the available information to predict the weather first, and then to write the forecast, which could be later recorded and sent to the local radio stations. Here, Scott points out that the meteorologists predict, measure, and share the information with others. From Mr. Anderson's presentation, the students also learned that the meteorologists share the information with the meteorologists in other weather offices in the country, before reporting it to the general public. Thus, contrary to many publications criticizing teacher's portrayal of a science as a solitary endeavor (Hewson, Kahle, Scantlebury, & Davis; 2001; McDuffie, 2001; among others), our students had a chance to learn that scientists are in constant communication with other scientists in the field.

Soon after the class, Scott told me that, he particularly mentioned about Sarah, the female meteorologist working with a number of high-tech instruments and doing an important job, so that the students understand that gender doesn't stand a barrier in doing such jobs. It's commendable that Scott exhibits an open mind, and shares the vision of American Association for the Advancement of Science (1993), National Science Teachers Association (1991) and the Council of Ministers of Education, Canada (1997) in regard to scientific literary development. Among other things, these organizations urge the teachers to expose the children to all career opportunities in the field of science, engineering, and technology. If we follow McDuffie's (2001) reasoning, which states that the teacher's attitudes flavor the classroom and affect students in profound way, it is fair to reason out that Scott's attempt would have encouraged the female students in the class to consider careers in science in the future.

5.3.6 Visit by TV Weather Anchor

The interpretation of what meteorologists do was reinforced by the visit of Johan Stern, a TV weather anchor. During his visit, he initially explained what he does as a weather presenter. In a simple and understandable language, he explained that he does a lot of computer work, and that the computers are very important for what he does. He told us that he spends much of his time in the graphics department, where he compiles various images. For example, he puts together the picture of the sun and the cloud and makes the rainfall. This visual image is presented to the public so that they could know what the weather is going to be. In his words," his job is to make the weather understandable for the folks at home." I really liked what he said about forecasting: *"...forecasting is a little bit like looking into a crystal ball and trying to predict the future and it's not very easy at all. It's hard to tell if the future is exactly right. That is why a weather forecast is really an educated guess."* To confirm his point, Johan said that sometimes the forecasters in Winnipeg might predict the next day to be a mainly sunny day with a temperature around 16 degrees Celsius. However, somebody else's prediction on a different television station might be that it is going to be 18 degrees. He tried to explain that he and his colleagues do not just sit at work and try to guess the weather. Instead, he said, "it is scientific educated guessing," because they are using science, satellite, radar, computers, computer models. Also, he said that they use various kinds of data and records from the past so that they could estimate what the weather would be like in the future.

The students also had a chance to ask him questions. Because we did not really know the topic of Johan's presentation, they did not prepare the questions in advance. Consider this following conversation to understand the type of questions students asked:

Conversation Excerpt # 5.13 Conversation with weather anchor

Dorothy: ***Do you believe in folklore?***

Mr. Stern: Do I believe in folklore? I read folklore and I don't mind reading it, ***I don't know if I believe in it, I guess it depends on the folklore.*** *There are always, but not always but very often there are some science behind folklore. Do you have any for me?*

Student: ***If onion grows thick, the weather will be severe in the winter.***

Mr. Stern: Is that right, you see there is probably some science to that right, because it's like the vegetables over all of time have probably used to protecting themselves in winter and that sort of thing and maybe the bark on the tree is a little thicker in a particular year and then it snows harder or something like that, there could be some science to that. Who has not asked a question? Okay go ahead.

Alek: ***What about red sky at night sailors delight, red sky in the morning sailors take warning.***

Mr. Stern: ***Thank you, ya I do. There is some science in that though.*** *What kind of science. Let's see if I can remember how to explain this. So a red sky at night sailors delight which means that the weather is going to be nice the next day. So if the sky is setting in the west, and its red, remember its clear skies that are the ones. Generally our weather moves across Canada from the west, so if there is clear skies in the west then we will get good weather, however red sky in the morning, sailors warning. Lets see now, that means that if the sun is rising and it is really red, we are looking at clear skies in the east, which means that clear weather has passed us so that is why .... and there is a reason why the sun is red when it goes over the horizon too.*

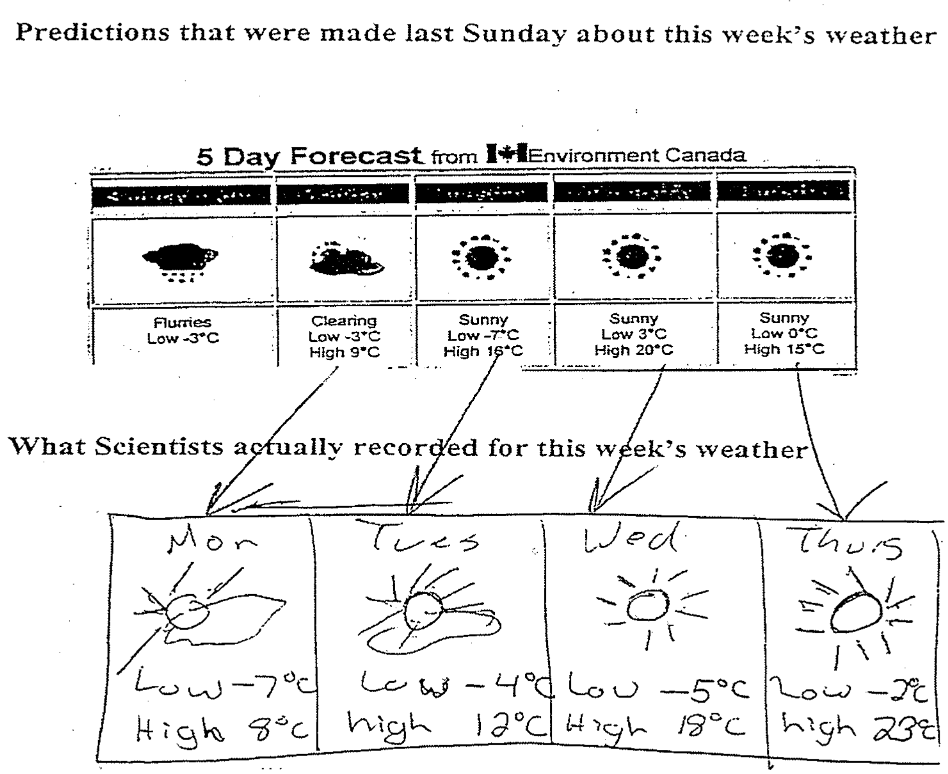
At first, Dorothy asks him about his opinion on folklore. Mr. Stern's silence made me guess that he was not prepared for such a question. But soon, he composes himself and replies that it depends on the type of folklore and somewhat agrees that there is often some science behind the folklore. He asks the students to give him an example of folklore. Dorothy asks, then, whether it is true that the weather is going to be severe in the winter, if the onions grow thick skins.

Mr. Stern must have seen some science behind this belief, because he answers that the vegetables probably develop mechanisms to protect themselves in winter by growing thick skins. He also says that, if the bark on the tree is found thicker in a particular year, it usually snows harder. Dorothy's question indicates that the students still struggled between the traditional and scientific way of predicting the weather.

Then, Alek asks Mr. Stern, if he believes in the saying, "Red sky at night sailors delight, red sky in the morning sailors take warning." Like Mr. Anderson, Mr. Stern too admits that he indeed believes in this one. He explains that the red sky is usually associated with the clear sky. Thus, if the sky is setting in the west and is red, we can expect to get a good weather in the morning, because generally our weather moves across Canada from the west. However, he says, "red sky in the morning, sailors take warning" means that if the sun is rising and it is really red, we are looking at clear skies in the east, which means that clear weather has passed us and we can expect bad weather. Alek's question also indicates that he, and probably the rest of the students are still wondering which method to believe.

5.3.7 Long Versus Short-term Weather Forecasts

In line with the 5-4-11 Specific Learning Outcome our students did a comparison of short versus long-term weather forecasts. Specifically, this outcome requires to contrast the accuracy of short- and long-term weather forecasts and discuss possible reasons for the discrepancies. At this point of our investigations, we already knew that scientists use weather instruments, computers, satellites and radar to predict the weather in the future. In this class, on long versus short-term weather forecasts, Scott wanted the students to decide which of the two types of forecasts were more accurate. It was also important that the students provide an explanation for their reasoning. This activity was first conducted individually, then in groups, which was then followed by the whole class discussion. For this lesson, on one Sunday, Scott printed off the five-day forecast for that particular week. Over the same week, our students recorded what the weather was actually like. To do this, they visited the Environment Canada web site and also took the readings with the instruments, which they designed by themselves. The following diagram compares the predictions made by our students with those of the scientists in that particular week.



It is to be noted that not all the students clearly understood what they were expected to do in this exercise. Shane, was the first one to admit that he was not sure what he was supposed to do. Scott then tried to explain with examples: "Shane, for example, the scientists said that on Monday it was going to be clear with a low of -3 and a high of 9. We recorded partly cloudy with a low of -7 and a high of 8. On Tuesday, they said it would be sunny, low -7 and high 16, we recorded partly cloudy, a low of -4 and a high of 12. Your job is to decide if the scientists were actually right when they gave us this forecast for the week." Shortly after Scott's explanation, the students started working on the assignment, and it is remarkable that they not only drew good conclusions but also gave reasonable arguments for their thinking. Their overall conclusion was that long-term forecasts are less accurate than the short-term forecasts. I particularly enjoyed the discussion between them and Scott. Consider this discussion, below:

Conversation Excerpt # 5.14 Class discussion

Scott: So what do you think Chantel?

Student: Not very accurate.

Scott: You think that it is not very accurate, why is that? Can you ***show me why****?*

Student: I do not know.

Scott: What in here did you see that tells you that it's not very accurate? Hum

Student: I am not sure.

Scott: What's your opinion Kathy?

Student: I think they are pretty accurate because ya, they are not off by much and they say clearing,……clearing up.

Scott: Hum, hum.

Student: ...and .... Monday,.... And they were only one off with the high.

Scott: Okay.

Student: These ones they are higher and these ones are lower with a low of –4, Jane?

Student: I think that they are not accurate at all?

Scott: Why do you think that there is such a difference between what they predicted for the week and what was actually recorded?

Jane: They do not know for sure what is going to happen and they are not always correct because they do not know everything.

Scott: Okay, so Jane, your answer is right along the lines that I was looking. ***You guys, because we are not fortune tellers, as Sammy said, and we are not god, we don't know for sure what is going to happen, so when the scientists predict what they think will happen, okay, they can't be 100% correct the whole time, that's why there is that difference.***

Student: They just lie.

Scott: No they don't lie Charity they give ***their best guess, and that's what a prediction is right?*** *We make predictions all the time, but it's our* ***best guess, we don't know for sure.*** *They predicted the sunny days though didn't they. That's pretty good because they can see the satellite clouds coming in right. So something's are easier to predict than others right?*

In the above conversation, it is remarkable how Scott cautions the students not to consider the scientists to be fortunetellers or those who come up with false predictions. Instead, the scientist's job is to interpret the data to the best of their ability. By saying so, Scott also implies that scientists are regular people and there is nothing odd or unexplained about their work. Scott's comment that scientists are neither fortunetellers nor gods dismisses the distorted image of a scientist as someone who is enigmatic, strange looking and whose work, like fortune telling is mysterious and secretive (Barman, 1997; Flick, 1989; Kahle, 1989; McDuffie, 2001; Rosenthal, 1993). As recommended by

Mason, Kahle, and Gardner (1991) Scott encourages the students to consider scientists as regular human beings, who interpret the data to the best of their ability.

At the end of this class, Scott summarized that "*people often have this idealized image of a scientist as someone who knows everything.*" However, he wanted his students to understand that science is not absolute and that scientists do not have all of the answers. His intention became apparent during our field trip. Consider one more comment that he made at the end of this class: "You guys, a lot of people look at scientists and say, wow, they are very smart people, they must have all the answers. They don't". Scott's teaching approach, contradicted the very many claims of authoritarian view in which scientific knowledge is presented as absolute truth and as a final form (Duschl, 1988; Lederman, 1992; among others). His teaching, on the other hand, exemplified that scientific knowledge is not absolute and final.

5.3.8 Just a Note to Say Thank You to the Experts

On many occasions, Scott emphasized that scientists are neither dogmatic nor do they have all the answers; instead, they just interpret data to the best of their ability. At the same time, he also suggested that they are experts in their field of study. This came about when the students were writing thank you letters to the people who helped in their study of the weather. They did this after our field trip to the weather office and after the visits from Mr. Birdie and Mr. Stern. Soon after Scott asked Zoe to distribute the handouts titled, *Just a note to say thank you,* to the class, the students were encouraged to write the thank you notes. Consider the following conversation:

Conversation Excerpt # 5.15 Class discussion

Scott: Zoe, could you please read the title of the paper I have just placed on you desk.
Zoe (reading): ***Just a note to say thank you.***

Scott: ***What do you think this is going to be for? What do you think this going to be for, what are we going to do on this page? Shane?***

Student: Write to Miss Biernacka.

Scott: Write to Miss Beata, well ya, we could write to Miss Beata, okay but there are some people that we need to thank even more than Miss Beata, even though she is doing a lot of hard work with us, okay. There are certain people that don't have to be here, and they come here, okay. Nick?

Nick: ***Mr. Birdie.***

Scott: Right, so we could write a thank you letter to Mr. Birdie. ***There is one more person though that shared the expertise with us and spent a lot of their time teaching us about weather.*** *Does anybody have any other ideas about that?*

Student: ***Mr. Anderson.***

Scott: Mr. Anderson, right from the weather office, and there is one more person coming this afternoon.

Student: Mr. Stern

Dorothy: He's on CKY.

Scott: CKY, he's the TV meteorologist guy. You might choose to write to Johan Stern, you might choose to write to Mr. Birdie, and you might choose to write to Mr. Anderson.

Scott: Okay so who are we writing to here?

Student: Mr. Johan Stern.

Scott: Johan, ***okay do you guys have the reason why you are going to write to him?***

Student: .....cause he's funny.

Scott: ***Just because he is funny.***

Student: I picked Mr. Anderson.

Scott: ***Why did you pick Mr. Anderson……?***

Student: ***Because he knows a lot about the weather.***

Scott: Hum, okay, that's could work. Okay, Rose how about you? Hang on, hang on, I'm actually interested in hearing what Rose has to say, what's your opinion there Rose, who would you pick to write to?

Rose: I do not know.

Scott: Mr. Anderson from the weather office, Mr. Birdie, our expert on aboriginal tales and folklore, or Mr. Stern, the TV weather man.

Student: I am not sure.

Scott: You don't know yet. Ok, Alright, ah, three,.....two, one, active listening please. Alright, so as I was walking around, it seemed to me that, it seemed like certain groups had different ideas, for example one group decided that they wanted to write to ***Mr. Anderson, okay and the reason was because they thought that he spent the most time with us and brought us into his office and his workplace and he spent a lot of time showing us exactly what we needed to see about weather, okay. Another group was thinking, well maybe Mr. Birdie was the best choice because Mr. Birdie came in and showed us a lot about aboriginal tales and folklore and we really didn't know a lot about folklore, ya, in fact,*** *Mr. Lister,* ***Miss L. and Miss Beata were are not experts on folklore so we didn't have a lot to share, but Mr. Birdie did. So, he kind of brought something to our research that we don't really know about ok., and then there is Mr. Stern, who we don't know what he is bringing this afternoon but we know he is a TV weather man, we know he is very busy and very important, and he is sharing some time with us and that's great****. Okay, so .... Yes you may. Nick could you take all three down there? Alright.*

In this conversation, Scott stresses that there are certain people who need to be thanked for their willingness to share their knowledge about weather with us. The students enthusiastically reply that they would write a thank you note to me. So, Scott has to explain to them that there are others who deserved more, because of the time and knowledge they volunteered to share with us. He makes them understand that neither he nor me are experts in the field as such they need to consider writing to experts like Mr. Stern, Anderson or Birdie. By pointing out that they were experts in the field, Scott instills the idea that scientists and scientific work are trustworthy. So far in our investigations, the students were learning that scientists do not always know everything. I think that it is also important for them to realize that scientists are not careless people, who try to do their work by just guessing.

Scott wanted to make sure that the students understood, who an expert is. Later on, during the construction of the weather instruments, an opportunity came up for him to clarify this matter. Jessica was working on the design of Stevenson's screen in which she glued popsicle sticks to make the legs for the body of the screen. Since she was quick and meticulous in making the two legs perfectly and being able to show the rest of the class, how to do the other legs, Scott pointed out that Jessica is an expert in doing this particular task. Immediately Emillio, who was assisting Jessica in this project, responded that Scott too is an expert as a teacher. Doubtlessly Emillio's statement was a compliment to his teacher. Yet, Scott made him as well as the class understand that as far as teaching the grade five class, he could be considered as an expert, but he was not an expert in any other areas.

5.4 Translating and Extending

The Translating and Extending phase of the Common Knowledge translates and extends students' understandings of science concepts to real world problems. For science educators, this type of education addresses students' ability to make connections among science, technology, society, and the environment (STSE). Science educators refer to STSE teaching as "authentic science" or interdisciplinary science, which places it within a larger societal context (Ebenezer & Connor, 1998). The Translating and Extending phase consists of two stages: design process and issue-based teaching. The design process connects science with technology (ST) and involves construction of an artifact, based on the information acquired throughout a science unit. Thus, it allows the students to see the practical application of scientific knowledge. The issue-based teaching, on the other hand, involves identification of an issue (problem) and extension of that issue into other disciplines, such as society and environment (SE). Thus, it allows the students to see that scientific knowledge is used to investigate and offer plausible solutions important to societal and environmental issues in today's world.

5.4.1 STSE – Design and Evaluation of Weather Instruments

In line with the 5-4-05 Specific Learning Outcome, our next project was to use the design process to build the assigned weather instruments. To build these instruments, each group of student conducted research, planned out how to build the instrument, selected appropriate resources, drew out a prototype, and finally constructed the instrument. They also wrote down a description of what and how the instrument supposed to work. Each student, on the other hand, documented the process of building the instrument in the Weather Instrument Brochure. The construction of the weather instruments required the collaborative effort of all the members in the group and this offered Scott a chance to emphasize on the benefits of sharing and collaboration within a group. Consider the following comment to one of the groups:

Conversation Excerpt # 5.15 Scott's comment

> *Scott: Kris, I want you to think what kind of materials you would use to build a wind wane. Your friend, Jane, already suggested Popsicle sticks. But, Sammy said that he got a better idea. Some of you can have yet other ideas, which you* ***might want to negotiate*** *with your friends before you decide on your final group design. Every member of the group needs to draw his own idea* ***and bring that idea back to the group for final negotiation. Everyone's effort all together*** *should produce a really good result."*

Here, Scott suggests, "Everyone's effort all together should produce a really good result." He emphasizes that if the group wants to arrive at a mutual understanding, they need to carefully listen to everyone's suggestions and negotiate with the others in the group before deciding on the final design. In other words, he tells the students to negotiate their ideas with others in a mature and democratic manner. I believe that working on such group projects make us want to say, "we are learning how to become better scientists." Certainly it gave an opportunity for the students to understand the concept of sharing and collaboration among the scientists. Furthermore, it made them realize that science is a collaborative endeavor, and that scientific knowledge is created and enhanced by a community of researchers. An individual scientist's confidence in some new information is usually considered to be insufficient to be regarded as new concept or scientific knowledge. It should stand up to the criticisms and reviews of fellow scientists (Machamer, 1998).

The "home made" weather instruments, made by the students were used daily for two weeks to measure the following components: wind direction (wind vane), wind speed (anemometer), sky conditions (our eyes), and precipitation (rain gauge) [Specific Learning Outcome: 5-4-06]. In fact, we took the activity a step further than what is required by the curriculum. Not only did our students used the instruments to measure certain weather parameters, but they also compared their data with those obtained by the scientists, using modernized scientific weather measuring equipments. This comparison allowed us to assess the accuracy of our homemade weather instruments. At first Scott asked the students to check whether their instruments were accurate or not, and to give the reason for their assessment. In order to do this, the students needed to compare their readings with those of the scientists. In other words, readings obtained by "home made" instruments versus readings of the professionals using scientific instruments. The students were able to do this comparison because they have kept a record of their own measurements and of those recorded by the meteorologists.

Because many of the students could not properly understand what accuracy really meant, Scott had to spend some time explaining it to them. He told them that while our class was recording the measurements of weather for two weeks, using the "home made" instruments, the scientists too were recording similar measurements with their instruments. He asked the students to check whether their readings corresponded with those of the scientists. If they found them to be similar, he told them that they could conclude that the instruments they designed gave accurate readings. If not, the instruments should be regarded as faulty or inaccurate. Scott gave them time to check out the readings and to conclude, as a group, whether their instruments were accurate or not. He also asked them to write a short summary on the accuracy of the designed instrument. Although, each group made only one instrument, in this activity, they were asked to evaluate the accuracy of all the instruments made by the class.

After the group interaction, the whole class gathered to share their findings. The class found out that most of their readings were not accurate. Mathew's reasoning was that it was because "the meteorologists had a lot better instruments". Scott agreed with Matthew's reasoning, and clarified that our "data were not as accurate as theirs because in most cases, except for the thermometer, we did not use professionally constructed instruments." Although our data were significantly different from those collected by the meteorologists, it was hard for some of the students to admit that. Students' job was to evaluate the accuracy of all of the "home made" designs the class made. It was evident that the students found it easy to criticize the instruments done by other groups but when it came to their own, they found it hard to disqualify the design. For example, Kristofer was very defensive of his group's wind vane. He insisted that his group's vane was pretty accurate. According to him the measurements were close enough considering the fact that his group's "vane was on the ground, while the one at the weather station he saw on our field trip was not." Even after the class went on to discuss about other things, Kristofer still focused on his weather vane. Scott took advantage of Kristofer's attitude and used it as an opportunity to mention to the other students that Kris's attitude is known as passion.

He pointed out that scientists are usually passionate about their work. Specifically, he said that "scientists are usually very passionate about their research and they can't get their own ideas out of their heads."

Anemometer was the instrument, which gave us the worst results, because as Kathy put it, "every day we were a little bit off from the scientists." The lively discussion about the anemometer gave Scott an opportunity to help the students speculate what kind of factors could have affected students' readings. In other words, Scott wanted the students to express their views. Consider the following class discussion:

Conversation Excerpt # 5.16 Class discussion

> *Scott: Can you think of anything else about the anemometer that might have affected our results?*
>
> *Han: Ya, Ours is made of cardboard so, it made it, we made it too hard.*
>
> *Scott: Okay, so you think the cardboard is too heavy to be pushed by the wind?*
>
> *Han: Ya.*
>
> *Jane: ...I don't think that the pencil is too heavy.*
>
> *Scott: So you think the pencil is too heavy too? Oh, ya, it could be. What else do you notice about the anemometer? **Do not forget that you have to explain why.***
>
> *Nick: **Oh, I hate those why questions.***
>
> *Scott: So, do you also think that it is inaccurate?*
>
> *Student: Ya.*
>
> *Scott: Okay, which means not accurate and the reason she gave was because our measurements were off from the scientists measurements are. Did anyone have a reason to explain why they think your measurements were off?*

Okay, this group over here had a good idea, ***Matthew what was your reason for the anemometer not being accurate?***

Matthew: Hum, we were a lot off because the pencil was too heavy.

Scott: Okay, so he thought that the pencil was too heavy to be pushed by the wind. The cardboard and the pencil were too heavy, it wasn't an accurate reading. So anyway our anemometer was inaccurate, I would agree with you, Emillio?

Emillio: All the instruments were not very accurate because we had a different angle, because they are at the forks and we are here in Prairie View School.

The above conversation reveals how Scott negotiated ideas with his students. Scott does not tell the students whether their reasoning is correct or not. However, he sees the importance of finding the reason for their decisions. He was not satisfied with "what" the students were thinking; he also wanted to know "why" they came to such a conclusion. During this conversation, a comment like Nick's, "I hate those why questions," indicates that the students always faced Scott's "why?" question. Such approach of Scott's only reflects how seriously he has taken his teaching, and how important it was for him to know that the students have understood the lessons. More importantly, Scott's approach fulfills the plea of many science educators, who would like to see the teachers placing greater emphasis on the understanding of the subject rather than merely memorizing the facts (Gallagher, 1991; Lederman, 1992). It is commendable that Scott, a novice teacher who was teaching science for the first time in his career had ventured into a contemporary approach, rather than a traditional method of teaching science by memorizing facts.

Scott's final summary on the topic was excellent. Consider his summary: *"... We found out, as good scientists would, that you need to be able to look at your own work and say, am I, is it working properly or do I need to fix something okay, and that's really what I want you guys to get from all of this okay. I mean, we could be studying weather, we could be studying changes in matter, we could be studying simple machines, and it doesn't matter. The fact is, that scientists when they invent and they research and they create, they also test and assess and then make changes and they keep doing that over and over again until they get something that is accurate...."*

I particularly liked the part, which implied that good scientists look at their work critically. Scott made sure that his students understood that the scientists test and evaluate their work critically. In the next activity, he encouraged the students to critically evaluate their designs and to discuss how to improve the accuracy of the instruments. At first, the students discussed the matter within the groups, and then each student separately wrote down the things needed for improvement. In regards to the anemometer, Rose wrote that she "would change the anemometer to be more accurate by changing the piece of cardboard and put a piece of metal instead because the pencil and the cardboard were too light."

5.4.2 STSE – Issue-based Teaching

To illustrate the connection between science, society and environment, for the unit on Weather, the *Manitoba Curriculum Framework of Outcomes* requires the students to study natural disasters (Specific Learning Outcome: 5-4-09). Specifically, the curriculum requires to provide examples of severe weather forecasts and describe preparations for ensuring personal safety during severe weather and related natural disasters. The curriculum gives the following examples of the natural disasters: tornado, thunderstorm, blizzard, extreme wind child, flood, forest fire. We wanted to make our study of weather very effective. So we decided to achieve this goal by making our study relevant to the local needs and concerns. Because of the location of the city in the Red River Valley, we decided to concentrate on flooding. At first, the students were shown the clips from the video, *The Flood of the Century*. This video documents the flood that happened in the Red River Valley in 1997, and it helped the students to think and explore the reasons for flooding. The students wrote their ideas and then shared them orally with the whole class. Scott recorded all of their ideas and then, in subsequent lessons, he used them in his teaching. Students' reasons for flooding fell into two categories: Precipitation and Sewer Backup.

Since our students' parents experienced the flood of 1997, we decided to involve them in this part of investigations as well. In addition to seeking their opinion on how floods form, we also wanted them to give us their view on how people need to be prepared for possible floods. And, most importantly, we were interested in their personal involvement and experiences with the last flood. So, the students were asked to interview their parents to find out answers to the following three questions: 1) How do you think floods form? 2) How should people be prepared for a possible flood? 3) How did the flood of 1997 affect your life and the lives of people you know? After interviewing their parents, the students were asked to write a written summary of parental ideas.

Parents' answers to the first question were grouped into three categories: Precipitation, Overflow of water bodies, and Precipitation and overflow of water bodies. Table 5.5 illustrates the three categories of parental ideas and provides an example of representative idea followed by the number of parents proposing this idea (in brackets).

Table 5.5 Parental reasons for flooding.

Category	**Representative idea**
Precipitation	My mother thinks that floods are caused by heavy rain storms and melted snow, and river flooding with water. (10)
Overflow of water bodies	My mother says that floods form when river is overflowed. (1)
Precipitation and overflow of water bodies	My father thinks that floods are formed by excessive rain fall, and it backs up the sewer, and the dams can not take it. And it can't take the water causes it to flood. Floods can also form by snow melting too fast. (1)

As shown in the above Table, there were ten parents who believed that floods are caused by heavy precipitation either in the form of rain or snow, which then leads to the overflow of water. Only one parent, Hanna's mother, believed that floods are caused by an overflow of the water bodies. And, one parent, Kristofer's father, thought that floods are caused by a combination of heavy precipitation which leads to the overflow of waters, which in turn causes damage to the dikes and flood ways. Note, that not all of the students got a chance to interview their parents, hence, we only had 12 responses.

Sammy's mother's answer to the second question, How should people be prepared for a possible flood? best summarizes the nature of parental ideas. She said that "people should be prepared by sandbagging their properties and trying to get extra food, generators for electricity, keep extra clothing and candles for warmth and for seeing in the dark or move to higher ground before the flood comes." This answer suggests that certain materials and activities are required to survive the flood situation. The list of necessary materials included: water pump, sand bags, boat, generators, life jacket, candles, food, water, and clothing. The list of activities included: sand bagging, digging ditches, cleaning garbage from sewer, getting to higher ground, and protecting personal belongings, love ones, and pets. In addition to being involved in the activities to save their personal lives, the parents also saw the need to volunteer their time to help others save their properties. These volunteering activities involved sandbagging and digging ditches. Peter's father, however, told his son that all of the above activities are "unnecessary unless people have insurance." According to him, "buying insurance is the best preparation because you can not do anything, you can not change the weather, you can not have 1000 sand bags sitting on your lawn waiting for the flood, can you?" I guess not.

Scott and I were mostly interested in the answers to the third question. We wanted to know whether the parents were involved in saving the city of Winnipeg from the flood of 1997. We were hoping to hear some powerful stories. Most of the parents who were interviewed said that they were "involved in sandbagging to help others protect their property." None of the parents, however, had any heroic stories of their particular involvement or about any damage that the flood caused to their property. Kristofer's mother was the only parent who was able to share a personal incident that happened during the time of the flood. She told Kristofer that she remembered the flood of 1997 because this was the time Kristofer's grandpa died. She particularly remembered the snowstorm the night before that prevented her from going to the hospital.

One of the important goals of STSE education is to provide opportunities for the students to acquire the information and decision making skills. It is found that these skills, in turn, are associated with the development of other potentials such as: identification and in-depth understanding of the problem, framing questions, gathering and analyzing data, sharing and evaluating findings, drawing possible solutions and suggestions, and choosing and implementing actions (Ebenezer & Connor, 1998; Pedretti, 1997; Aikenhead, 1997). These skills also make a person scientifically literate. To develop the decision making skills in our students, Scott presented the students with a written Newsflash, which informed them of the high alert flood watch for the city of Winnipeg, and also about the nearby cities, which are already underwater. This news also informed that the floodway would not be sufficient to protect the city against the current heavy downpour of rain.

Soon after the showing of the Newsflash, Scott presented a situation, which required the students to decide on the items, they would choose to survive the flood. The scenario was that soon after the people heard the Newsflash, they saw through the windows that the streets are getting flooded. Their basements were already underwater, but the upper levels of their home were still fine. The people needed to get to the roof to be safe and to be rescued. Since the water was moving in very fast, the people had time only to grab 10 items before their main level gets flooded. The question was, then," What 10 items would you bring to the roof as a flood survival kit and why?"

As usual, Scott gave the students enough time to negotiate the situation with their group members, before presenting their choices and reasons for their choices to the whole class. The following class discussion presents the items, which I highlighted in bold letters, that the students decided to include in their flood survival kit:

Conversation Excerpt # 5.17 Class discussion

Scott: Okay, which group would like to share with me their 10 items that they chose for their flood survival kit. Hum, let's go with group #5.

*Zoe: **Four boxes of cereal** because it will not spoil. **Dry clothes** to change, three **bottles of clean water** so you do not get dehydrated, a **backpack** to store things, a **blanket** to keep you warm, **batteries for a flashlight and flashlight** to send SOS.*

Scott: Okay.

*Charity: **Lucky thing**, for good luck, okay.*

Nick: Blanket to keep dry.

Scott: Blanket to keep dry. Emillio, how was your groups results? Did you all manage to agree on one, okay then let's hear that list from this group then?

*Student: **Nonperishable foods** so they will not spoil.*

Scott: What do you mean nonperishable?

Student: Like what can't perish or get rotten.

Scott: Okay, good, good, yup.

Student: ***First aid kit****, so we can…if somebody gets hurt, and water jug so we won't be dehydrated, clothes so we won't be cold, old clothes.*

Scott: Okay.

Student: ***Inflatable mattress so we can sleep*** *on, books to keep us busy, flashlight to see in the dark,* ***extra pair of shoes****, just in case our shoes are wrecked. Batteries for flashlight and a life jacket just in case one of us falls into the water.*

Scott: Hum, I noticed that you, I noticed that this group here and this group, they both had water so we don't get dehydrated, I am kind of wondering about the fact that you are surrounded by water in the flood?

Emillio: Ya but it's very muddy.

Scott: Dirty muddy water, okay, so you are saying it's not really drinkable then.

Student: No.

Scott: So you got to bring clean water then. I noticed that Zoe said three bottles of clean water right. Alright let's hear Jessica's list here.

Student: A weeks supply of food to eat, clothing to wear, ***matches for SOS****, fireworks for SOS, cell phone for emergency calls, aid kit for is someone gets hurt,* ***gazebo for shelter****, fishing device, 10 days supple of water to drink, a red blanket to keep warm and also for SOS.*

Scott: To keep warm and SOS, what do you mean the blanket and SOS?

Student: The red blanket.

Scott: Oh, the red blanket, okay. So a red blanket is a good thing to wave so the people can see you from the sky, that's what you mean. I actually liked this groups approach too. ***I mean this group was talking about the survival, right, it definitely is good things to survive while you were there, until someone comes. This group thought more along the lines of how are we going to get help if someone is coming around, okay how are we going to signal them down.*** *They have fireworks, they have matches to create a fire or smoke signal, they have a red blanket. What's that?*

Student: How would you set up a gazebo on your house?

Scott: A gazebo, well I think that what they meant was a gazebo tent probably, or something that would cover you, right, maybe a parasol, like a beach umbrella or, something, is that what you guys meant? Jessica is that what you meant by gazebo, something that would cover you, shelter?

Student: Yes.

Scott: Yes Dorothy?

Student: ***I don't think they should have a week's supply of food because what happens if you eat it all and you have nothing left?***

Scott: Okay, so you don't think they should have a 10 day supply of food, well it's a good opinion to have, but maybe they have a 10 day's supply of food and they ration it out to themselves, hey, there's that word that I used earlier this year, okay, ration. They ration it out to themselves. So that they are only eating like a quarter of what you would normally eat, so it last for 40 days instead of 10, right. It's possible, that's there ideas though. I am finding it interesting though ***Dorothy that you are thinking in your mind about whether or not that is a good idea for you and whether you would do that or not****. This group here, Jane?*

Student: ***Telephone*** *so you can phone people.*

Student: Huge water bottle to last 10 days, life jacket to ..., sleeping bags to sleep in, ***my cat.***

Scott: Your cat, okay.

Student: so he won't die, a blanket to cover up with, clothes to change in.

Scott: Flashlight and what? Okay I guess that is the end. Peter? I guess this group had different ideas so Peter?

Student: Cell phone for rescue.

Scott: There's that cell phone again right, that calling for help idea, okay.

Student: ... for drinking, some not perishable.

Scott: Nonperishable food okay.

Student: ***Life jacket.......*, *sleeping bag*** *for sleeping, ..., clothes in case we get wet.*

Scott: Okay.

*Student: Flashlight to see in the dark. ....**tooth brush....***

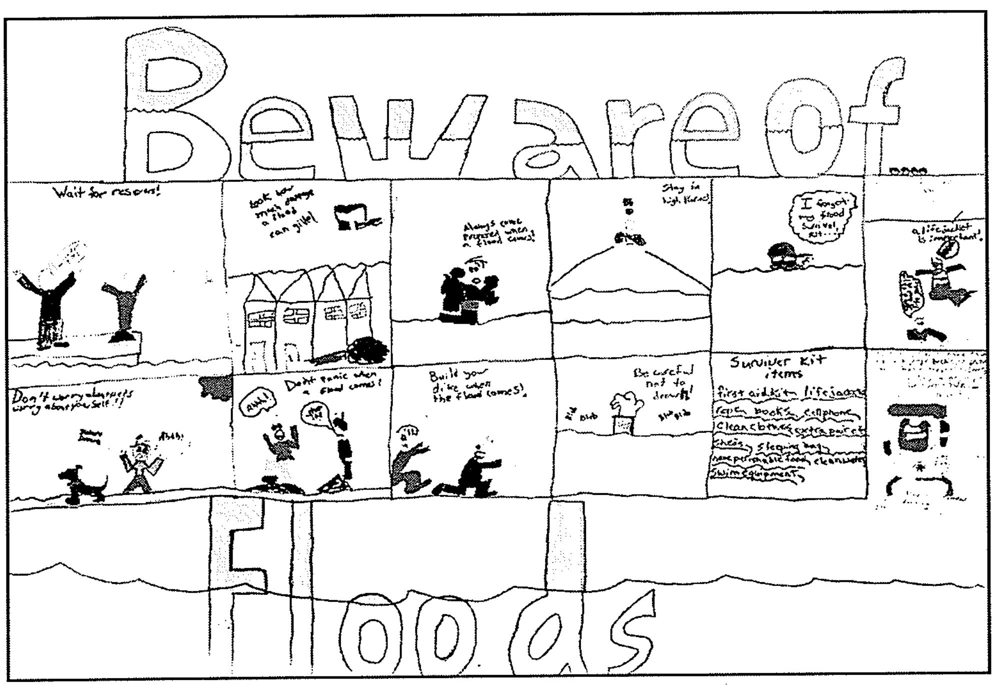
Student: A first aide kit if you fall off the roof, and medicine to get better when you are sick.

*Scott: Okay, good. So I notice that every group is basically **thinking about what we need as human beings to survive.** There was a lot of groups that said nonperishable food items, clean drinking water, first aid kit and medical supplies such as pills and things that we would need, okay and **there is one other thing that we need as human beings that too often people forget about, okay. We need entertainment, we need something to keep our mind busy or we go crazy,** seriously, imagine being stranded on a roof all by yourself, even if you have food and water to help you survive, you can't move off the roof, you have nothing to do, no one to talk to, nothing to entertain you, image being like that for 20 days, okay. It gets to you.* (Class discussion, May 14, 2003).

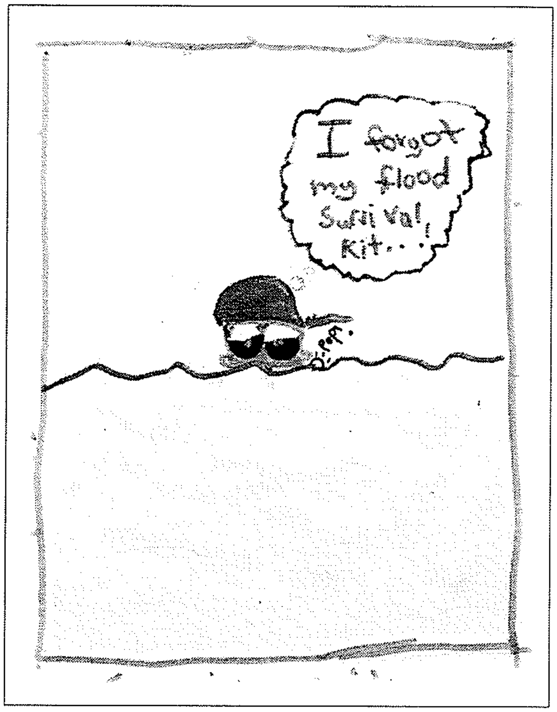
As indicated by Scott, the items selected by the students could be grouped into two different categories. One group of students decided to select items that will help them survive until someone comes and rescues them. The items selected by this group included nonperishable food items, clean drinking water, first aid kit, clothes, shelter, and medical supplies. The other group of students thought more along the lines of drawing attention to get help and to be rescued. Their choice of items included flashlights, matches and red blankets, which are required to send signals to the rescuers. Scott added one more important item to the list by saying, " something to keep our mind busy or we go crazy."

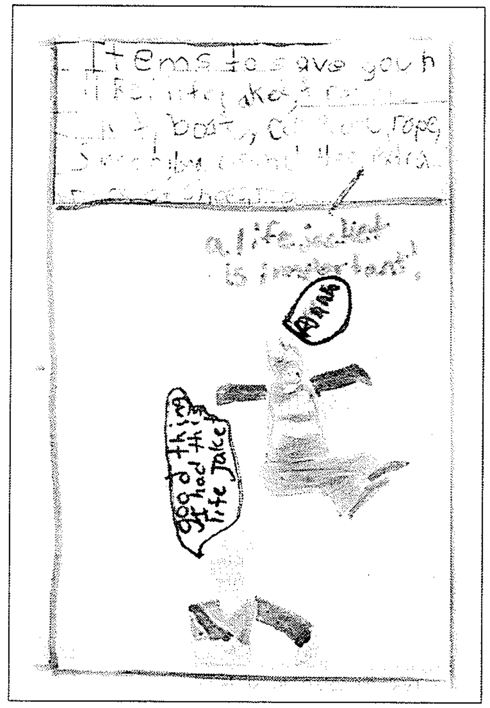
Another important goal of the STSE education is to empower the students to take action when it comes to a particular societal issue. Such action could be done through: education, letters and petition writing, posters, brochures, etc. (Ebenezer & Connor, 1998). Our students decided to choose posters and letters for this purpose. Their group project was to create a flood-warning poster to inform the rest of the students in school about the dangers of floods. And they posted their work on the walls around the school. Scott suggested that their posters should warn of the danger the floods could do to people and their property, as well as provide necessary information on how to get prepared in case of a possible flood. An example of one of the students' posters is given below, in Figure 5.1. The whole view of the poster is followed by isolated images from this poster.

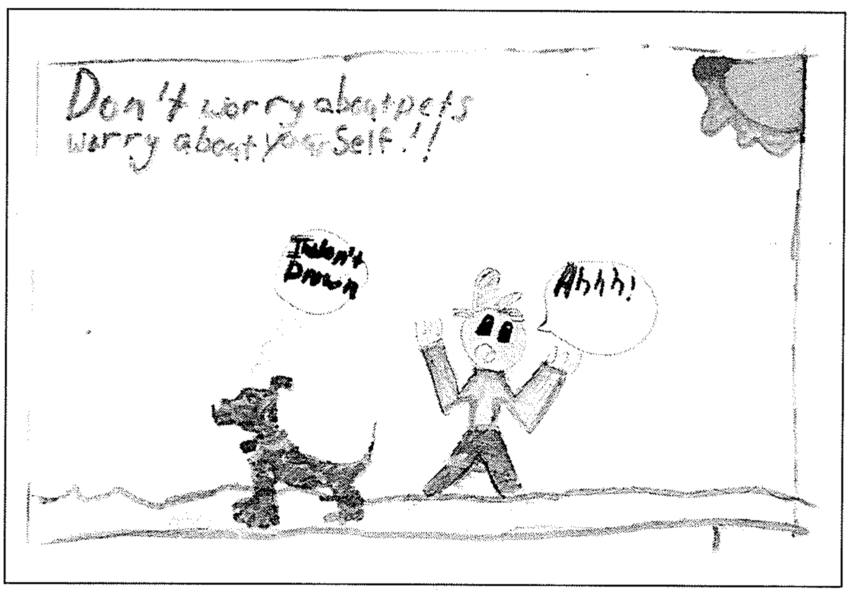
Figure 5.1. Flood warning poster.



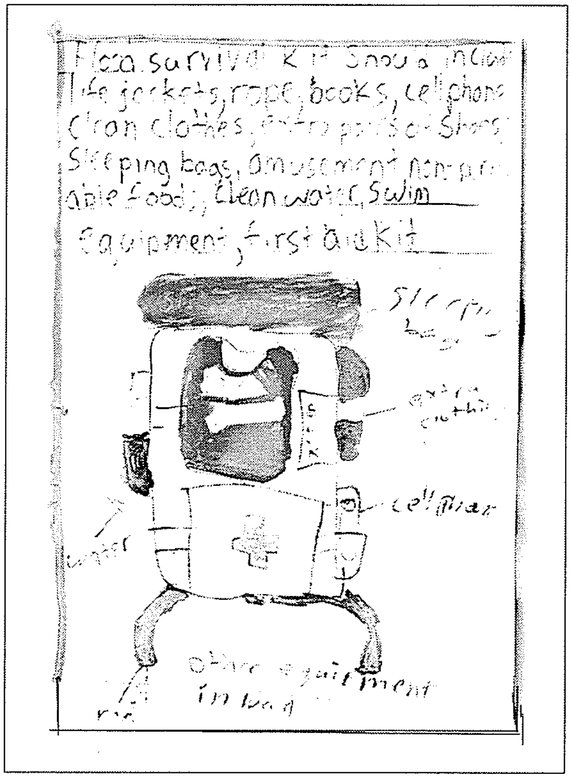

Wait for rescuers!
Over here!
help!
Look how much damage a flood can give!
Always come prepared when a flood comes!
Stay in high places!


I forgot my flood Survival Kit..!


Items to save your
a life jacket is important!
good thing I had the life jacket


Don't worry about pets
worry about yourSelf!!
I don't Drown
Ahhh!


Don't panic when a flood comes!
Ahhh!
stop it!
Build your dike when the flood comes!
Be careful not to drown!
Blub Blub
Blub Blub
Surviver Kit items
first aid Kit, lifejackets
rope, books, cellphone
Clean clothes, extra pair of
sheos, sleeping bag,
none perishable food, clean water
Swim equipment,



In addition to the posters, each student was asked to share his/her knowledge about floods with others in the community. The students chose to write a letter to a student in another class or to a staff member. In that letter, they wrote about the dangers of flooding, when to expect such flooding in Manitoba, why people need to be on the look out for the floods, and how to be prepared at home for any possible flooding. Note the following excerpt from a letter written by Rose:

> *Dear Grade One,*
>
> *I am writing to you about floods. We have to look out for floods in our city, because it is located between the Red River Valley and if it rains too much, the river will get overflowed, and it can create a flood...One of the dangers of floods is floods can wreck homes, and people can loose their homes, belongings, and even pets. We can prepare for a possible flood at home by having a flood survival kit. Some of the items that should be in a flood survival pack are: non-perishable*

food, first aid kit, a big bottle of clean water, clothes, inflammable mattress, and other items.

Throughout our study of floods, the students had a chance to observe and probably develop the principles of sustainable living such as stewardship and global responsibility, or as one of the students put it, "good sportsmanship." The students were able to witness good sportsmanship in three different ways. Firstly, it was through the documentary video on the flood that happened in 1997. Secondly, Scott told them about this flood, and how he personally attempted to help in saving the city during that period. He was in grade twelve at that time and he took active part in the sandbagging and, thus, helped saving the city from the floods. The story of his involvement, which he shared with us, truly made a great impact on the students.

Lastly, the students interviewed their parents to find out how they were involved in saving the city of Winnipeg and how the flood of 1997 affected their lives. Parental involvement indicated responsibility for local issues.

5.5 Chapter Summary

In this chapter, I reported how Scott presented the NOS through the first three phases of the CKCM. His determination to eliminate the stereotypical image of scientists from the students' minds displayed how truly he desired his students to have a clear picture of science and scientists. He clearly presented what scientists do and how they conduct their investigations. In his portrayal of the scientists, Scott made sure to point out that scientists are neither magicians nor dogmatic people with absolute answers. Instead, he frankly acknowledged that scientists might not have answers to all the questions. In other words, his teaching approach contradicted the very many claims that predominantly promoted an authoritarian view of the community of science. Further, at the weather office, Mr. Jason Anderson's acknowledgment of not having "a cut and dry solutions to all the questions" reinforced what Scott tried to instill in the students' minds. The students also had a chance to learn that the scientific knowledge is limited. In this curricular unit, the students realized that the weather is constantly changing and not even the scientists with their powerful and modernized instruments could accurately predict the weather all the times. Furthermore, Scott made is clear to the students that scientists have investigative minds, look at their work critically, frame questions, and propose solutions.

Also, by organizing a field trip to the weather office, Scott gave the students an opportunity to meet some scientists there and to see what they do at work. As a result, Scott enhanced the curiosity of the students and opened the possibility of them pursuing scientific careers in the future. Seeing the female meteorologist at work amidst high-tech instruments surely must have instilled a desire in the female students to consider a career in science in the future. Thus, Scott's teaching approach demonstrated that he tried to teach according to the principles of multicultural science education. This type of education requires the teachers to look for appropriate resources, which would promote science education of all students regardless of their sex and ethnic background (CMEC, 1997, NSTA, 1991). In this situation, by choosing to use that particular book, Scott suggested that female students have equal opportunities of achieving well in science and furthermore pursuing science careers in the future.

In the last 35 years, it is reported, not much progress has been made toward achieving equity in science education. For example, Hewson et al. (2001) report that differences continue to exist in the access, retention and achievement of students depending on their culture, gender, race, and/or socioeconomic status. Dale Baker in an article in the October 2002 issue of the *Journal of Research in Science Teaching* poses a question, "Where is Gender and Equity in Science Education?" To answer this question, she reviewed articles that appeared in the *Journal of Research in Science Teaching,* starting from the first article, which was published in 1971. In summary, Baker hopes that the new century brings a broader awareness of the importance of gender and equity, and she leaves it up to the reader to answer the question, "Where are gender and equity in science education?"

It was such a pleasure to see Scott, a beginning teacher with a right disposition toward equity in science education. Scott's good attitude toward equity in science is very valuable considering the age group he was teaching. I particularly emphasize the age, because research has shown that most students around this age have a tendency to either develop an interest in science or shy away from the subject. For example, in the 80's, many researchers reported that in the middle school, female students begin to have negative attitudes toward science. Obviously, such a negative attitude prevents them to seek any scientific careers or to see them as scientists in the future (Fennema & Peterson, 1986; Grant, 1983, Kahle & Lakes, 1983; Meece,. 1984; among others). Similar claims were also made more recently. For example, in 2003, Jayaratne, Thomas, and Trautmann cited Andreman and Maehr (1994), Eccles (1997) and U.S. Department of Education (1998) reported that in the middle schools, or at the beginning of junior high schools, girls' perception of their abilities begins to decline (more than that of boys). Consequently, they tend to express little interest in science. Since this is the time they are faced with various choices in the curriculum, they struggle to choose or not to choose science subjects in the middle school.

Once in high school, the segregation becomes even more obvious and the girls do not see themselves as being the "scientists" type (Carlone, 2004). It is particularly evident in the so-called hard science subjects, such as physics and chemistry (Carlone, 2003; Haussler & Hoffmann, 2002). Schulenberg, Goldstain, and Vondracek (1991) explain that potential recruits may believe that a successful scientist must be a genius, enjoy working alone, and have a limited kind of social life and they do not want to choose this lifestyle.

Scott also made sure that his students understood the processes involved in the construction of scientific knowledge. He mentioned to the students that through their investigations of weather, they have learned to "become better scientists." This training process to become better scientists was mostly evident in the way the lessons were structured. Scott provided many opportunities for the students to share their ideas with others as well as respect the ideas proposed by others. Certainly it gave a chance for the students to understand the concept of sharing and collaboration among scientists.

Furthermore, Scott helped the students understand that scientific knowledge is used to investigate and offer plausible solutions to solve societal and environmental issues in today's world.

Chapter 6

Assessment of Scientific Literacy Development

6.1 Introduction

Chapter six focuses on Reflecting and Assessing, the fourth phase of the CKCM. The purpose of this phase of the model, in line with the *National Standards*, is to provide feedback to teachers, so that they could make necessary adjustments in their teaching, and to allow students to assess for themselves, how well they are meeting the expectations of the teachers (NRC, 1996). In line with these two *National Standards* on assessment, Chapter six first presents Scott's reflections on his teaching of science that focused on developing scientific literacy. Following which students' development in scientific literacy is presented.

Through my on-going conversations with Scott, I was able to gather his reflective thoughts on our efforts to develop scientific literacy of his students. Through various methods, I was able to assess students' development of scientific literacy in terms of the three notions ("what," "how," and "why") presented in the first chapter. To assess students' understandings of the "what" of science, I evaluate their knowledge of the principles and concepts of weather, outlined in the *Manitoba Curriculum Framework of Outcomes* as well as their ability to use that knowledge in out of classroom contexts. To assess students' understandings of the "how" of science, I evaluate their understandings of the NOS. And, to assess students' understandings of the "why" of science, I evaluate their ability in making the science, technology, society, and environment connections.

The evaluation of students' understandings of "what," "how," and "why" of science is based on my conversations with Scott and his students, selected pieces of students' written work, students' conversations with others, and selected questions of the performance-based and written tests. The test items I analyzed correspond to the lessons I presented in Chapter five. In presenting the assessment conversations, I highlight, in bold letters, the worthwhile expressions in each excerpt, and then provide interpretations of these expressions below each excerpt.

6.2 Scott's Reflections on Scientific Literacy Development

Many authors postulate that reflective approach should be an integral part of every teacher's classroom practice (Abell & Bryan, 1997; Clift, Houston, & Pugach, 1992; Shepard, 2000; Zeichner, 1999; among others). A "good teacher" is a reflective teacher, one who inquires into his or her thinking and practice with an eye toward making improvements (Zeichner, 1999). Teachers need to reflect on their work, look at their aims in relation to the outcomes, be open-minded about children's potential and make judgments about whether the activities of a particular lesson or series of lessons were the best possible ways of helping children learn (Shepard, 2000).

Ebenezer and Connor (1998) incorporated the Reflecting and Assessing phase into the CKCM to stress the importance of reflective practice in science education, and to encourage teachers to critically evaluate their teaching. These authors claim that professional growth both in pre-service and in-service education can be achieved through the adoption of responsibility for one's own actions and through the analysis and critical evaluation of one's own practice. There are different methods of reflective practice. These methods include action research (Cornett, 1995; Zellermayer, 1990), case studies (Wallace & Louden, 1992), portfolio generation (Barton & Collins, 1993; Peterson & Peterson, 1991; Wade & Yarbrough, 1996), personal journal writing (Bolin, 1988; Holly, 1989), dialogue journal writing (Zulich, 1992), research (Cochran-Smith & Lytle, 1999), and reflecting with the "other" on electronic platform (Ebenezer, Lugo, Biernacka, & Puvirajah, 2003).

As Scott's science educator, I encouraged reflective practice in his methods course in the form of journal writing. And, when I collaborated with him during this research project, I wanted him to reflect upon his practice. This time, however, I chose face-to-face dialogue as a preferred method of reflective practice. Through my continuing conversations with Scott, I desired to find out what he thought about our efforts to develop scientific literacy of his students. By talking to Scott, I have moved away from this individualistic notion of reflection, and I have shown him that reflective practice can also be mediated and enhanced by others, which I think, is important for beginning teachers. Furthermore, I hope, that by conversing with him I encouraged him to start a journey as a reflective science teacher. Consider the following conversation:

Conversation Excerpt # 6.1: Teacher-Researcher Conversation

Beata: What about ***our major goal, which is development of scientific literacy.*** *Are we doing it, according to your understanding?*

Scott: *I think* ***we are doing a great job. I think the kids are really picking up a lot****, in fact I don't know if I told you that the other day that I asked the students, how they thought their learning was going...*

Beata: *Um-hmm.*

Scott: *Informally.*

Beata: *Yeah.*

Scott: *I didn't ask them to write anything down.*

Beata: *Yeah.*

Scott: *How they thought their* ***learning was compared to how it normally is, how they are enjoying it compared to what it normally is****. And I said if, you know this isn't an indication whether you like me better or whether you like the other teacher better I said how do you feel about science on the whole, they raised their hands,* ***most of them raised their hands saying that they, that they were learning a lot more.***

Beata: *Um-hmm.*

Scott: *Two kids learned, actually I did tell you this before. Yeah. Two kids raised their hands and said ...but they learned the same.*

Beata: ***It does not matter if they are learning more or less. What I want to know is whether they are learning in the mode of the NOS, whether they are really understanding the true NOS.***

Scott: ***I think they are because we are presenting it that way to them.***

Beata: *Ok.*

Scott: ***Everything that I do in the classroom is through the NOS*** *and that's what I'm trying to bring ... for example you brought up the situation with Peter, asking that question, and* ***me telling them tat I don't have all the answers.***

Beata: *Um-hmm.*

Scott: *And* ***that's true, scientists do not have all the answers****. Another thing, Jason Anderson said that as scientist, we don't know for sure, we don't have all the answers; we are researching to find out.* ***The very process that we are doing, the design process, researching is the NOS.***

Beata: *Um-hmm.*

Scott: ***Plotting, reviewing, constructing and then evaluating.***

Beata: *Evaluating.*

Scott: ***The whole process that we are following and everything that we are doing is the NOS.***

Beata: *Hmm.*

Scott: *And we are* ***trying to teach that indirectly.***

Beata: *Yeah.*

Scott: ***You can directly teach the NOS****. You know you can directly teach the NOS* ***in a university course.***

Beata: *Why?*

Scott: ***But you can't with kids, it something that it needs to be acquired through experience.***

Beata: *Now, do you think that they are developing scientific literacy?*

Scott: ***I think that they are developing it a lot further than they wouldn't have they been using the model.***

Beata: *Ok, why do you think that?*

Scott: ***Because my kids have the tendency to learn everything just that what's on the surface.***

Beata: *Um-hmm.*

Scott: *For example when we do a, like math, right now they are having a test on shapes.*

Beata: *Um-hmm.*

Scott: *Geometric shapes, 2-D, and 3-D solids, and things like that so, they can learn but it looks like, they can learn what the name is, but if you ask them to you know, to describe and see the shape in the world, or you ask them about to manipulate the shape or to be creative and use the shape in a certain way, they would have a difficulty doing that.*

Beata: *They do?*

Scott: *Yeah, it's the abstract concept that they don't get, and to be mathematically literate with the sense to 2-D, 3-D solid and geometric shapes ...they wouldn't be able to do this type of thing.*

Beata: *Um-hmm.*

Scott: ***So, normally my kids tend to learn things on the surface, what they need to get by on the test. Right?***

Beata: *Ok.*

Scott: ***So, and you see that in your assessment, because we assess not just for the surface stuff but also for the you know, abstract thinking and the abstract concepts that they need to understand to be fully literate...***

Beata: *Um-hmm.*

Scott: ***In that...so I mean generally they tend to pick up just the surface stuff, but for some reason, common knowledge construction model, this kids are really understanding and internalizing the stuff that we are teaching them about weather. Withstanding a few selective people ...who no matter what method you use are not gonna get it.***

Beata: *Um-hmm.*

Scott: *That she's got it, you know she understands, so... Not only that but who, Matthew the other day, who,* ***but he is usually right on the surface kind of person, he'll get everything on the surface abstract concepts forget it.***

Beata: *Um-hmm.*

Scott: ***And we were standing at the back there, what is that called, "Anemometer" and he could tell me right away, and what is used for, " measuring wind speed", but the thing is though you could tell this kids that that's an anemometer but for them to understand how it works is an accomplishment.***

Beata: *Um-hmm.*

Scott: ***And for them to understand you know, what it's measuring, that's definitively beneath the surface,*** *and they can do that.*

Beata: *I noticed that, I noticed that, that they are so enthusiastic and that they all use it to try and ...*

Scott: *I'd say right now* ***I would consider my kids semi literate, with respect to weather.***

Beata: *Um-hmm.*

Scott: ***The only reason why I say semi is because we have not yet covered how they actually go and take the information and apply it by themselves. They will know it when they start plotting their own data and report.*** *And, analyze it so right now do they understand how we measure and predict weather? Yes they do.*

Beata: *Yeah.*

Scott: *They understand how the two of these, and things like that.* ***We have also covered umm, the fact that weather affect us in our daily lives and they have shown me that they understand that through, through, you know the kids coming and telling me, "Yeah I checked the weather forecast, that's why I'm wearing my shorts", and thing like that...***

Beata: *Um-hmm.*

Scott: ***So we have done a good job so far, through the model, of letting the students internalize this and make it their own, it's something that they can now use in their lives.*** (Teacher-Researcher Conversation, April 25, 2003).

In the foregoing conversation, I ask Scott about his views on our efforts to develop scientific literacy in the students. He seems to be satisfied with our method, for he tells me that "we are doing a great job." However, at this point, Scott tends to focus mainly on the students' achievement of learning the concepts and principles. According to Bereiter and Scardamalia (1987) this would be classified as low literacy and Hazen and Trefil (1991) would see this as the ability to "do" science. We should strive to develop high literacy in students by building their capacity to apply scientific knowledge to everyday life problems that they might encounter.

Scott also seems to associate the development of scientific literacy with enjoyment. He even tells me about an informal survey, which he did to check whether the students were enjoying what they did in class. Through that survey, he specifically expected to find out whether the students were learning more, less or the same, in comparison to the previous units studied that year. Scott mentions that when he questioned the students, most of them raised their hands to say that they were learning a lot more in this unit. Only two kids said that they were learning the same.

Since I was more interested in a high literacy level, I explain to Scott that students' enjoyment of doing the study is not as important as their understanding of science. When I ask his opinion on this matter, he reassures me that everything that the students do in the class relates to the NOS. He, then, talks about the contemporary image of the scientist he tried to present and how, through examples, he made it clear to the students that they can't expect the scientists to have all the answers. Then, he goes on to say, "The whole process that we are following and everything that we are doing is the NOS." He includes research and design into this scientific process. He points out that we are trying to teach science "indirectly."

According to Scott, the NOS could be taught directly in a university course, but not in a grade five classroom. At this age, he says, the students can only acquire the understanding "through experience." His statement indicates that Scott believes in an implicit, rather than explicit approach to teaching NOS. Some researchers would disagree with Scott in this regard. For example, Abd-El-Khalick et al. (1998) and Driver et al. (1999) believe that explicit approach is more effective in helping learners achieve adequate understandings of the NOS. These authors, as well as Lederman et al., 2001 claim that this understanding should not come as a by-product of teaching science.

As the conversations continue, Scott acclaims the CKCM for the students' scientific literacy development. Curious to know what made him think so, I ask him to explain why he believes that the model helps the students with the scientific literacy development. At first, he talks about his students' learning habits. Then he tells me about his students having a "tendency to learn everything superficially." It means that the students are capable of memorizing certain concepts, but, they are unable to apply them into other situations. To illustrate his point, he explains how the students tend to be good at learning the geometric shapes of objects and memorizing their names, but they are not so good at being creative or use the shape in a certain way. In other words, he means that the students have difficulties with abstract thinking. He claims that the CKCM, on the other hand, helps his students "understand and internalize the stuff that we are teaching them about weather."

At this point of the study, Scott considers the students to be "semi literate" in regard to the study of weather. He thinks that the students did not have enough opportunities to "take the information and apply it by themselves." According to him, when the students start using the instruments to measure the weather, and use the data to make the weather report for the school, they will get the opportunity to apply the information. However, Scott says that he is pleased to see his students making the connections between science and their daily lives. For example, he says that the students usually tell him that they choose to wear shorts to school, if the weather report predicted a warm and sunny day. Scott affirms me that the CKCM has helped him do a good job in "helping students internalize the information" and to be used later in their lives.

Scott's conclusion suggests that the students are trying to assimilate what they have studied (concepts, principles, and theories) into their everyday life. The student telling, "Yeah I checked the weather forecast, that's why I'm wearing my shorts," is an evidence of that, states Scott. The fact that the students watch the weather channel before making a decision about what to wear, confirms that they are trying to practice what they have learned in class. One can only hope that the students will continue to do so in the future too. In other words, the students have developed the ability to use science, without formal instruction (Aron, 1983).

Whenever I had an opportunity, I asked Scott about the students' overall progress. When I talked to him about it shortly after our study on folklore, he sounded very pleased. He told me that ever since we started the study, he had noticed a difference in children's attitude towards science and learning. He was happy to point out that even the students who showed no interest in school-work or were weak in their studies, started to exhibit interest and enthusiasm towards learning now. For the first time, the students were able to take science out of the classroom and apply it to their daily lives. In the following conversation, Scott gives an example of one such student.

Conversation Excerpt # 6.2: Teacher-Researcher Conversation

Scott: *I was just going to say that, ummm, I've had a few incidents where the kids take it beyond where the teachers is in class, like it was Joey this morning who started crying to me really about covering enough ground because he is not the brightest kid academically, he doesn't do very much* *work,* ***but once in a while he says something maybe he was really paying attention.***

Beata: *Did he say anything related to weather?*

Scott: *Yeah because yesterday it was related to it, yesterday we had an assembly.*

Beata: *Yes.*

Scott: *And I,* ***there was a little spider crawling across the floor and I stepped on it, and today when it started raining he came to me and said remember when you stepped on the spider yesterday, did that made it rain.*** *I said Oh, I said really, he goes yeah,* ***that's weather folklore,*** *he said.*

Beata: *Really?*

Scott: *Ya.*

Beata: *That's great.*

Scott: *And* ***it has nothing to do with aptitude either,*** *he reads at a grade five level, and he is in grade four.*

Beata: *Um-hmmm* (Teacher-Researcher Conversation, April 18, 2003).

In this excerpt Scott talks about Joey, who hardly showed interest in any of the subjects from the beginning of the year. Surprisingly, during the study of weather, he started to pay attention in class. Once, he noticed Scott accidentally stepping on a spider that was crawling on the floor. When it rained the next day, Joey connected the spider squashing incident with the rain, and told Scott that it was probably raining, because Scott stepped on the spider on the previous day. "That is weather folklore," proclaimed Joey. Scott also told me about Charity, who showed immense interest in the study of this unit. She shared with Scott, how she enjoyed watching a girl dancing in an Aboriginal program on the television. According to Charity, the girl looked very strong and powerful when she was dancing. In her words," as if she had a little man living inside her and dictating her all the moves." It is interesting how Charity associated this little strong man with Chakapish, a character in the Aboriginal legend, which Mr. Birdie told us when he visited our class. This legend could be read in Appendix D.

The above two examples illustrate how we were able to motivate students' interest in science and help them develop a positive attitude towards the subject. I hope our efforts and intention would result in producing independent and enthusiastic learners of science, who do not completely rely on the formal instruction of the subject.

6.3. The Development of "What", "How", and "Why" of Science

In this section, I provide evidence of students' development of the "what," "how," and "why" of science.

6.3.1 The Development of "What" of Science

To assess students' understandings of the "what" of science, the understanding of concepts, principles, and theories related to weather, I analyze: student-researcher interviews, station-to-station test, written unit test, selected items of students' written work, students' weather report, and students' conversations with others.

6.3.1.1 Students-Researcher Interviews

On April 21, 2003, two weeks into the study of the unit on Weather, I conducted a group interview with students - Rose, Bonny, Ian, Dorothy, Timothy, Nick and Shane. The purpose of this interview was to find out how closely they paid attention to the subject and their analysis of it. I was also curious to know if they could assess their own progress. So, I asked them to compare their pre-instructional views with the current ones. I requested them to compare the statement they had written in their notebooks on the first day of the lesson, with their present understanding of the subject. Consider the following conversation related to the question, how do you think people predict weather?

Conversation Excerpt # 6.3: Researcher's Interview with a Group of Students

Beata: *Now, I would like you to turn the pages in your book into the first page and look at what you wrote. Then, I would like you to tell me if your thinking has changed now.*

Beata: *Dorothy, what did you say about predicting weather?*

Dorothy: *I said that people go out and look at the weather,* ***I actually said that they drive a car and predict how it would be in a day or two.*** *My reason was that I did not know, because nobody has told me, so I just guessed.*

Beata: *And, what would you say now if I had asked you this question?*

Dorothy: ***That they use computer, radar, but not by car.***

Beata: *But,* ***did you really mean that they use a car to do that or did you mean that they observe?***

Dorothy: *They can go outside and look.*

Beata: *What about you Ian?*

Ian: *I said that they* ***predict by looking what the weather is like in other places****.*

Beata: *Were you correct?*

Ian: ***Yes and no****. Yes because* ***Mr. Brown drew us a map and showed that the weather is moving, and Mr. Stern also said that.***

Beata: *Would you say the same thing now after studying the weather with Mr. Brown in your science lessons?*

Ian: ***Yes. I thought about that because I saw on T.V. that people predict in the same way for other things****, for example waves.*

Beata: *Shane: What did you say?*

Shane: *People* ***look at moisture, because if there is moisture in the sea, it goes to the clouds and there is rain.*** *And, I know because people tell me, like my brother did it for his science fair project.*

Beata: *If I had asked you now, how people predict weather, would you say?*

Shawn: ***I would say the same thing. Moisture always goes into the clouds.***

Beata: ***Are there any other ways of predicting the weather.***

Shane: *Yes,* ***there are also satellites and computers.***

Beata: *Rose, what did you say?*

Rose: ***That they use big satellite system. And, I was right except that I did not say that the satellite is in outer space.***

Dorothy: ***So now you know.***

Rose: *Yes.* (Students- Researcher Interview, April 21, 2003).

The above conversation shows that the students are able to acknowledge their prior conceptions of predicting the weather. During our exploration activity, Dorothy had written, "people drive a car and predict how it would be in a day or two." And, she admits that she had come to realize people use computer and radar to predict weather, but, not a car. Later, she agrees that a car could be just a vehicle of transport for observation purposes. Ian wrote, "they predict the weather by looking what the weather is like in other places." He claims to be right in his view, because the map Mr. Brown (Scott) drew showed the movements of the weather. He also points out that Mr. Stern, the TV weather anchor who visited our classroom, also talked about the movements of the weather *(see Conversation Excerpt # 5.13)* and so did Mr. Anderson, when we visited the Environment Canada Weather Office.

Shane sticks to his original view of looking at the moisture content in the clouds for predicting the weather. According to him, "the moisture always goes into the clouds." But, he is also aware of the fact that satellites and computers are being used for the purpose. Rose's perception seems to be right from the beginning, for she knew on the first day itself that a big satellite system being used for predicting the weather. But she agrees that she did not mention earlier about the satellite being in an outer space.

To assess students' understanding of the topic, I put forth the following questions at the end of our conversation: 1) What have you learned that you did not know before? 2) Why is weather important to people? 3) What kind of occupations rely on weather? The students' answers, written verbatim, are presented in the following table.

Table 6.1 Students' responses to researcher's questions about weather.

Student's Name	What have you learned that you did not know before?	Why is weather important to people?	What kinds of occupations rely on weather?
Bonny	I learned that the wind always moves from high pressure to low pressure.	I am not sure.	The meteorologists
Rose	I learned a lot at the weather office.	Rose: Because they can plan ahead of time. Beata: What do they plan ahead of time? Rose: Like if they are going somewhere, like to the beach.	Beata: What about people other than meteorologists? Rose: It is important to farmers. Beata: Why: Rose: Because if they know the weather, and they want to plant something, they can do it before it is going to rain.
Timothy	Tim: I learn about that laser thing that shoots to the sky. Beata: What is the name of that thing? Tim: Radar.	People can plan ahead, if they know what the weather is going to be like?	Tim: The army. Beata: In what sense? Tim: So they can look at the weather and if it is sunny, they can prepare and take their stuff. Yes, because if it is like foggy they can go for ambushing and if it is stormy, they would go to the bankers.

Ian	I learned that air has friction.	They can plan what to do.	People who work on air planes, like pilots.
Dorothy	I learned how to protect myself from tornadoes.	Because when people would like to go for a picnic or something and they find out that it is going to rain, they can change their mind. Or, if there is tornado coming their way, they could be warn and prepare themselves.	I know who needs to be aware of the weather! Like the people who work at camps, like those boys camps. Like the teachers there. Because they might be on a field trip and they might find out that the storm is coming so they would need to find shelter.
Shane	About the instruments, like anemometer and barometer and stuff. I only knew about the thermometer.	I do not know.	Shane: Like people who look for bears. Beata: Are there people who specifically look for bears? Shane: Ya. Beata: And do you know what their name is? Shane: Like a vet. Beata: Kind of. A veterinarian is like an animal doctor. If the animal is sick, it is taken to be seen by a veterinarian. But, have you heard about zoologist or ecologists. Their work might actually involve tracking animals. Shane: Like my uncle needs to go to Alabama or something, but, he

			does not want to go because of SARS. Beata: But, SARS does not have anything to do with the weather. Shane: But he will have to drive there with a track and if it is raining, he will not go. Beata: O, if he wants to drive there, the weather is very important, yes.
Nick	That air has mass. It was my favorite thing.	They can plan what to do.	Maybe people who do not have a car and ride their bike to work.

From the above Table, it is evident that the students realized that they were learning a lot of new information. Bonny acknowledges that the wind moves only from high pressure to low pressure, and Ian speaks about air having friction. Rose agrees that she has gathered a lot of information at the weather office. Timothy mentions about the radar, and Dorothy proudly tells that she has learned how to protect herself from tornadoes. Nick states he has learned about air friction, while Shane admits that instead of knowing about just one instrument, the thermometer, he has come to know about various weather other instruments.

In regard to the question, "Why is weather important to people?" the students replied unanimously that knowing the weather forecast is important to people, because it helps them to plan their activities ahead of time, and to protect them from severe weather conditions, tornadoes, for example. The students were enthusiastic, when it came to listing the occupations that rely on weather. As shown in Table 6.1 (above), Bonny mentions that weather is important to meteorologists, which was somewhat a logical conclusion at this stage of our investigations. Since I was more interested in finding out the student's ability to translate his/her acquired knowledge to contexts other than meteorology, I ask Rose (see last column of the above table) to think of people other than meteorologists. It is interesting that she names the farmers, whose activities are more or less dictated by the weather. In a way, her answer sounds correct at this point. When Timothy talks about the army, I ask him to clarify his answer, so that others could understand his reasoning for choosing the army. So, he explains that the army would get inside the bunkers if they foresee a storm coming, but they could take off their "stuff" on fair and sunny weather. Ian, whose answers were always laconic, says that weather is important to "people who work on air planes, like pilots." Dorothy seems to see the matter in a different way, for she enthusiastically blurts out, "I know who needs to be aware of the weather!" And she mentions that the teachers, especially those who work at camp, rely a lot on the weather for planning out their activities. It is quite unclear; when Shane answers that the weather is important to those who look for bears. Unable to guess whether he means the ecologists or the zoologists, I ask him whether he could name the people who look for bears. When I learn that he refers to a vet, I feel that I need to explain to him that a veterinarian is an animal doctor, and then inquire whether he has heard of zoologists or ecologists before. But, Shane quickly changes the topic and starts talking about his uncle, who does not want to go to Alabama because of SARS. I considered this information irrelevant and try to tell him so. But, he explains that if it is raining, his uncle will be reluctant to drive his truck all the way to Alabama. Well, I must admit that I had to agree with Shane in this case. And, when Nick points out that the weather is important to people who do not have a car, but ride their bike to work, I had to agree with him too.

6.3.1.2 Station-to-station Test

Our students wrote the station-to-station test on May 5, 2003, after they had finished studying the major part of the unit. The test consisted of 15 items. With their test booklets in their hands, the students circulated among the 15 performance-based stations, which Scott and I had set up in the school gym. Because of the time constraints, students needed to move around in groups of five, but once they were at a station, they were given sufficient time to complete the task individually. The goal of this station-to-station test was to give students an opportunity to observe and manipulate objects that were used during our investigations, answer questions related to set-ups, and carry out short investigations.

The policy of the Red River School Division is to introduce tests in grade five, thus, Scott's students were quite used to writing tests. However, they were not familiar with the performance-based type of tests. Since this kind of test is new to them, I was keen to find out about their opinion, and as such I talked to few students after the test. To my relief, they were all positive in their answers and found no problem in answering the questions. As Nick put it, "the test was all that weather stuff they did in class with Mr. Brown." He also told me that one of the reasons why the test was easy is "because we have been doing a lot of demonstrations that helped him learn and we worked hard on everything." Dorothy had totally different reasons for liking the test. She liked the test "because she could move, had a lot of space to write," and, most importantly, "it was harder for the other students to copy from her, since there was nobody sitting right beside her." Ian also liked the fact that he could move among the stations, "somehow his body liked that."

In the following paragraphs, I analyze students' answers to 3 questions of the station-to-station test. I reason that these questions are authentic because they require students to apply their knowledge and reasoning to situations they "encounter in the world outside the classroom, as well as the situations that approximate how scientists do their work" (NRC, 1996, p. 78). In the following paragraphs, I analyze students' answers to these three questions. The rest of the questions of the station-to-station test could be seen in Appendix E.

Question #1

On this webpage, you can see that scientists have taken pictures of weather.

a) What instrument did they use to get these photographs?

b) Look at how the weather is moving in this picture. What kind of weather do you expect here in Winnipeg in the near future?

At this station, we placed the computer, which the students have been using to record the weather information, and write the weather forecast. To answer the question, students needed to demonstrate their skills to: a) use the computer to access the satellite imagery, and b) to analyze the satellite imagery to predict the upcoming weather. This question, not only tests the students knowledge of the satellite as one of the measuring device used by meteorologists to predict the upcoming weather, but, also to test their ability to interpret the information to predict the upcoming weather. The ability to forecast the weather, in turn, reflects the development of scientific literacy in the "what" notion. This notion stresses that scientifically literate students need to develop knowledge of scientific facts, concepts, principles, laws and theories (NRC, 1996) and the ability to use that knowledge in everyday life to make informed decisions (Hazen & Trefil, 1991). In this case, on the bases of satellite imagery, the students were supposed to predict the weather for Winnipeg. Since the imagery showed clear sky, we were looking for a question along those lines. This question reveals to students that there are various sources where they can obtain scientific information. It also emphasizes the need to study science to be informed of consumer facts.

Question #2

Name the weather instrument that you see in the drawing and explain how this instrument works using pictures and words.

At this station, we placed a picture of the radar system. The students needed to: a) identify the instrument shown in the drawing, b) demonstrate their understanding of how this instrument works. This question, thus, tests not only students' ability to recollect the information, they had acquired both in class and on the field trip, but, also to demonstrate their ability to use this information to explain how this instrument works. This question is in line with Hodson's (1993) recommendation to teach not only what we know but, also how we know.

In this question, we were looking for an answer similar to the one given by Jessica, who wrote that "it is radar, which shoots up a laser and when it hits something it sends a signal back saying there is clouds or something coming. If the laser does not come back, the scientists will

know the sky is clear." And, the satisfactory picture to support this answer looked as the one by Ian, shown below:

Question #3

Do you believe in Folklore? Explain why or why not?

As described in Chapter five, in section 5.3.2, we spent a significant amount of time talking about various ways of predicting and measuring weather. We talked about plant, sky, and animal folklore as well as weather related sayings. I noticed, though, that for a long time, the students could not decide whether to believe in folklore or in scientific methods of knowing. For example, during our field trip to the Weather Office, Nick asked Mr. Anderson, the city meteorologist, whether he believes in folklore. Even when Johan Stern, the TV anchor, visited our classroom, he was asked the same question by another student *(See Conversation Excerpt #5.13).* I also noticed that at the beginning of our investigations, the students had a hard time accepting the "the knowledge of their parents' generation" about predicting and measuring the weather. For example, when Dorothy's mother, in *Conversation Excerpt # 5.4* tells her daughter that people can predict weather by the pains and aches in their joints, Dorothy, unable to grasp what her mother was talking about, requests her mother to tell about some professional way of predicting the weather. Emillio and Jessica are also dissatisfied with their parents' ideas about traditional ways of predicting the weather (see *Conversation Excerpts # 5.5 and # 5.6,* respectively), so was Hanna in the *Conversation Excerpt # 6.5.*

For question 3 stated above, we received a variety of answers. A group of students, including Nick, wrote that they "do not believe in folklore because it is just a saying. I just know that it is just not true, it is just an old thing that they say." Another group too declared their disbelief in folklore, but they tried to be specific and support their answers with suitable examples. Rose, for instance, wrote that she does "not believe in folklore because like in animal folklore, a cat might just be stretching instead of cats stretch all the way can predict or measure weather." There were also students, like Jessica, for example, who were undecided and wrote "no and yes, some of it is true and some is not, hard to tell." Only a few students wrote that they "believed in folklore because it is often true." Hanna, was the only one in that group of students, who believed the folklore to be true, and provided an example to support her answer. She wrote that she does believe in folklore "because the saying about ground hog day my grandpa told me it was real and I believe him! Why, I do not have a clue but I just do believe him." It is probably worth mentioning that Hanna was one of those students who, in conversation with her mother *(see Conversation Excerpt # 6.5),* expressed a view that indicates to me that she believes in scientific way of knowing rather than in folklore. She bluntly told her mother that she was not interested in some idea that involved sticking the broom in the snow to see how much it equals.

In the process of analyzing students' answers to the folklore question, many thoughts came to my mind. I realized, at grade 5 level, students mainly rely on the information provided by the teacher. During our study of various ways of predicting and measuring weather, Scott did not provide the students with any definite answers. Instead, he allowed them to make their own interpretations. As a result, some students, who see the teacher as an authority on the subject, were unable to make up their minds. Since the teacher did not provide definite answers, some students based their answers on the opinion of the trustworthy adults, whom they have met during this study. For example, Timothy wrote on the test that he did not believe in any folklore other than "that saying about the red sky." His answer reflects what he had learned from the two meteorologists, Mr. Anderson and Mr. Stern. When we met Mr. Anderson at the Weather Office, he told us that he believes in the "Red sky at night…" and Mr. Stern also said that there is a lot of truth in this particular saying, for it could have some scientific explanation *(see Conversation Excerpt #5.13).*

6.3.1.3 Written Test

The written test, comprising of long answer-type questions, was written after we had finished our investigations on weather. In this section, I analyze the answers to three questions because, I believe, that they are authentic and that they reflect students' ability to use their knowledge of the weather (Hazen & Trefil, 1991). See the rest of the questions of this written test in Appendix F.

<u>Question #1</u>

> *Why do you think that the measurements that we took with our weather instruments were different from those that scientists took?*

This question relates to the lesson on the Design and Evaluation of Weather Instruments, described in Chapter five, section 5.4.1. It reflects students' ability to use their knowledge in analyzing the data and drawing out conclusions. It aligns with science educators' and science education organizations' recommendations that state scientifically literate people should be able to analyze information and draw conclusions (Ebenezer & Connor, 1998; CMEC, 1997; NRC, 1996; Matthews, 1998; among others). The question required the students to speculate the probable reasons for the discrepancies between their measurements and those of the meteorologists. Hence, in line with Hodson's (1993) advice, it motivated the students to explain the discrepancies. Most of the students were able to draw relevant conclusions. Some, like Kathy, for example, explained that the discrepancies occurred because "our instruments were not professional ones, but the instruments that the scientists used were professional." Like Rose, the majority of the students within this category, tried to reason out, "We built our weather instruments out of things like cardboard, pencils, and other things, while the scientists' instruments were made of things we do not have." Some students focused on the design of their instrument and attempted to explain why the device failed to work. For example, Alek, wrote, "The base of the weather vane was too light, and not stable enough to give good readings." Also, he wrote, "Next time he would use a base made of metal, not a paper plate." Zoe's answer was similar to Alek's. She concluded, "Our instruments were not sturdy enough and some of them were not even outside." Because the rain gauge is made of glass, and considered hazardous to young kids, they were allowed to leave the device only once outside.

<u>Question #2</u>

How do floods form and what should people do to prepare for possible flood?

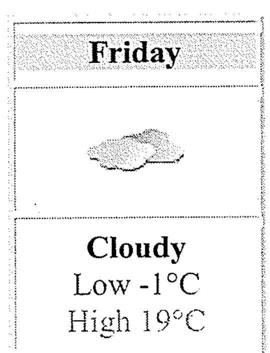
This question relates to our study of floods, which I described in Chapter 5, section 5.4.2. The question consists of two components. The first part requires students to recall the information on flood formation. The second part, on the contrary, requires students to apply their acquired knowledge in science and make informed decisions in their everyday lives. Hence, this question responds to the call of many science educators

(Rutherford & Ahlgren, 1990; Aikenhead, 1997; Lederman & O'Malley, 1990; Zoller & Gross, 2001).

The list of students' recommendations closely paralleled the discussion that took place in class, which I have presented in Chapter five, in section 5.4.2 *(see Class Discussion in Conversation Excerpt # 5.17).* And those recommendations could be grouped into the following three categories: a) gathering items that could increase the chances of personal survival, b) helping others, and c) ensuring future welfare. The list of personal items that the students listed for this question included: first aid kit, cell phone, medicine, water, enough food, emergency bag, boat, sleeping bag. The list of different ways to help others involved: building dikes, sandbagging, putting plastic around their house. Only Peter came up with a suggestion, "People need to get insurance for the future." Peter was the one who mentioned a need to purchase insurance in my interview with him concerning what people need to do to be prepared for.

<u>Question #3</u>

Look for the weather forecast below:



a. *How do you dress for this day? Why?*

b. *What advice would you give to people so that they can plan their day out for this day?*

This question also requires students to use their knowledge to derive informed decisions. At first, we asked students to justify their choice of clothing for any particular type of weather. Then, we asked them to take advantage of their knowledge and advise others about the weather, so that they too could plan their daily activities accordingly. And, Sammy's answer typifies the students' ability to choose proper clothing for any particular weather, for he wrote, "Wear short sleeve shirt and pants, because it might be cloudy in the morning, and then warm up later," Even Sammy's advice of, "Do not make plans too big because it is cloudy and it could rain." gained a mark, for the second part of the question.

6.3.1.4 Selected Items from Students' Written Work

We asked students to document the design process of their weather instrument in the form of a brochure (see a copy of this brochure in Appendix G). In addition to drawing the instrument, and providing the step by step instruction for how to make the instrument, they were asked to give a detailed description of the group effort and how the instrument measures weather. In this assignment, students were expected to demonstrate their capability of seeing the practical use of their knowledge. Many students wrote good essays, describing how the particular instrument worked. Kristofer's description of the weather vane clearly indicates that he understood how his instrument worked. And, he was able to justify his choice of materials too. Consider the following fragment from Kristofer' essay (written verbatim):

> *"Our instrument is called the weather vane, it spins around, and if it points on north the wind is coming from north. We used cardboard for the tail, and the front arrow because paper would be to light …."*

To get a feel for the type of explanation we were looking for (the whole essay is included in Appendix G). After students designed their instruments and used them to measure weather for two weeks, I talked to them to find out how they would improve their design. Consider the following conversation with Kristofer and Rose:

Conversation Excerpt # 6.4: Students'-Researcher Conversation

Beata:	*Okay. If you were to design this instrument once again, would you do anything differently?*
Kristofer:	*Uh, maybe try to use metal and stuff instead of plastic and paper and all that.*
Beata:	*Oh, is that right, metal instead of plastic and paper.* ***Metal for what?***
Kristofer:	*For the stand part and the part where it holds the arrow and the tail.*
Beata:	*Uh hm.*
Kristofer:	*And then the bottom of (inaudible) probably put like cardboard or something, so it doesn't break as easily.*
Beata:	*How would you improve the instrument you built?*
Rose:	*I think* ***we would use like something like we would put some weight on it, and we would put some heavy things on it so it would be more accurate.***
Beata:	*Uh hm. We would put some heavy things on it –* ***where exactly would you put it on that anemometer?***

Rose: *Like the anemometer* ***we just used a pencil, so we might use like a metal – a small metal bar instead.*** (Students'- Researcher Conversation, May, 5, 2003).

This conversation reveals that the students not only understood the material, but they also identified their mistakes. In fact, they even come forward to suggest how they would improve their designs. For example, Kristofer says, if he is given another chance to make the weather vane, he would use metal, instead of paper. And Rose tells that if she ever gets a chance to do the anemometer again, she would definitely use some heavier material for it, because the pencil that she used was too light to withstand the impact of the wind.

6.3.1.5 Weather Report

An assignment in this part of our study called for the application of students' knowledge on weather to their day to day living. It specifically required them to make use of the instruments they have designed, to measure the temperature, wind's velocity, its direction, atmospheric pressure, and the various types of cloud formation. For this assignment, the students were required to visit the Environment Canada Website and record the meteorologists' latest report on similar weather conditions. The students also used the website to record the next day's sky conditions as well as its high and low temperature. In addition, they checked the satellite image maps to interpret the upcoming weather. Then, with all the available data in hand, they wrote down the weather report and weather related recommendations. Later they announced their report over the intercom to the entire school. The following weather report (written verbatim), prepared by Tim's group, shows what this assignment was about. As you would notice, the recommendations mostly revolved around what to wear to school, what to do after school, and how to plan the weekend under certain weather condition.

> *Good morning!*
>
> *This is Prairie View School Weather report for April 29, 2003. The sky is sunny and the temperature is currently seven degrees Celsius. The winds are blowing from the west at seven kilometers per hour. We can expect a high of 12 degrees Celsius and a low of minus four degrees Celsius. We do not expect to see rain today. Tomorrow we can expect to see sunny skies with a high of fifteen degrees Celsius and the low of minus four degrees Celsius. Our advice for these weather conditions is that it will be a good day for kite flying. And, also wear shorts and a T-shirt.*

In 1997, Aikenhead reported that scientifically literate individuals should be able to translate their knowledge of concepts, principles, and theories into their everyday life, so that anyone could understand and place news of the day about science in meaningful context. Furthermore, a literate person should be able to continue to learn science throughout their life without formal instruction (Arons, 1983). I believe this assignment addressed the above two recommendations. By writing the weather report, students exhibited their ability to use pertinent instruments to measure the current weather conditions. They also needed to demonstrate their ability to use the computer, and to graph the information on the board. Most importantly, they needed to interpret all the data they have collected by themselves, and those obtained from the computer, to write the weather report and provide the relevant recommendations. In other words, the students needed to use the information to make valuable decisions, and to incorporate science into their daily living. This assignment allowed students to be aware of the accessibility of scientific information to general public, as well as the application of such information in everyday occurrences like, whether we "travel to work, fly a kite, go to the beach, or plan an ambush." Furthermore, as mentioned by Scott in the *Conversation Excerpt # 6.1*, after completing this assignment, students reached a higher literacy level. Before this assignment, they were considered by Scott "semi literate."

6.3.1.6 Students' Conversations with Others

I was glad to notice, on many occasions, that students were making reference to what they have studied in class. For example, when they interviewed their parents or siblings (Chapter five) regarding their views on measuring weather, they seemed to be knowledgeable enough to educate their family on the subject. In *Conversation Excerpt # 5.5*, Jessica corrects her mother by telling, it is not a bucket but a rain gauge, which is used to measure precipitation. In another conversation excerpt (*Conversation Excerpt # 5.6),* we find Emillio educating his mother on the various weather measuring instruments. Emillio does not find his mother's answer satisfactory, when she says," Some people can smell that the rain is coming." So, he asks her whether she meant that the people could sense the moisture in the air. Later in the conversations, when the mother mentions about using a bucket to measure the weather (rain), Emillio corrects her by telling, "That is called the rain gauge." Here, by providing the scientific terms for the instruments, both Jessica and Emillio not only educate their mothers, but they also reveal their interest and knowledge of the subject. However, some students tend to be sarcastic when they heard the responses from their parents during the interview. Consider the following conversation between Hanna and her mother:

Conversation Excerpt # 6.5: Hanna interviewing her mother

Hanna:	*How do you think people measure weather?*
Mother:	*Measure weather, Hm, What do you mean by that?*
Hanna:	*I am not talking about something like sticking the broom in the snow and measuring how much it equals. I am talking about something like how people measure weather with the thermometer. So, I am asking you to tell me what kind of instruments people use to measure weather with.*
Mother:	***Thermometers, barometers****. Just looking outside you can tell what the weather is going to be like, on the computer* ***watching the weather patterns****. That is it.*
Hanna:	*O.K. This is what I wanted to hear. Thank you* (Mother-Student Interview, April 16, 2003).

In this conversation, when Hanna's mother asks her to clarify what she means by her question, Hanna expects her mother to give her the "right answer," she wants specifics. She tells her mother that she is not interested in anything like "sticking the broom in the snow and measuring how much it equals." Hanna is serious, while she talks about the professional instruments people use to measure weather. She is happy when her mother finally mentions the thermometer, barometer, and computer.

Kathy also showed evidence of learning the material when she interviewed her cousin. Consider the following conversation:

Conversation Excerpt # 6.6: Kathy interviewing her cousin

Kathy: *How do you think people predict the weather?*

Cousin: *I think they go* ***outside and feel the weather*** *and they experiment with the big things,* ***like big machines****.*

Kathy: ***Do you think they use big mechanical instruments or home made products?***

Cousin: *I think they use big mechanical instruments.*

Kathy: *Do you have an example?*

Cousin: *I think they use* ***big computer.***

Kathy: *How do you think people measure the weather?*

Cousin: *I think they use a* ***big thermometer*** *and take the temperature.*

Kathy: ***How do you think people use the thermometer? Like what I mean is where they put this thermometer. Do they put it in the air, or grass, or do they leave it somewhere.*** *What do you think?*

Cousin: *I think they just stick it in the air.*

Kathy: *What about measuring the amount of rain?*

Cousin: *I think they have a special* ***instrument*** *that they can use to see how much it has rained.*

Kathy: ***O, it is very good. It is almost like a real thing. I am impressed with you.*** *So do you maybe know how people measure how fast wind is going?*

Cousin: *Well, I think they have a* ***wind tracker*** *and when the wind goes by it takes speed.*

Kathy: *Ok, that is a really good guess. Good imagination* (Student-Cousin Interview, April 18, 2003).

In this conversation, Kathy asks her cousin to give her an example of a weather forecasting instrument. Her request suggests that she is aware of different types of instruments that are used to measure weather. Then, when her cousin tells her that people use thermometers to measure weather, Kathy wants to make sure that her cousin fully understands how thermometers are used. So, Kathy asks her cousin to clarify the answer. Because her cousin is unable to provide specific answers, Kathy avoids questioning her about other weather parameters. Instead, she puts forth the following question: "What about measuring the amount of rain?" I wasn't surprised that Kathy asks about rain, because Kathy's group was in charge of building the rain gauge. When her cousin tells her that a special instrument is used to measure the rain, Kathy looks impressed. She even sounds like an expert on rain gauge, when she says to her cousin, "O.K, it is very good. It is almost like a real thing. I am impressed with you." Later, when Kathy questions about the instrument that measures wind speed, her cousin mentions about a wind tracker, instead of the anemometer we had built and used in class. However, Kathy acknowledges that her cousin has got good imagination.

It was quite evident that group interactions enabled students to gain knowledge and better their understanding of the unit. In the next conversation, Alek, Ian, Dorothy, and Joey discuss the accuracy of a weather instruments - the weather vane. Consider the following conversation:

Conversation Excerpt # 6.7: Group Conversation

Alek: *I think our weather wane* ***is sort of accurate.***

Ian: *But you have to say why. I think that it* ***is not accurate, because they say south west and we said west.***

Dorothy: *O.K. so we have to make a decision.*

Ian: *So what is our decision then, and let's stick to two sentences. I think that our weather wane* ***was not very accurate.***

Alek: *It is* ***actually pretty accurate****, right Joey.*

Ian: *We are pretty accurate?* ***It does not make sense.*** *We* ***can only say that we are pretty accurate because our weather vane is not high up, it is on the ground and theirs is high up.***

Alek: *How do you spell accurate?*

Dorothy: *I will spell it out for you.*

Ian: *What do you have Joey?*

Joey: *I wrote what you said.* ***Pretty accurate because it is on the ground while theirs is high up.***

Scott: *The wind vane measures the wind direction right, Alek, What do you think then, is it accurate or not?*

Student: *Oh, we think that the* ***weather vane was pretty accurate because our weather vane was on the ground and theirs is not, and theirs is like in the air*** (Group Conversation, May 12, 2003).

In this conversation Alek is not sure whether the instrument was accurate or not. Initially he thinks that it is pretty accurate. However, Ian points out to him that it can not be accurate because the meteorologists have estimated the south west direction of the wind, while they said west. Alek is not convinced, so he seeks help from Joey and tries to convince him that their weather vain is pretty accurate. But Joey is not sure either. So, finally Ian decides to agree with Alek, provided they take into consideration the fact that the two instruments were positioned at different levels: their weather vane on the ground, and the meteorologists' vane installed up in the air. At this point, Alek does not respond to Ian's comment. Instead, he asks the spelling for the word," accurate." However, when Scott later asks him for his opinion, Alek recites what he has learned from Ian.

The above discussion reveals how important it is to give opportunities for the students to interact and freely express their views. Curious to know whether the students fully realized the benefits of group discussion, on May 13, 2003, I asked several students what they thought of group work. My conversation with Dorothy reveals how most of the students viewed group discussions:

Conversation Excerpt # 6.8: Student - Researcher Conversation

Beata: *Do you think that group work is important?*

Dorothy: *Uhm, Yes.*

Beata: *Why is that?*

Dorothy: *Uh, because when we – when groups work together then people learn more.*

Beata: *Uh hm.*

Dorothy: ***Like when we did that climate one – the climate and weather, we*** *didn't know which one was which and so we agreed – finally we agreed on some, and some people learned that this one doesn't really in weather and this one goes in climate.*

Beata: *Do you prefer working in groups or do you prefer just working by yourself?*

Dorothy: *Uhm,* ***in groups.***

Beata: *In groups. Why is that?*

Dorothy: *Uhm,* ***because it's a lot more fun and other people get to learn from what you have to say*** (Student-Researcher Conversation, May 13, 2003).

In the above *Conversation Excerpt,* Dorothy suggests that group work is important because people learn more while working in groups. She gives a specific example associated with the class discussion of weather versus climate. During that discussion her group did not always agree whether the given items were related to climate or weather. But, at the end they agreed, and like Alek, in the *Conversation Excerpt # 6.7* above, people learned from each other. Dorothy also says that she prefers working in groups because it is fun and other people could learn from what she had to say.

6.3.2 The Development of the "How" of Science

In Chapter one, I theorized that the "how" notion of scientific literacy refers to students' understandings of the NOS: 1) empirical (based on and/or derived from observations of the natural world), 2) partially based on human inference, imagination and creativity, 3) tentative (subject to change), 4) theory-laden (subjective), 5) socially and culturally embedded, 6) developed through many methods (Abd-El-Khalick & Lederman, 2000; Lederman et al., 2002; Schwartz & Lederman, 2002). In Chapter five, I demonstrated how Scott modeled the NOS through the first three phases of the CKCM. He presented the NOS by painting a sophisticated image of science practitioners, the scientists. In his portrayal of the scientist, Scott made sure to point out that scientists are open minded and creative, and because they do not have answers to all questions, they share their findings with others. Scientific knowledge is thus tentative and limited. Scott also made sure that his students understand the processes of science. Meeting with the two meteorologists, Mr. Anderson and Mr. Stern further reinforced the contemporary image of the scientist, Scott had presented to the class. These two scientists acknowledged their inability to provide all the answers and the necessity of collaborating with others, utilizing many methods, and continually participating in professional development to keep up with the changes and advancements in their field. To assess students' understandings of the NOS, I analyze students-researcher conversations and selected items of student's written work in the next two sections.

6.3.2.1 Students-Researcher Conversations

In Chapter five, I have presented how Scott portrayed the contemporary image of scientists and the inquiries they conduct in their work. However, I was curious to know how students picture these scientists. So, again, toward the end of our investigations, on May, 15, 2003, I talked to a few students and asked them how they view scientists and their work. Consider the following conversation:

Conversation Excerpt # 6.9: Student-Researcher Conversation

Beata:	*Uh hm. What about – what do you think scientists do?*
Nick:	*Meteorologists or other scientists?*
Beata:	*Both.*
Nick:	*I (inaudible) from other scientists, well meteorologists they kind of like – this is on weather right?*
Beata:	*Uh hm.*
Nick:	*Okay, they just study* ***weather and maybe if they have time they go to other schools and help the other kids learn, like on their projects or something like that. Like sharing what they know. And for other scientists I'd say studying new specimens and all that, maybe create some things.***
Beata:	*Like what?*
Nick:	*A portion or something,* ***a potion.***
Beata:	*A potion –* ***what's potion?***

Nick: *Uhm some kind of chemical or something.*

Beata: *0,* ***pollution.***

Beata: *Okay. So do you think that scientists are always correct?*

Nick: ***No, with the educated guesses I'd say no.***

Beata: *No, so when they did that long-term and short-term forecast, yes, it showed that they were not correct when they were doing the long-term forecast. Why do you think it might be?*

Nick: *Maybe because* ***they didn't put much effort into doing the educated guesses. Maybe they just didn't use the instruments.***

Beata: *Uh huh. Would you like to be a scientist?*

Nick: *Um, kind of yes and no.*

Beata: *Why?*

Nick: ***Cause I'm afraid that like I'm always nervous before like I'm performing against with other people and if – like if I forget to say something I'll say something wrong I might be embarrassed.***

Beata: *About - ?*

Nick: *It's kind of a yes and no things.*

Beata: *Okay. But why yes? So that was a no, yes? But why yes?*

Nick: *Because* ***it's interesting and I said I have experience.***

Beata: *You have experience?* ***What kind of experience?***

Nick: *Uhm, like things I already know and like how to use those instruments* (Student-Researcher Conversation May 15, 2003).

When I ask Nick in the above conversation to tell me what scientists do, he wants me to be more specific and clarify whether I am asking about meteorologists or other scientists. I make myself clear and suggest to him that he can talk about both. He chooses to talk about meteorologists first and says that meteorologists just study weather, and, if they have time, they go to schools to help kids learn, do their projects, and to "share what they know." And for other scientists, he says that they are studying new specimens and "maybe create some things." At this point, I ask him to be more specific and tell me what kind of things. He specifies that it might be something like a "potion". I still am not sure what he means, so he explains that a "potion" is "some kind of chemical or something." Then, I figured out that he means pollution.

However, Nick was not sure, whether he wants to be a scientist or not. When asked, he gives me the vague, 'yes" and "no" arguments. Because he is familiar with various weather instruments now, and finds the work interesting, Nick thinks of becoming a scientist. But, at the same time, because he gets nervous working in groups, fearing he might forget to say something or say something wrong, he seems reluctant to make that choice.

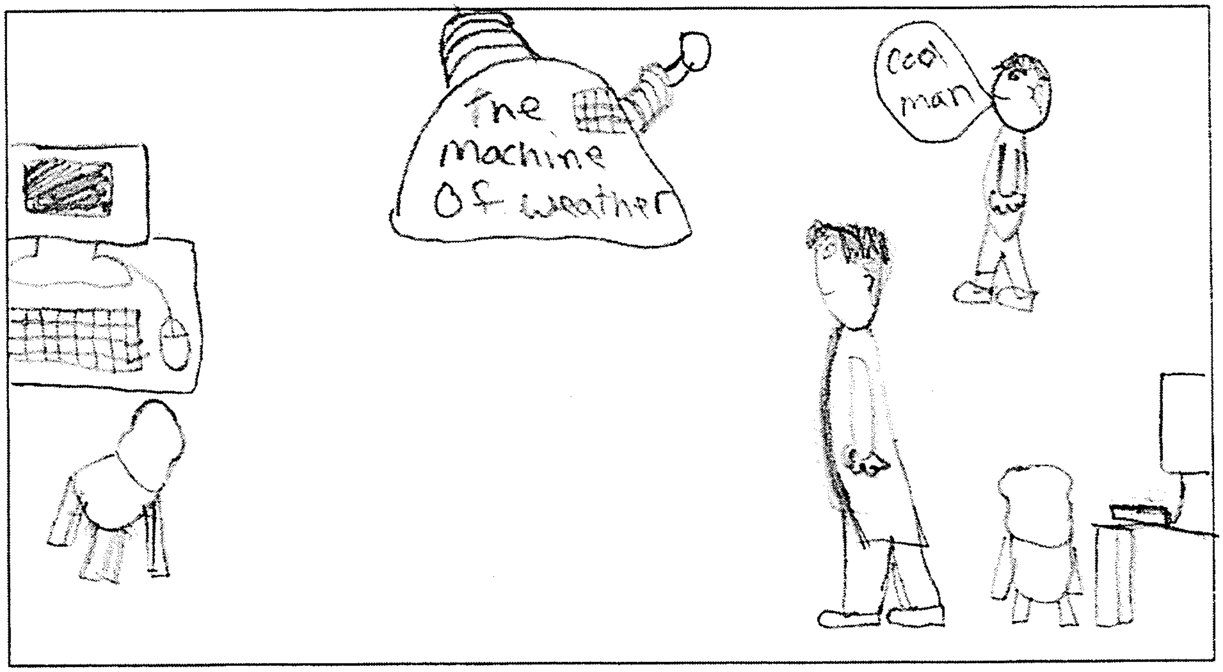
Nick's reference of scientists making educated guesses to predict the weather is the reflection of Scott's teaching. In *Conversation Excerpts # 5.11* and *# 5.14,* Scott uses the same words. Even Mr. Anderson (the city meteorologist) and Johan Stern (the TV weather anchor) used the exact words when they addressed the class. I am not surprised when Nick repeated the same words, because he always did exactly what the teacher expected him to do. Nick was not the only student, who mentioned about scientists sharing the knowledge with others. The students' comments about scientists sharing the scientific information with kids, fellow scientists and people in the community revealed their understanding of collaborative nature of scientific work. I should commend Scott for promoting such positive attitude in students, by giving them opportunities to freely discuss their views in their groups, and then demonstrating and executing it to be done in the class in a friendly and professional manner.

6.3.2.2 Selected Items of Students' Written Work

My conversations with Scott, and his teaching documented in Chapters four and five revealed Scott's determination of presenting the contemporary image of the scientist to his students. Nevertheless, I was keen to know whether he succeeded in instilling that image in his pupils' mind. So, the day before our trip to the Weather Office, we asked our students to draw a picture of a scientist at work. In this exercise, we did the Draw- a-Scientist Test (DAST), which has been found to be a useful as a research and teaching tool (Barman, 1997; Chambers, 1983; Rahm and Charbonneau, 1997; Rosenthal, 1993).

The students did not draw the image presented by McDuffie (2001), a nerd with glasses, working in isolation with strange equipment. Their drawings looked like the one below, done by Jane.

Figure 6.1 Sample student's drawing regarding an image of a scientist.



In addition, we asked students to write down who and what they expect to see on our field trip to the Weather Office. Sammy's description is the reflection of what most of the students wrote. Consider his response (written verbatim): "*I expect to see at the weather office a lot of machines for weather. I would probably see meteorologists at the weather office, and lots of types of maps what they use. And also see meteorologists working on the computer to see how the weather is.*"

6.3.3 The Development of the "Why" of Science

In Chapter one, I theorized that the "why" aspect of scientific literacy reflects students ability to make STSE connections. Science educators claim that this skill makes learning more authentic, because developing connections places science within a larger societal context (Hodson, 1998; Martin Sexton & Gerlovich, 2001; Tolman, 2002). It allows students to see that today's society faces numerous problems and issues, which require cooperative effort to be resolved (Hodson, 1998).

An important goal of STSE education is to provide opportunities for students to acquire informed decision making skills (Pedretti, 1997). Those decision making skills are, in turn, associated with the development of other capabilities, such as: identification and in-depth understanding of the problem, framing questions, gathering and analyzing data, sharing and evaluating findings, drawing possible solutions and suggestions, and choosing and implementing actions (Ebenezer & Connor, 1998). Those skills, in turn, are necessary for the citizens to be considered scientifically literate. Another important goal of the STSE education is to empower the students to take action in regard to a particular societal issue. This action taking could be done through various means, such as: education, letter and petition writing, posters, brochures, etc. (Ebenezer & Connor, 1998).

To illustrate the STSE connections in the Weather unit, the *Manitoba Curriculum Framework of Outcomes* requires students to study natural disasters (Specific Learning Outcome: 5-4-09). Scott and I decided to concentrate on flooding, an issue important to the local society and environment. In Chapter five, section 5.4.2, I describe a lesson, where the students were discussing the reasons for flooding and the precautionary measures that needed to be taken in case of a possible flood situation. This activity, thus, met the first goal of the STSE education, which is informed decision making. In section 5.4.2, I provided evidence for students' ability to make decisions to prepare themselves for floods.

To meet the second goal of the STSE education, this is action taking, our students decided to educate the community by making posters and writing letters. In Chapter five, section 5.4.2; I presented one of those posters (Figure 1) to inform the school community about the dangers of floods. Each of those posters included the following information: a) the damage that floods can cause and the effect the floods can have on people's lives; b) advice for the community on how they can be prepared in case of a possible flood.

In Chapter five, section 5.4.2, I included Rose' letter, which revealed her understanding of this issue, concern for the community, and her ability to offer good advice. In Appendix H, I included another letter written by Sammy to Kindergarten class. In his letter, Sammy is also able to give his younger friends good advice. He sounds serious by telling them that "he is here to tell them about floods." He also warns them that they have to be on the look out for floods because "they can kill you if you do not know what to do." In his letter, Sammy sounds very knowledgeable when he tells the younger kids how floods happen and how to prepare for a possible flood situation.

6.4 Students' Assessment of Their Own Learning

Many researchers advise that scientifically literate students are those who are enthusiastic and independent learners (Aikenhead, 1994, 1997; Hodson 2003; Pedretti, 1997). They are the ones, who have positive attitudes and display keen interest in learning without formal instruction (Arons, 1983; Shamos, 1995). They are also the ones who are responsible citizens, role models and action takers (Hodson, 2003). No doubt, our students demonstrated some of those characteristics. They displayed a positive attitude towards science, and demonstrated the ability to enquire about science and apply it to other scenarios outside their classroom. They were curious, enthusiastic, and eager to participate in all of the activities. They showed interest to share their knowledge and educate the community. They displayed an overall positive attitude towards learning science. At the end of our study, on May 15, 2003, I talked to some of the students to find out why they liked our study of the weather. Dorothy, for example, mentioned that she liked science because it "was fun and she could do lots of experiments." Kathy too expressed a similar view. Science was her "favorite subject because she had a chance to do a lot of activities, more than before." Shane told me that he preferred the science class to Physical Education, "because it was fun, interesting, and he got to do projects and use all the instruments and go on the computer and building that screen for the thermometer was good." Bonny also considered science to be fun. Rose, even considers of becoming an inventor one day. Sammy too says that he "wants to be a scientist himself." Joey says he liked science, because he could try various methods and use a lot of different things. "Doing experiments and the field trip was fun." says Emillio. And, Zoe admits that she likes science, because she "was learning new things." At the end of our study, I also asked the students to evaluate their own learning of science, and they all agreed on "learning lots." Dorothy summarized it jokingly by saying that if I want to see how much they have learned, I should have a look at the amount of paper she has stacked in her duo tang. And, as she said, Dorothy surely had lots of papers in her duo tang.

6.4 Chapter Summary

In this chapter, I concentrated on the last phase of the CKCM, known as the Reflecting and Assessing. The purpose of the phase is to provide opportunities for the teacher to reflect upon his/her practice and to evaluate students' knowledge. Through my on-going dialogue with Scott, I was able to find out about his views on our effort to develop scientific literacy. Scott believes that at the grade five level, students can only acquire an understanding of the NOS "through experience." Scott's claim indicates that he favors the implicit approach rather than the explicit one, when it comes to teaching science.

Scott reflected that the CKCM was a big factor in students' scientific literacy development. He believed that the model helped students develop a thorough understanding of the material, rather than superficial one. The model helped students to develop abstract thinking and, more importantly, it encouraged them to translate the material into other contexts. Scott also pointed out that due to our effort, students attained a positive attitude towards learning science. In fact, some students showed remarkable interest and an ability to incorporate science into their lives outside the classroom.

In this chapter, I also presented evidence for students' scientific literacy development in the three aspects of science, namely, the "what," "how", and "why" of science. To assess students' understandings of the "what" of science, I evaluated their understanding of the principles and concepts of the unit (Weather) and their ability to apply that knowledge into their daily activities. To assess students' understandings of the "how" of science, I evaluated their understandings of the NOS. And, to assess students' understandings of the "why" of science, I evaluated their ability to make the STSE connections.

Chapter 7

Summary, Discussion, and Implications

7.1 Summary

A story of a teacher-researcher collaborative effort to develop scientific literacy of grade five students in the context of a curricular unit on Weather has been narrated in this thesis. This story begins in Chapter three where I described my own experiences as a student, researcher, and elementary science teacher educator. Those experiences have helped me realize the needs of the pre-service, and, consequently, beginning teachers with respect to their preparation to teach science. For teachers to feel comfortable to develop scientific literacy of their students, teachers need to be helped in developing a deep understanding of the content knowledge of science (what), the nature(s) of science (how), and the applications of science (why).

To help build capacity of a grade five teacher, Scott, in developing scientifically literate students, I collaborated with him to plan and implement a curricular unit on Weather. Our partnership followed an organic model of collaboration, in which we were equal partners in every step of the project, and we were equally responsible for the outcomes. For our mutual learning, collaboration between us thrived on sustained dialogue. Our collaboration characterized the contemporary trends of professional development, for it involved real practitioners working in an authentic classroom setting with students over a long time to achieve a common goal.

Our goal was to develop scientific literacy of the grade five students in an inner city school in accordance with the conceptions proposed in Chapter one, which points to three notions of scientific literacy: 1) the "what" of science, 2) the "how" of science, and the "why" of science. The "what" of science refers to an understanding of the concepts, principles, and theories. The "how' of science emphasizes how scientists conduct scientific inquiries, referring to the NOS. The "why" of science refers to the ability to make science technology, society, and environment (STSE) connections.

To develop these three notions of scientific literacy, Scott and I used a teaching model known as the *Common Knowledge Construction Model [CKCM]* (Ebenezer & Connor, 1998). The CKCM incorporates four interrelated worlds of meaning making: students' world, the teachers' world, the curricular world, and the physical world. As the title of the model indicates, its aim is to achieve a common understanding among these four worlds of meaning making. The model consists of four interactive phases: 1) Exploring and Categorizing, 2) Constructing and Negotiating, 3) Translating and Extending, and 4) Reflecting and Assessing.

This thesis narrates how Scott incorporated his ideas about science and scientists into each of the four phases of the CKCM. For the Exploring and Categorizing phase, Scott explored students' ideas about how people (1) predict weather, and (2) measure weather, and, in turn, students explored parents' ideas of these concepts. Students' and parents' ideas were separately categorized based on each of the foregoing concepts, and then compared. For the Constructing and Negotiating phase, Scott taught several lessons based on the phenomenography of weather from the NOS perspective. For the

Translating and Extending phase, Scott enabled his students to apply their knowledge of science into everyday contexts, which involved making connections among science, technology, society, and environment (STSE). The STSE connection was discerned in the construction of a weather instrument and the study of floods, an important societal and environmental issue in Manitoba and other parts of the world. Finally, the Reflecting and Assessing phase highlighted Scott's reflections about our efforts to develop scientific literacy and the methods we used to assess students' scientific literacy development.

7.2 Answers to Questions and Discussion

In this section, I answer the five research questions guiding this study. Each answer is supported with evidence from my in-depth, classroom-based study, and a critical review of the literature.

Question 1: *What views of scientific literacy does a grade five teacher hold?*

Scott's ideas about scientific literacy were discerned in our prior and during his teaching dialogues. My prior instructional conversations with Scott revealed that he viewed a scientifically literate student as someone who has: 1) definite interest in the subject area, 2) vocabulary to support what one knows, and 3) willingness to explore and apply information to another setting *(see Conversation Excerpt # 4.1).* Scott argued that people couldn't be considered literate in any subject area without being interested in it. No one would disagree with Scott that interest in the subject is a very important factor in developing students' scientific literacy. History of science clearly shows that scientists study about a particular area, because they are interested in it. The aspect of "interest" is also a key element in Manitoba's vision for scientific literacy (Manitoba Education and Training, 2000). It is the interest in learning science that leads to curiosity, creativity, and imagination. Interest is a key factor in the development of problem-solving and decision-making abilities to become lifelong learner and to develop a sense of wonder about the world. Science educators concur that an individual's interest in the subject is crucial to the development of positive attitudes toward science (Carin & Bass, 2001; Ebenezer & Connor, 1998; Martin, Sexton & Gerlovich; Tolman, 2002).

Scott's second characteristic of a scientifically literate student referred to the development of relevant vocabulary. Like Bruner (1986) and Lemke (1990), Scott emphasized the importance of knowing the language of science to be able to actively and confidently participate in science. However, Scott placed too much emphasis on the rote learning of vocabulary, an approach he consistently argued for *(see Conversation Excerpts #4.2, 4.3, and 4.4).* Furthermore, he misinterpreted the curriculum, thinking that students need to memorize the vocabulary at the beginning of the curricular unit before carrying out their investigations. Science educators, however, claim that this approach is a reason that eventually turns off many students from pursuing science in the future (Ebenezer & Connor, 1998; Peters & Gega, 2002).

The last characteristic of a scientifically literate student Scott shared with me, before he started teaching the unit, was willingness to explore and apply knowledge to other contexts *(see Conversation Excerpts #4.1, 4.5).* However, contrary to the beliefs of policy makers, scientists, and science educators, Scott did not associate application with making STSE connections. He only saw it as the ability to discover new applications for what has been learned in class (see *Conversation Excerpts # 4.1, 4.5).* Our *Conversations # 4.6 and 4.7* revealed that Scott had the belief that scientific way of thinking should help students succeed in their future endeavors.

However, he associated this scientific way of thinking with the mythical step-by-step process, known as the scientific method (McComas, 1996) *[see Conversation Excerpt # 4.8].*

Although Scott was under the impression that this step-by-step, laboratory methodology was the route taken by most scientists *(see Conversation Excerpt # 4.9)*, he visualized a contemporary image of a scientist. He did not see a scientist as someone carrying out experiment in the laboratory with an imposing array of esoteric equipment (Howe, 2002). He knew that this is a stereotypical image, and he urged people involved in science education of young children to "do their best to build a different image of what science is" *(see Conversation Excerpt # 4.11)*. He himself saw science as an exciting and creative pursuit. And, as a teacher, he was determined to demonstrate to students that all of them could participate in science and consider science for their careers *(see Conversation Excerpt # 4.11).* Tobias (1990), who argued that students are not "dumb, but, they are different," would agree with Scott that presenting science as a creative and interesting discipline can motivate many students to consider science in their career plans.

When our study was well under way, on April 25, 2003, I again talked to Scott about scientific literacy. The purpose of my on-going dialogue with Scott was to find out if there were any changes in Scott's views on scientific literacy. This time, I wanted to reflect about our efforts to develop scientific literacy in his students. Scott's views did not change significantly. He still considered the ability to apply science into other contexts as an important attribute of a scientifically literate individual *(see Conversation Excerpt # 6.1).* Consequently at that stage of our study of weather, he thought of his students as "semi-literate" because they have not had many opportunities to "take the information and apply it by themselves." If I apply Scott's reasoning about semi-literate versus literate, these students would become literate after they had used their weather instruments, written weather forecast, and reported it to the whole school.

Question 2: *What are grade five students' conceptions about weather? And how are these different from their parents'?*

As shown in Table 3.3 in Chapter three, Scott and I subdivided our investigations of weather into three phases: 1) Weather Forecasts: Different Ways of Predicting and Measuring Weather, 2) Properties of Air and Clouds, 3) Weather and Climate (STSE). To find out what kind of ideas our students had about predicting and measuring weather, Scott asked them to respond, in writing, to the following two questions: 1) How do you think people predict weather? and 2) How do you think people measure weather? I grouped students' ideas to the first question into 4 teacher-made categories: Traditional Knowledge, Technological Advances, Maps, and Toys (see Table 5.1).

Table 5.2 shows the categories of students' ideas of how people measure weather. The three major categories are: Instruments, Technological Advances, and Sensing the Environment. The conversation between Sammy and his mother was the best reflection of what parents thought about predicting and measuring weather *(see Conversation Excerpt # 5.3).* Interestingly, parallel to the grade five-science curriculum, the mother separated the different ways of predicting weather into traditional and scientific. To give an example of the traditional ways of knowing, she recalled growing up on the farm and observing the natural environment. For example, she told Sammy how she used to foretell weather by looking at the clouds. The fluffy and white ones were bringing sunny and hot weather, while the "sun dogs" were an indicator of a very cold weather. To give an example of the scientist way of predicting weather, Sam's mother talked about meteorologists who "use computers and other high-tech equipment and certain types of weather maps."

In terms of measuring weather, Sam's mother also separated the many different possibilities into more "traditional ones," that she probably remembered from the farm, and more "sophisticated ones," used by professionals. She said, for example, that people could stick a yardstick into snow to measure the amount of snowfall. Or, people can use anemometer to measure the wind velocity and barometers to measure the barometric pressure in the air.

The most obvious difference between students' and parents' ideas about predicting weather (Table 5.3) was the fact that the parents were aware of the "old wise tales" passed on from one generation to the other. For example, the parents talked about predicting weather on the basis of animal behavior or aches and pains in the body. Among students, only Kathy and Isabella mentioned animal and plant behavior.

As shown in Table 5.3, both students and parents believed in the observations of the natural environment to predict weather. Students' beliefs, however, were more general in comparison to those of their parents. For example, students told us that people could look at the sky. Most of the parents, however, were more specific and talked about the shape and color of the clouds, for example. Table 5.3 also shows that none of the parents included any toys in their predictions of weather. None of students, on the other hand, associated their predictions of weather with cold and warm air masses, while some parents did.

Both students and their parents had similar ideas about measuring weather. As seen in Table 5.4, most students and parents associated the measurements of weather with instruments. The only difference within the Instrument category was that students were able to name thermometer as the only one standard instrument that can be used to measure weather. Parents also knew of barometers and anemometers. Both students and parents knew of the measuring devices, which I labeled "No Name Instruments." Among these, students listed measuring cups, a ruler to measure snow, and a bucket with a ruler. The parents talked about a mill, buckets, something like a fan, and color changing figurines.

There were only two parents whose ideas belonged to the second category of Technological Advances. Bonny's mother talked about weather balloon, while Emillio's mother mentioned that everything is computer based. Furthermore, there were three students who talked about sensing the environment, while the parents did not put forth any ideas belonging to this category.

Question 3: *How does the teacher develop scientific literacy when he incorporates students' conceptions of weather into the curriculum?*

The learning of the NOS may be implicit and/or explicit (Abd-El-Khalick & Lederman, 1998). The understanding of the NOS may be implicitly facilitated through the teaching of processes of science, science content course work, and doing science. This approach, however, neglects the reflective components related to the NOS (Akerson et al., 2000). The understanding of the NOS may also be facilitated through teaching explicit examples from the history and philosophy of science and/or specific instruction directed at the various aspects of the NOS (Akerson et al., 2000). Both implicit and explicit approaches to the teaching of the NOS have been tested in the context of the science methods courses. Recent literature, however, suggests that the explicit approach is more effective in developing teachers' appropriate conceptions of the NOS (Abd-El-Khalick & Lederman, 1998; Abd-El-Khalick et al.,1998; Driver et al.,1999).

Which approach did Scott choose to present the NOS? According to Scott, it was impossible to teach science directly in a grade five classroom *(see Conversation Excerpt # 6.1).* He believed that grade five students could only acquire the understanding of the NOS "through experience." He pointed out that we were teaching science "indirectly." These comments indicate that Scott believed in an implicit, rather than explicit approach to teaching science. Some researchers would disagree with him in this regard. For example, Abd-El-Khalick et al. (1998) and Driver et al. (1999) suggest that explicit approach is more effective in helping learners achieve adequate understandings of the NOS. These authors and Lederman et al., 2001 claim that this understanding should not come as a by-product of teaching science. Likewise Abd-El-Khalick et al., (1998) report that one cannot claim that he/she understands physiology of the respiratory system simply by breathing air.

Scott's approach to teaching science, though, was not entirely implicit. It is true that he created many situations through which students could "experience" how scientists conduct inquiries. For example, he allowed students to negotiate every major topic and/or problem with their peers without stressing to them that this is one of the qualities of the NOS. There were many situations; however, where he directly pointed it out to students that our particular way of learning science resembles the methods scientists follow to conduct their own investigations. For instance, during the process of designing weather instruments *(see Conversation Excerpt # 5.15)*, he explicitly told students that if they want to arrive at a mutual understanding, they need to carefully listen to everyone's suggestions and negotiate with others in the group before deciding on the final design. Thus, he emphasized the concept of sharing and collaboration among the scientists (Machamer, 1998). In another conversation, Scott made it clear to students that "through our weather training, we are learning to become scientists and to think about weather how a scientist would." *(see Conversation Excerpt # 5.8)*. These examples indicate that Scott incorporated elements of both implicit and explicit approaches into his teaching.

Question 4: *What aspects of scientific literacy are evident when a class of grade five students studies a unit on Weather?*

To answer question 4, I present evidence for the development of three aspects of scientific literacy: the "what", the "how", and the "why" of science.

The What of science. The development of the understanding of concepts, principles, and theories, in this case, the concepts of weather was shown by students' performance on the station-to-station test and written test, their class discussions, their conversations with others, as well as their written work. For example, my conversations with students indicated that they were understanding the material and gradually developing a more sophisticated understanding of the concepts of weather. *Conversation Excerpt # 6.3*, for instance, shows that students were able to acknowledge their earlier understandings about predicting weather. In this conversation, Dorothy admitted that she came to the understanding that people use computer and radar to predict weather, but not a car, as she has thought at the beginning of our investigations. In the same conversation, Shane, Rose and Ian were also able to tell their progress on the understanding of how people predict and measure weather.

Furthermore, my conversations with students (summarized in Table 6.1) clearly showed that they themselves were aware of learning new ideas. Bonny acknowledged that wind moves only from high pressure to low pressure, and Ian spoke of air having friction. Timothy learned about the radar, and Dorothy learned how to protect herself from tornadoes. Nick talked about friction, while listed various weather instruments. Table 6.1 also demonstrates that these students were able to justify the importance of weather to people. They all agreed that knowing weather forecast is important to people, because it helps them to plan their activities ahead of time and to protect them from severe weather conditions. Students were also creative, when it came to listing the occupations that rely on weather.

Evidence of students' understanding of the "what" of science was also obvious in their conversations with their teacher, siblings, parents, and with each other. For example, when they interviewed their parents or siblings regarding their views on predicting and measuring weather, they were knowledgeable enough to either educate their family on the subject *(see Conversation Excerpts # 5.5 # 5.6),* or appreciate the "right" answers given by the respondents *(see Conversation Excerpt # 6.6).* If not satisfied with the answers, like Kathy, in *Conversation Excerpt # 6.6*, or Emillio, in *Conversation Excerpt # 5.6,* students asked their parents for further clarification. Some of them, like Jessica and Hanna *(see Conversation Excerpts # 5.6, # 6.5)* felt so knowledgeable that they allowed themselves to be sarcastic when they heard the responses from their parents during the interviews. Students' learning from each other was also obvious in-group conversations. In Chapter six, I included one group conversation *(see Conversation Excerpt # 6.7)*, where Alek recited what he had learned from the conversation with his peers.

Scott and I were also involved in conversations with each other to reflect and evaluate students' progress. I analyzed one such conversation in Chapter six *(see Conversation Excerpt # 6.2),* where Scott talked about Joey. During our study of weather, Joey started paying attention in class. Furthermore, he was able to apply the information studied in class into other situations. Scott assured me in our conversations that Joey was not the only student, who showed greater interest in science and school in general since the beginning of our investigations. Scott mentioned that our study motivated students' interest in science and helped them develop positive attitudes toward the subject. A positive attitude toward science, highly recommended by Arons (1983) was also evident in my conversations with students.

Students also demonstrated the ability to use the knowledge, which according to many authors is sign of scientific literacy development (Hazen & Trefil, 1991). Both the station-to-station test and the written test demonstrated students' ability to draw conclusions, analyze data, make recommendations, and give advice to others. Additionally, students developed skills to access the Environment Canada website and analyze the satellite imagery to predict the upcoming weather (Question 1, station-to-station test, discussed in Chapter six). They demonstrated the ability to identify professional weather instruments, and in line with Hodson's (1993) recommendations, explained how they worked. In Chapter six (Question 2, station-to-station test), I analyzed students' understandings of one of the suggested instruments, the radar. However, I also observed their proficiency in regard to other weather instruments.

Although proud of weather instruments they designed by themselves, students were able to recognize why their instruments were inaccurate and suggest necessary improvements to weather instruments that they were designing, and specified why their particular instruments did not work *(see Conversation Excerpt # 6.4).* Kristofer, for example, identified that if he had a chance to do weather vane again, he would use metal, instead of paper. Rose suggested that heavier materials would also work better in case of anemometer.

In addition to being able to analyze information and draw conclusions, students also demonstrated the ability to use information to make informed decisions and give advice to others, a skill highly recommended by educators (Aikenhead, 1997; Ebenezer & Connor, 1998; Pedretti, 1997) [see Question 2 of the written test, discussed in Chapter six]. For example, students were able to decide how they need to be prepared for possible floods as well as give recommendations to others. Students also demonstrated the ability to make simple decisions related to their everyday life, such as what to dress for a particular day or what kind of activities to plan (see Question 3 of the written test, discussed in Chapter six).

One of the biggest challenges for students and probably one of the greatest signs of their scientific literacy development was the proficiency in making weather reports. To do so, students were required to visit the Environment Canada Website and record the meteorologists' latest report on weather conditions and interpret the data to write weather report and make weather related recommendations, which were announced for two weeks to the whole school. Later they announced their report, over the intercom to the entire school. Through this assignment, students showed their ability to translate their knowledge into everyday contexts (Aikenhead, 1997). Furthermore, they demonstrated their ability to interpret information (CMEC, 1997; NRC, 1997).

I believe that the teacher and I developed the "what" of science at the grade five level. The above examples and those presented in Chapters five and six, illustrate that students developed an understanding of the concepts recommended by the grade five-science curriculum. More importantly, they were able to use those concepts in their lives to make their own decisions as well as give advice to others.

The How of science. The development of the second notion of scientific literacy, the "how" of science, was evident in Scott's modeling of the NOS through the first three stages of the CKCM. In his teaching, Scott painted a contemporary image of scientists. He emphasized that scientists are open minded and creative, that they do not have answers to all questions, that they share their findings with others, and that scientific knowledge is tentative and limited *(see Conversation Excerpts # 5.11, 5.14).* Scott also made sure that his students understood the processes of science. To do that, he provided many opportunities for students to experience how scientists conduct their inquiries. He also allowed many opportunities for students to negotiate their ideas with others in a group setting. Furthermore, he made sure that students developed an ability to analyze data, draw conclusions, ask questions, conduct investigations, evaluate available information, and make informed decisions.

Scott's efforts of modeling the NOS were reflected in students' understandings. Through my conversations with students, I found out that they were aware of the collaborative nature of scientific work. Nick, for example pointed out that he would have liked to become a scientist. However, he was nervous of the collaborative work that is required of scientists *(see Conversation Excerpt # 6.9).* Students also informed me about scientists sharing information with others, which revealed their understanding of the social nature of scientific work. The characteristics of the NOS were also evident in students' written work (see section 6.4.2 in Chapter six).

Which characteristics of the NOS, discussed in the first two chapters, have our students understood through our study of weather? I believe that through the lessons our students experienced, they understood that science is partially based on human imagination and creativity, tentative, socially and culturally embedded, empirical, and developed through many methods. I also believe that students did not understand that science is theory-laden (subjective), that there is a distinction between observation and inference, and between scientific theories and laws.

The Why of science. The third aspect of scientific literacy refers to the "why" of science or the ability of making the STSE connections. The purpose of ST education is to understand the connections between science and technology (Ebenezer & Connor, 1998). And, the goals of SE education include the development of the decision making and action taking skills (Pedretti, 1997; Hodson 1993, 1998).

In Chapter five, section 5.4.1, I described how our students combined their knowledge of science and technology in the design of weather instrument. I also emphasized that that students were able to evaluate their instruments and suggest how they would improve their designs. In Chapter six (section 6.4), I outlined students' ability to make decisions in regard to a pertinent societal issue of flooding. In terms of action taking, our students decided to educate the community by making posters and writing letters. In Chapter five, section 5.4.2, I presented one of those posters designed to inform the school community about the dangers of floods. Each of those posters included two pieces of information: a) the damage that floods can cause and the effect the floods can have on people's lives; b) advice for the community on how they can be prepared in case of a possible flood. In Chapter five, section 5.4.2, I included a letter written by Rose, which reveals her understanding of this issue, concern for the community, and ability to give sound advice.

The Translating and Extending phase of the CKCM encourages teachers to empower their students to make decisions and take actions in regard to pertinent societal and environmental issues (Ebenezer & Connor, 1998). Science educators also advice that if students receive adequate education in STSE issues, they will be better citizens, who are concerned about their environment and the well being of their society (Aikenhead, 1997; Hodson, 1998; 2003). I believe that our study of the floods was a good introduction to the life long learning and responsibility (see Chapter five, section 5.4.2). I reason that Scott's story of his involvement in protecting the city from the flood of the century, students' parents' involvement in helping others save their properties, and our class activities helped students realize that societal and environmental issues are everyone's responsibility and that as students, they can participate in decision making and action taking in regard to those issues.

Aikenhead (1992) claims that scientifically literate people should understand how decisions are made at the local, provincial, and national government levels, and within the private and individual sectors. These science educators believe that scientifically literate individuals posses critical thinking skills, which allow them to: a) evaluate the pros and cons of any scientific or technological development, b) examine potential benefits and costs, and c) recognize the underlying political and societal forces, which drive the development and distribution of scientific and technological knowledge and artifacts.

In light of these claims, a question might be, did Scott and I provide enough opportunities for students to make decisions and take actions? More specifically, did we make students aware of how decisions are made at the government levels, and allow them to have a voice in making those decisions? The answer to this question is that we have not. I wonder, however, if at this grade level students are competent enough to take such action. But, with respect to the issue of flooding, we could have let students debate the local issue of the flood way. For example, we could have encouraged students to utilize the knowledge they learned to discuss the pros and cons of this initiative and ponder over potential benefits and costs to the city of Winnipeg.

Question 5: *What are the highlights of teacher-researcher collaboration in the context of developing scientific literacy?*

Based on the experience of teacher-researcher collaboration in this study, I would like to recommend to others not to follow the traditional, exploitative nature of classroom-based research described by Janesick (2004), where the researcher observes and evaluates the teacher's knowledge and methods and then leaves the scene. I did not act as though I had all the knowledge. I never diminished, devalued, or questioned the teacher's expertise. To the contrary, I appreciated Scott's knowledge and treated our collaboration with Hathaway's (1985) idea in mind, which emphasized that the universities and schools are each other's own best resources. Scott on the other hand, opened the doors of his classroom, was open to my ideas, and willing to devote time to this project. Most importantly, he trusted me with the CKCM and was willing to use it as the medium to teach the unit, or, more specifically, to develop scientific literacy of his grade five students. This thesis clearly illustrates our conceptual growth. It shows how we pulled our strengths to merge theory and practice. I had the theoretical knowledge in teacher education, which I have acquired through my Ph.D. course work and my university teaching experiences. Scott, on the other hand, as a representative of a public school system, had the practical knowledge. Thus, as recommended by NRC (1996), we created optimal collaborative learning situation in which the best sources of expertise are linked to achieve common goal.

Many researchers embrace collaboration and they write about productive school-university relationships (Ballone-Duran et al., 2005; Bartolo & Palffy-Muhoray, 2001; Caton, Brewer, & Brown, 2001; Haney, Czerniak, & Lumpe, 1996; Supovitz & Turner, 2000; Posnanski, 2002; Stein, 2001). Others, however, report that the development of a relationship between university researchers and public school practitioners is problematic at best (Ball, 1990; Connelly & Clandinin, 1990; Johnston, 1990). These researchers claim that university researchers often treat schools simply as data collection sites, rather than contexts for the mutual construction of knowledge with experienced practitioners. Researchers act as if they have "the knowledge to improve the teaching practice if only the teachers would accept it and integrate it into their teaching" (Johnston, 1990, p.174). Furthermore, they devalue teachers' practical knowledge and treat them as objects to be studied.

I believe that our collaboration was successful because I bridged my world as a researcher with the world of a teacher by engaging in this teacher's professional life, not as an external imparter of knowledge, but as a participant in a shared construction of knowledge. Scott was an expert in his field; he had very good professional judgment on educational issues, and was familiar with the rules and regulations of his school and school divisions. Furthermore, he knew very well the capabilities and limitations of students in his class and was able to make informed decisions. For example, as I have already described in Chapter five (section 5.3.4), I was very uneasy during our preparation for the field trip to weather Office, while he, having greater professional judgment, was very confident in his students' abilities to ask relevant questions.

There were many other situations where he had better judgment than I did. For example, students needed some time to handle the interviews with their parents and Scott was aware of that. At the beginning of this process, there were some glitches, for example, Dorothy forgot to bring the recorder back to school. Shane forgot to interview the parent. And, Peter did not know how to operate it. When all of this was happening, I was convinced that this assignment is not going to work out. But, Scott suggested that we just need to give them more time. Another time, I was not totally convinced in students' ability to handle the mechanics of the station-to-station test. To Scott, it was "just a piece of cake." He was right. After our field trip to weather Office, he felt that it was necessary to summarize the information that was presented to us in classroom setting. This was an excellent idea and professional decision on Scott's part. This follow-up class (described in Chapter 5, section 5.3.5) clearly illustrated that some students were still struggling with the information presented to them, and Scott's summary helped them understand the information. These examples illustrate that Scott had good pedagogical content knowledge (PCK). It refers to a teacher's unique knowledge of how to create learning opportunities that make particular content more comprehensible to others (Shulman, 1987). Furthermore, as suggested by NRC (1996), Scott was able to use this knowledge to make effective decisions.

I reasoned, and Scott actually agreed with me that the factors that helped him develop this good understanding and judgment of his students were his own behavioral and learning problems, as well as his drive to better himself. In one of our prior-instructional interviews, on January 8, 2003, he mentioned that he "knows where a lot of his students are coming from." He also explained to me that, as an undergraduate student, he was eager to find out his own learning style. As a result, "he was very talkative, always had his hand up, always asking, trying to figure out where he fits," a process he benefited from as a teacher.

Clift et al., (1990) advise that collaborators consist of practitioners and researchers from diverse role groups, who carry with them preconceived notions of role relationships and hierarchies. I think, and I hope that Scott would agree, that we were equal partners in the process of planning and delivery of the unit and that there was no clearly established hierarchy. It might be because of the simple fact that in our partnership, I represented the university as a student, not as a professor. He, on the other hand, took part in it as a confident professional working on his own territory, and together we collaboratively developed a teaching unit, monitored the process, and evaluated students' conceptual development. If there were any hierarchy in the project, it was we: teacher and researcher team versus my advisor. Both Scott and I were "novice" in many aspects of this project and we often relied on my advisor's expert knowledge, especially in regard to the CKCM. There were, however, certain behaviors displayed by Scott that might indicate that I was in charge, that I had a "higher position" in Clift et al's (1990) hierarchy system. For example, Scott always consulted with me, prior to giving anything to students in writing. Although he prepared all of the handouts by himself, he always e-mailed them to me for my final approval.

I believe that, out of Whitford et al's. (1989) three models of collaboration: symbiotic, organic, and cooperative (described in Chapter one), our partnership was of organic nature. In this model, both parties work together to fulfill the same goals, which are carefully identified. Furthermore, in the organic model, the results are jointly owned and both parties are equally involved in all endeavors. At the same time, however, there are warnings that this type of collaboration is complex and is built with much time and effort (Dixon & Ishler, 1992). In addition, in organic relationships, explicit attention to the identification and development of common interests need to receive institutional support necessary to sustain the collaboration.

Our model was of organic nature because our mutual purpose was to develop a research study, monitor the process, and evaluate the results, all of which had scientific literacy of students in mind. We both collaborated to implement the new instructional design, the CKCM. Furthermore, we were both equally involved in every step of the journey as well as equally responsible for the results. The result we were aiming for in this project was developing adequate level of scientific literacy in students. Additionally, our activities received support from my university as well as his school and school division, which allowed us to complete such an elaborate project.

I can also identify elements of Whitford et al's. (1989) symbiotic model of collaboration, which is characterized by reciprocity and mutual self-interest. In this type of collaboration, the attitude is: " I will help you with your concerns or your problems if you will help me with mine." In other words, both parties involved in this type of collaboration are interested in gaining something out of it and fulfilling their own goals. Although, I was genuinely interested in learning through this project and gaining experience to benefit as a science educator and researcher, I was also interested in achieving my goal, which was completion of my Ph.D. program. I wonder, then, which of the two interests was stronger? Furthermore, it was very important to me to collect data in that particular time because I made many arrangements in my professional and personal life to do so.

What were Scott's personal and/or professional goals? Although it was never said, I personally think that one of the reasons Scott agreed to this intense collaboration with me was his interest in his professional growth. He was interested in having research experience to stand out among other teachers, which would eventually help him achieve his goal of becoming a school principal. As I narrated in Chapter three, he was a leader and he wanted to take advantage of his leadership skills. But, he wanted to utilize his leadership qualities as a principal, not as a teacher. In other words, Scott treated this project as an excellent opportunity to enrich his resume. What I admire about him, though, was the fact that he was willing to grow to leadership through service.

Would Scott's students develop scientific literacy if Scott and I were not collaborating? I know that due to our collaboration, Scott used the CKCM to teach the unit, and by doing so, he made a big step toward scientific literacy development. I am not sure, however, whether he would have used the model if I were not there. Natalia, the beginning teacher whom I described in Chapter three, did not use the model to teach the grade seven. Scott told me that Mr. Sobolewski, the other grade five teacher, from Scott's school only used certain aspects of it. Scott explained that it was "because the model requires the teachers to put a lot of thought and effort into planning, preparation and delivery of the unit." Scott had the opportunity chance to use the CKCM during his teaching practicum, but he did not. I conclude, then, that he would not have used it if he were not collaborating with me. But, after working with me, Scott had a better disposition towards the model, and credited the model for his students' scientific literacy development *(see Conversation Excerpt # 6.1).*

What were our specific roles in the development of scientific literacy of the grade five students? Firstly, I approached Scott with a general design of the study and with a lot of different ideas. He, on the other hand, helped me fine tune those ideas and evaluated them in terms of practicality and difficulty. Finally, he implemented those in his classroom. However, we were both learning from each other throughout the project. I reason that students benefited greatly from my presence in their classroom. Scott would not have had the time to design such a rich unit by himself and students would not have the same experiences. Just to list a few examples: students would not have gone on the field trip to weather Office or had guest speakers visiting their classroom. They would not have a chance to interview their parents about various aspects of weather. And, they would not have had an opportunity to announce weather report to the whole school and make relevant recommendations. Furthermore, they would not have had a chance to negotiate their ideas, discuss their ideas in groups or experience in writing the station-to-station test.

I asked Scott at the end of our collaboration, on May 16, 2003, whether students would have developed scientific literacy, if we had a different approach. Specifically, I asked if students would have developed scientific literacy, if we had followed *Hands on Science*, which is an activity book that addresses each of the Specific Learning Outcomes of the grade five science curriculum. Teachers, especially the beginners, often religiously follow the book. Scott's response to my question was "that we would have missed everything other than the content knowledge," which means that students would not have had a chance to develop the "how" and "why" of scientific knowledge. I reason, then, that due to our collaboration those "how" and "why" issues gained greater importance in his teaching. I would like to take some credit for the development of these two notions of scientific literacy. When we were planning the unit, I told him that whatever we are learning must have the "how" and "why" aspects. Scott took it seriously. So seriously that students became aware of his new demand of explaining why and how things happen. Recall the class conversation *(see Conversation Excerpt # 5.16)* in which one of students, Nick, complains about these "why" questions.

I also conclude that through our collaboration, Scott started practicing certain teaching methods. For example, Scott was not fond of providing opportunities for students to negotiate their ideas in small groups. I, however, strongly believed that this approach would help students realize how scientists conduct their inquiries. Scott has not practiced this strategy before. He even mentioned, during one of our planning sessions that "it might be a challenge to them since students were only used to discuss their ideas with a partner." However, he was willing to implement this idea of mine, which ended up being successful.

7.3 Implications and Recommendations

In this section, based on my experiences as the elementary science teacher educator and findings of this project, I discuss teacher education and make recommendations for teacher education and professional development.

7.3.1 Teacher Education

How could educators help teachers gain a better understanding of the NOS and the development of NOS in particular social contexts? And when does education in NOS need to begin? There seems to be two schools of thought. Some scholars believe that positive changes in teachers' views of the NOS ought to properly begin in teacher preparation, by incorporating the NOS into the science methods courses (Driver et al., 1997; Gopnik, 1996; Hagen & Kegler, 1994; Loving, 1991).

Other scholars, however, argue that it is best to explicitly develop sophisticated views of the NOS in the context of the science content courses (Akerson, Abd-El-Khalick, & Lederman, 2000), which elementary pre-service teachers are required to take to fulfill the science requirements for their Bachelor of Education degree. Science courses for elementary teachers are usually offered by specific science departments, and educators usually put great emphasis on the content pertinent to a specific science discipline without any or with very limited emphasis on the NOS (Akerson et al., 2000; Ballone-Duran, Czerniak, & Haney, 2005). This supports the earlier argument that the development of the adequate understandings of the NOS should occur in the context of the science methods courses since it might be teachers' only opportunity to acquire this type of knowledge before entering the classroom (Akerson et al., 2000).

Is teachers' appropriate understanding of the NOS sufficient in an effort to educate scientifically literate students? Lederman and his colleagues in a series of articles suggest that it is not (Gess-Newsome & Lederman, 1999; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Schwartz & Lederman, 2002). These authors claim that teachers need to develop a combination of subject matter knowledge, PCK relative to the NOS, knowledge of the NOS, and intentions toward teaching the NOS in order to be proficient in teaching science. It is logical to reason, then, that teachers should develop the required knowledge during their university education and training. However, it does not seem to be the case. Many researchers criticize pre-service teachers' knowledge in each of these domains. In terms of the subject matter knowledge, several studies indicate that during their education, future teachers do not acquire sufficient knowledge in the subject matter and as a result do not feel confident to teach science (Borko, Eisenhart, Brown, Underhill, Jones & Agard, 1992; Cochran & Jones, 1998).

Knowledge of the subject matter or lack of such has an impact on teachers' PCK. The PCK addresses two aspects, which are: 1) the knowledge of the topic-specific instructional strategies to teach the subject matter and the 2) knowledge of learners and their requirements for developing meaningful understandings (Zembal-Saul, Krajcik, & Blumenfeld, 2002). Research indicates, however, that pre-service teachers have difficulties with the development of appropriate content specific representations (Borko & Putnam, 1996).

Research also suggests that pre-service teachers have limited knowledge in the second aspect of the PCK, which refers to the learners and classrooms (Civil, 1992; Grossman, 1991). The pre-service teachers have hard time anticipating what students already know, what topics they find difficult, how they might respond to instruction, and what questions they might ask. In other words, they have limited practical knowledge of learners and classrooms and therefore tend to become overwhelmed by the complexities of classroom contexts (Zembal-Saul et al., 2002).

Experienced classroom teachers have the same problems as the ones listed above for the pre-service teachers. For example, several experienced elementary teachers, in the *Journal of Science Teacher Education*, describe their journey to become better elementary science teachers (Dickinson, Burns, Hagen, Locker, 1997). These teachers reveal that they were reluctant to teach science because they felt inadequately prepared and did not know enough science. They neither felt confident in their ability to be effective science teachers nor saw the importance of becoming effective at teaching science. Furthermore, they were under the impression that the most important skill to be developed in the elementary school is the ability to read and write. They did not see science as helping their elementary students become literate.

What these teachers revealed further confirms the claims researcher makes about teacher preparation to teach science. For instance, Schoenberger and Russel (1986) report that elementary teachers consider science as a frill to be added only if other subjects were finished and reviewed. In another study, Stefanich (1992) claims that 80% of the instructional time is spent on science textbook reading. Similarly to Dickinson's study, many researchers add that elementary teachers lack confidence in their abilities to teach science due to their weak subject-matter knowledge (Garbett, 2003; Garbett & Yourn, 2002; Kallery & Psillos, 2001; Levitt, 2001; Sanders & Morris, 2000; Watters, Diezmann, Grieshaber, & Davies, 2001).

Garbett (2003) suggests that teachers' subject knowledge impacts their pedagogy, specifically their ability to make new ideas and understandings accessible to young learners and to ask meaningful and appropriate questions. For example, the less teachers know the more often they dominate classroom discussions without eliciting any questions from students (Carlson, 1991). Furthermore, such teachers plan the lessons around their knowledge rather than taking into consideration the ideas offered by their students. Science educators, however, suggest that children bring a whole array of ideas and understandings into the classroom that should be recognized by the teacher and incorporated into the lesson plans (Driver, Guesne, & Tiberghain, 1985; Ebenezer & Connor, 1998).

The above criticisms in regard to teachers' subject-matter knowledge and PCK as well as those I presented earlier in Chapter one in regard to teachers' understandings of the NOS or lack of such, suggest that universities do not adequately prepare teachers to face the complexity of their occupation. This is an alarming problem, especially because recent research studies indicate that a classroom teacher is the most important factor in the achievement of any educational goal, scientific literacy included (Sanders, 1998 a, b).

As a solution to those criticisms, based on my research findings, I would like to make the following three recommendations for teacher education and professional development with the goal of scientific literacy development: 1) The NOS should be taught in the science methods courses, 2) Universities need to offer science courses with an aim to prepare future teachers to confidently teach the science content of K-8 curriculum, 3) Science educators should collaborate with beginning teachers to help them translate the knowledge acquired at the university into their classroom practice.

7.3.1.1 Recommendations for Teacher Education with Respect to NOS

I recommend to use the CKCM because it facilitates the development of the five foundations for scientific literacy, the NOS being one of them, recommended by the Manitoba Education and Training (2000). Thus, it is suitable for beginning teachers who are often struggling to meet the demands of their profession. The Manitoba five foundations for scientific literacy, which are adapted from the *Pan-Canadian Protocol for Collaboration on School Curriculum* are: 1) NOS and Technology, 2) Science

Technology, Society and Environment (STSE), 3) Scientific and Technological Skills and Attitudes, 4) Essential Science Knowledge, 5) Unifying Concepts.

The goals of the first foundation, *NOS and Technology* are well incorporated into the first two phases of the CKCM. For example, the Exploring and Categorizing phase allows students to learn that scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Since the aim of this phase is to incorporate everyone's ideas, it allows students to see that accepted knowledge involves many participants with diverse backgrounds and that there might be many explanations for the same phenomenon. This phase also reveals important aspects of scientific attitude. It shows that scientists must be open-minded, honest, non-dogmatic, and respectful of the ideas proposed by others (McComas, 1996; Matthews, 1998). The Constructing and Negotiating phase, on the other hand, allow students to see that learning in science stems from curiosity, creativity, imagination, and intuition. Furthermore, through this phase, students further realize that scientific knowledge is tentative, has history, and is developed through many different methods.

The second foundation, *Science, Technology, Society and Environment (STSE)*, is best reflected in the third phase of the model, which is known as Translating and Extending. In this phase students develop an understanding of the relationship among science, technology, society, and environment. To be specific, as the title indicates, this phase allows students to translate their science knowledge into technology, society, and environment. Through this phase students learn that science and technology interact with and advance one another. They also have an opportunity to see science in larger societal and cultural context.

The third foundation, *Scientific and Technological Skills and Attitudes*, could be incorporated into each of the phases of the model. The model allows students to develop necessary skills for solving problems, for communicating ideas and results, for working collaboratively, for appreciating the ideas and contributions of others, and for making informed decisions and acting upon those decisions. Depending on the unit and the nature of activities, the model facilitates the development of the fundamental scientific inquiry skills, such as: questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting, analyzing, and interpreting data.

The fourth foundation, *Essential Science Knowledge*, is acquired in the Constructing and Negotiating phase of the model where students construct and negotiate knowledge of concepts in science and learn how to apply their understandings.

The last foundation, *Unifying Concepts*, includes the key ideas that underline and extend science into areas such as mathematics, language arts, social studies, and art. The unifying concepts help students construct a holistic understanding of science and its role in the society. Throughout all of the phases of the model students use their knowledge acquired in other subjects to do measurements, graph results, interpret data, present and argue their ideas, discuss related societal issues, and construct artifacts.

7.3.1.2 Recommendations for Teacher Education with Respect to Science Content

Throughout this project and throughout my experiences as a science teacher educator, I observed that the knowledge in the subject matter is as important as the knowledge of the NOS (Gess-Newsome & Lederman, 1999; Lederman et al., 2001; Schwartz & Lederman, 2002). In this study, I observed that the two beginning teachers, Natalia and Scott, whom I came to know during my Ph.D. studies, displayed a very different aptitude for teaching science. Natalia wasn't prepared to teach the content of science unit on Materials and Structures in grade seven. In other words, she wasn't ready and did not feel confident to teach the "what" of science. She also did not portray the "how" of science, despite the fact that the contemporary philosophy of science was emphasized in her science methods course. Furthermore, she decided to finish the unit after two weeks, while normally four to six weeks are required to finish the material of any curricular unit. Scott, on the other hand, felt confident to teach the grade five curricular unit on Weather and he did a good job teaching both the "what" and the "how" of science.

Why was there such a difference in the quality of teaching between these two teachers? These two teachers received the same training from the Faculty of Education at the University of Manitoba. Natalia graduated in 2000, while Scott graduated one year later. They both majored in elementary education and both were required to take six credit hours in sciences to fulfill the science requirement for their degree. By coincidence, they both took the same course, which was the Earth Science from the Geology Department at the University of Manitoba. Scott told me that he "chose geological science firstly because this course was most relevant to the elementary and middle years science curriculum." Secondly, he chose geological science "because in his first two years of university he was very unsure of the direction he wanted to take and this course was recommended to him by a friend, who had taken the course." Natalia took the same course to fulfill her science requirement and she gave me similar reasons to justify her choice of a course.

I, however, strongly disagree with both Scott and Natalia. I think that a course in geological science is irrelevant to the elementary and middle years science curriculum. In my opinion, this course prepares future teachers to teach only two units of the elementary and middle years curriculum, which are Rocks and Minerals in grade four and Weather in grade five and later on in grade seven. This course, however, is not useful for most of the other K-8 curricular units. It was only by coincidence that Scott benefited from his choice while teaching the unit on Weather, while Natalia did not. He was open to my ideas, conducted discussions, provided room for questioning, handle the material with ease, because he felt competent and confident to guide students' questions. He often allowed the discussion to be student driven, rather than dominating it, which is rare in classrooms instructed by teachers, who have weak content knowledge (Carlson, 1991). The teaching that went on in Scott's class, however, could have been different if he had taken a different course. Like many pre-service teachers, he could have taken a course in botany, rather than in geological science, to fulfill his science requirement.

The fact that Natalia decided to finish the unit earlier indicates to me that she did feel confident to teach it and did not have time to learn the material. Borko (2004) and

Enchos and Riggs (1990) claim that lack of confidence in their ability is common among teachers who major in elementary education. These researchers further explain that teachers' lack of confidence in their ability to teach science is due to their weak subject-matter knowledge, which was clearly evident in Natalia's case. The lack of confidence usually backfires and, as a result, less time is spent on science, as compared to other subjects (Czerniak & Lumpe, 1997). And, it indeed happened in Natalia's classroom. In Chapter three, in section 3.2.2.1, I write about her decision to terminate science to complete the curriculum of another subject. I reason, and she herself admitted that she did not feel confident to teach it. In her exact words, *"I felt unprepared, I felt that I did not have any knowledge in science, I did not know what to teach. I felt that I was only one hour ahead of students. I was even afraid of their questions. I was totally lost...I was looking forward to the professional days when I could meet other teachers and share ideas...."* (Teacher-Researcher Interview June 20, 2002). To me, it was disturbing to hear her make this comment. I am sure, though, that if she had taken a course that gave her an overview of science, she would have felt prepared to handle the questions and her teaching would have been different.

Neither Natalia nor Scott had the opportunity to take a science course that would prepare them to teach a wide spectrum of the K-8 science curriculum. Consequently, I propose that pre-service teachers are advised and/or required to take a course that explores science from an interdisciplinary perspective, with an aim to foster scientific literacy and develop critical thinking skills. Such a course needs to draw topics from biology, chemistry, geography and physics and these topics must be relevant to the

Manitoba elementary and middle years science curriculum. Understanding of the NOS should also be incorporated into the design of such courses.

The University of Winnipeg, for example, is taking steps to implement a multidisciplinary science course, which is aimed at Education and Liberal Arts students who want to learn a general science course at a qualitative level. It is a 6 credit hour course. The title of this course is *Science: A world view*, and it intertwines elements of Biology, Chemistry, Physics, and Earth Sciences. My experiences, research, and interest in teacher education were instrumental in the implementation of this course. I am also one of the educators, who have designed this course, and I am teaching parts of its curriculum. I teach the biology and chemistry components, and my colleague, Vesna Milosevich-Zdjelar, from the Department of Physics concentrates on physics and earth sciences. Like myself, Randy Kobes, who is the head of the Physics Department, and Annabelle Mays who is the dean of the Faculty of Education, also saw the need for this interdisciplinary course and helped me to initiate it on campus. It started as an experimental course in the summer session of the 2002/2003 academic year.

We designed the course, keeping Manitoba's conceptions of scientific literacy in mind. Through our course, students, future teachers among them, have opportunities to gain an understanding of general issues that affect their lives, such as rapid scientific and technological innovations, the need for a sustainable environment, economy, and society and the presence of science and technology in daily life. Thus, the course places science in the larger context of humankind and society. It stresses important environmental issues and provide students with knowledge that allows them to make informed decisions in regard to those issues.

The benefits of taking this course are twofold. Firstly students develop a general understanding of science from a multidisciplinary perspective. This understanding, in turn, allows them to be informed citizens and to use science in their everyday lives (Durant, 1993; Hazen & Trefil, 1991). Our overall motto is to teach the intricate mixture of facts, vocabulary, concepts, and history and philosophy to help our students understand public issues. Secondly, those students who are aspiring to become teachers are prepared to teach the Manitoba K-8 science curricula. I make this claim because the course was initiated with this purpose in mind and it incorporates most of the topics of those curricula. Hence, this course stresses the "what" of science. Furthermore, both Vesna and I incorporate history of science to our instruction, which helps our students with an understanding of the NOS. Hence, this course does not neglect the "how" of science. Specifically, we try to include short explicit examples to clarify and emphasize each of the six characteristics of the NOS, discussed in chapter two. It needs to be emphasized, however, that the aim of this course is to help our university students understand the K-8 science content, rather than the philosophy of science. We assume that the NOS is studied in detail in the science methods courses.

The course is gaining a great popularity. It started during the spring and summer session of 2002/2003 academic year as an experimental course for students who are seeking a Bachelor of Education degree from the University of Winnipeg. The course was initially offered for exclusively for students who obtain their degree through the

Winnipeg Education Center, which is affiliated with the University of Winnipeg. The center is an urban institution offering higher education for mature students, who have financial need and are often in difficult personal situations. Because of its popularity, the dean of education pushed for the course to be offered for the university community at large. In 2004/2005, our course was offered in the evening with an enrollment of 40 students. This year, 2005/2006, the course is being offered during the day with an enrollment of 101 students.

To make the elementary teacher preparation programs effective, I propose an approach similar to the one being tested at the University of Winnipeg. The assumption is that a teacher graduating from the University of Winnipeg acquires the subject-matter knowledge, with emphasis on the application of science and explicit instruction on the NOS through the multidisciplinary course in science. It is also assumed that through the science methods courses, the pre-service teachers gain further insights about the NOS so they feel comfortable and proficient in the preparation of the scientifically literate students. I also feel that it would be beneficial if the instructors involved in teaching the science content courses also had knowledge in the pedagogy of teaching science. This happened to be the case at the University of Winnipeg, where both Vesna and I are certified teachers, and we both have experience in teaching science methods courses. I have taught at both local universities, while Vesna has done it at the University of Winnipeg. Furthermore, I believe that it would be ideal if the same instructor(s) were teaching the science methods course and the science content course. I am presently discussing this matter with the dean of the Faculty of Education.

7.3.1.3 Recommendations for Professional Development

One needs to realize that learning to teach is a life long process. It starts at the university and continues in the form of professional development throughout teachers' in-service lives (NRC, 1996). Professional development for in-service teachers is seen by many as the best approach for changing teaching practices (Haney, Czerniak, & Lumpe, 1996; Supovitz & Turner, 2000; Posnanski, 2002). That change in the professional development practices is seen, by the current reform effort, as important as change in how science is taught (NRC, 1996). Natalia commented that she was unprepared, afraid of students' questions, lost, and that she was looking forward to the professional days to meet with the other teachers to share ideas. The professional days she was referring are one-day workshops for in-service teachers, offered by her school division.

I postulate that our contemporary model of collaboration can serve as a prototype for other school and university personnel who wish to combine forces in order to better prepare teachers as well as researchers. The fact that our partnership was long term and engaged the teacher as well as students in real teaching automatically gave it a contemporary status, contrary to one-day workshops, which are considered traditional (Darling-Hammond & McLaughlin, 1995; NRC, 1996). Furthermore, it allowed for the development of both subject matter and pedagogical content knowledge (Cohen & Hill, 1998). Because of our on-going conversations, our partnership was of reflective nature. In line with Yager's (2005) recommendations for a good professional development, it was thorough and the activities directly corresponded to the curriculum.

Our partnership also reflected the recommendations of the NRC (1996). Actually, it directly mirrored some of the professional development standards put forth by this organization. For example, Standard D (p.70) suggests that schools and higher education institutions must enter into true collaboration. The same standard continues that professional development activities should involve actual students, real curriculum, and real student work, which was the case in our situation. It also met the recommendation of NRC (1996b) and other organizations, such as NSB (1999) and NSF (1996), which advocate that practitioners from various fields should collaborate with public school teachers to achieve excellence in science education.

One of the rules of a good professional program is to have teachers continue implementing the ideas acquired through professional development into their teaching (Harcombe, 2001). Hence, it would be interesting to do a follow up study to see if, after collaborating with me, Scott used the CKCM or the ideas that we have developed in his teaching. Doing it, however, was impossible because after working with me, Scott was offered a position as a high school computer specialist in the Red River School Division (2003/2004 school year). A year after that, intrigued by the opportunities of associated with web design, he pursued a one-year Certificate in Web Design at the Continuing Education Division of the University of Winnipeg. To support himself during this program, he chose to work as a substitute teacher. At the same time, he also started, on part-time basis, a master's degree in the field of educational administration. He was, then, well on his way of becoming a school principal.

7.4 Recommendations for Future Research and Final Conclusions

As I continue my journey as a science educator, I would like to find out if the recommendations I made with respect to teacher education significantly influence teachers' understanding and classroom practice. I have realized that teaching about the NOS within the context of the science methods course has a positive impact on classroom practice. In order to portray the NOS to teachers and consequently their students, I used the CKCM. In this study, however, the NOS was taught implicitly in the elementary science methods course as well as grade five classroom. In my future research, I would like to find out what is an impact of explicit instruction about the NOS on pre-service teachers' understanding of the NOS and their ability to incorporate the NOS into their classroom practice.

In this study, Scott and I used the CKCM to develop scientific literacy of grade five students. This undertaking was not difficult, because every grade five student can contribute worthwhile ideas about weather. I also postulate that if we had used the CKCM in grade seven to study the unit on Weather, we would have been even more successful in our efforts to develop scientific literacy of students. Because of the spiral nature of the Manitoba science curricula, the grade seven students would have retained some of the knowledge they have acquired earlier, in grade five, for example. Hence, grade seven students would have offered sophisticated ideas about weather to be negotiated in the Constructing and Negotiating phase of the CKCM. I am wondering, however, if the unit on Simple Machines, in grade three would provide a good ground for the implementation of the CKCM. Hence, in my future research, I would like to use to CKCM in an earlier grade, such as grade one, for example.

Based on this study and my experiences, I have also concluded that elementary teachers are not adequately prepared to teach the science content of the K-8 science curriculum. Furthermore, to solve this problem, I recommended that universities need to offer courses that approach science from multidisciplinary perspective and that all pre-service teachers aspiring to teach either at the elementary or middle years level should be required to take such courses to feel confident to teach the curriculum. I would like to find out, however, what are the specific contributions of the multidisciplinary science course, I have developed at the University of Winnipeg, to teachers' practice.

I have learned a lot from Scott, his students, and this research project in general. It encouraged me to reflect on my own practice. Through this project I have learned how I can improve my teaching of the NOS in the context of the science methods course as well as biology in the context of the multidisciplinary science course. I would strongly recommend our approach to novice professors, researchers and graduate students who are interested in conducting their own research in the context of the classroom by working with teachers and their students and, hence, being involved in authentic situations. Furthermore, I would also recommend our approach to teachers who are interested in their own conceptual and professional growth by collaborating with others.

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Websites:

<www.floodwayeia.com>

Appendices

Appendix A

Calendar of planning (prior teaching events)

December 18, 2002 Meeting with teacher (Scott) and principal (Anna Zahn)

Time: 1 hour (after school; 4:30)

Location: Prairie View School

Objectives:

A) to personally talk to the teacher and principal,
B) to talk about ethics

Notes:

1. None of the conversations were tape recorded since, at that time, I have not received the ethics approval or the permission from the principal to conduct the study in her school.

January 8, 2003 1st interview with teacher (Scott)

Time: 2 hours (after school; 4:30)

Location: Prairie View School

Objectives:

A) to learn about Scott's background,
B) to talk about characteristics of an inner city school and his experiences in an inner city setting,

Notes: tape recorded interview

January 22, 2003 2nd interview with the teacher (Scott) and 1st and only interview with the principal (Anna Zahn)

Time: 2 hours (after school; 4:30) with Scott; 1 hour with Anna

Location: Prairie View School

Objectives:

A) to discuss Scott's views about scientific literacy,
B) to learn about the nature of Middle Years students (Scott),
C) to talk about characteristics of inner city school and students (Anna)

Notes: tape recorded interviews

February, 2003 Beata's research receives ethics approval

Proposal defense

March 11, 2003 Planning of the unit (P # 1)

Time: 2 hours (after school; 4:30) with Scott

Location: Prairie View School

Objectives:

A) to generally plan the unit

March 26, 2003 Letters and consent forms sent home by Scott

March 27, 2003 Beata visits the school to talk to the students

Time: 0.5 hour

Objectives:

A) to explain the purpose of the study
B) to explain student's involvement in the study
C) to distribute letters and consent forms to the students

Notes: All students signed the consent forms at me presence. I got two questions:

1. How old are you? (Shane)
2. If my mother did not sign, will I still be able to participate in your study and go on field trips? (Zoe)

March 30, 2003 Planning of the unit (P # 2)

Time: 4 hours; 10:00

Location: The University of Manitoba (spring break)

Objectives:

A) to plan in detail the first component of the unit

March 31, 2003 Planning of the unit (P # 2)

Time: 3 hours; 10:00

Location: The University of Manitoba (spring break)

Objectives:

A) to finish planning the first component

April 2, 2003 Planning of the unit (P # 2)

Time: 8 hours; 10:00

Location: The University of Manitoba (spring break)

Objectives:

April 21, 2003 Planning of the unit (P # 3)

Time: 2 hours

Location:

Objectives

May 4, 2003 Planning of the unit (P # 4)

Time: 4 hours

Location:

Objectives:

A) to plan the component on climate

May 9, 2003 Planning of the unit (P #4)

Time: 2 hours

Location:

Objectives:

May 13, 2003 Planning of the unit (P # 9)

Time: 1 hour

Location: Prairie View School

May 19, 2003 Marking

Time: 1 hour

Location: The University of Manitoba

Total hours of planning: 28

Marking: 1 hour

Appendix B

Ethics consent forms

March 26, 2003

Parent consent form

Research Project Title: Nature of scientific inquiry in a grade five science class.

Researcher: Beata Biernacka

Dear Parent/Guardian

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your child's participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take time to read this carefully and to understand the accompanying information.

I am a Ph.D. student at the Faculty of Education, University of Manitoba and I wish to conduct research in your child's science class. The title of my research project is: Nature of scientific inquiry in a grade five science class. I have chosen Brooklands School because the science teacher, Mr. Lister, was a student of mine at the University of Manitoba and I am interested in documenting how Mr. Lister translates the nature of science which was addressed in his Elementary Science Curriculum and Instruction class at the university into his classroom practice.

To fulfill this project, I will be visiting your child's science class for 6 weeks, starting on April 7th, 2003. In this research project, I will be audio-taping the dialogues that will take place between the teacher and the students and among the students themselves. However, please be informed, that only those students who give consent will be audio-taped. In addition, I would like to analyze written work done by your son or daughter, for example: science notebook, science journal, science assignments and tests. Thus, selected pieces of your son's/daughter's work might be photocopied.

Since the scientific inquiry will be a natural part of the learning of science concepts, I do not anticipate any disruptions to normal class routines. There will be no class time lost because the inquiry will be incorporated into the units of study as recommended by the science curriculum documents.

During the process of data collection, the information obtained from your son/daughter will be available only to myself, my research supervisor, Dr. Jazlin Ebenezer, and to the science teacher, Mr. Adam Lister. After the data have been collected and analyzed, I would like to use the excerpts of the audio-recordings and fragments of your child's written work in my Ph.D. dissertation. Hence, I wish to obtain permission from you to use the excerpts of the audio-recordings and fragments of your child's written work in my Ph.D. dissertation. Your child's name, though, will not be identified in my dissertation. The audio-tapes taken in your child's classroom will be erased as soon as they are transcribed for later analysis. Also, the photocopies of your child's work will be destroyed as soon as I am finished with analyzing them.

I would like to assure you that confidential records, such as: students' marks, health records, and personal records will not be consulted for the purpose of this study. Furthermore, I would like to emphasize that this study is looking very specifically at curriculum and instruction, not student performance. Hence, I will not evaluate your child's performance in the science class.

Throughout the course of this project, a summary of study results as well as a final summary, will be available to you, upon request, from me at the address provided in this letter. Please be informed that participation in this study is completely voluntary and your decision will <u>not</u> affect your child's grades, class standing or access to any school programs. Your child will also have the opportunity to withdraw from this study at any time and his/her withdrawal will not affect his/her class standing. To withdraw from the study you or your child should inform the teacher, Mr. Adam Lister. After the teacher has been informed your child will no longer be audio-taped and his/her written work will not be collected and analyzed.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to have your son/daughter participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. Your child is free to withdraw from the study at any time, and/or refrain from answering any questions he/she prefers to omit, without prejudice or consequence. Your child's continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your child's participation. You may obtain further information either from me, Beata Biernacka, , my supervisor, Dr. Jazlin Ebenezer, , or the teacher, Mr. Adam Lister, at

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-mentioned persons or the Human Ethics Secretariat . A copy of this consent form has been given to you to keep for your records and reference.

.... Date ....

Parent's/Guardian's Signature

.... Date ....

Researcher's Signature

My address: Beata Biernacka
The University of Manitoba
230 Education Building
Winnipeg, Manitoba
R3T 2N4
b.biernacka@uwinnipeg.ca

March 26, 2003

Student consent form

Research Project Title: Nature of scientific inquiry in a grade five science class.

Researcher: Beata Biernacka

Dear Student,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take time to read this carefully and to understand the accompanying information.

I am a student at the University of Manitoba and I would like to do research in your classroom. I have chosen your class because of your teacher, Mr. Adam Lister. He was a student of mine at the University of Manitoba and I would like to observe how Mr. Lister translates the information studied at the university into his classroom teaching. Thus, I will come to your class and watch how you and your teacher do science activities together. I would listen to your talks and take notes. I will also tape record you when you do science activities together. In addition, I would like to read your science notebook, science journal, and some of your science assignments and tests.

In your science class, the teacher will put all the students who wish to work with me in separate groups, and I will audio- tape only these groups of students. I will then listen to the audio tapes and keep only the parts that are helpful to me for my study. I will erase the rest of the audio-recordings taken in your classroom. After reading your science notebook and your science assignments, I might ask you whether I can make a photocopy of your written work, and give you back the original. But, I will not be upset with you if you do not want to give me your work. When I am finished with this project, I will destroy the copies . I will also ask you, your science teacher, and your parents/guardians to let me write about the science you are doing in your classroom.

I would like to assure you that I will not have any access to your marks, health records or personal records at any time during the study or after the study. In this study I am only interested in the curriculum and instruction, not your performance. Thus, I will not evaluate you in your science class.

I will share what I learned in your science class with your science teacher. I will also tell my supervisor, Dr. Ebenezer, at the university what you talked about in your science class. I will also show her your written work, and let her listen to the tapes. However, I will not use your name when I talk with her. Also, if I write anything in the future about this study, your name will <u>not</u> be mentioned.

I would really like you to work with me in this science project. But, if you do not want to show me your written work and allow me to audio tape you, neither I nor your teacher will be upset with you. Your teacher will not take any marks off from your class work just because you do not want to take part in this research project.

If you decide to work with me but later change your mind, that is also OK. You can stop at any time, and no one will be angry with you. To withdraw from this project, please inform your teacher. After your teacher has been informed you will no longer be audio taped and your work will not be copied and analyzed. And, if you do not agree to take part in this project, you will still take part in <u>all</u> science activities that your teacher planned for you.

While I am doing this project, as well as when I finish this project, I can send you something to read that will tell you about what I have found. If you wish to talk to me, show your work to me, and to allow me to take audio recordings of you, you need to sign this paper and return it to your teacher as soon as possible.

Before you sign this paper, I will come to your class and talk to you in class. At that time, you can ask me any questions you may have, and I will be happy to answer them. If you have any questions before the project begins, during the project, or after the project is over, you can ask your parents/guardians, your science teacher, or myself. As well you and your parents/guardians may phone me at the university. You and your parents/guardians may also call my supervisor, Dr. Ebenezer, at the university.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. You may obtain further information either from me, Beata Biernacka, at , my supervisor, Dr. Jazlin Ebenezer, , or the teacher, Mr. Adam Lister, at

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-mentioned persons or the Human Ethics Secretariat at . A copy of this consent form has been given to you to keep for your records and reference.

....	....
Student's Signature	Date
....	....
Researcher's Signature	Date

My address: Beata Biernacka
The University of Manitoba
230 Education Building
Winnipeg, Manitoba R3T 2N4

March 17, 2003

Teacher consent form

Research Project Title: Nature of scientific inquiry in a grade five science class.

Researcher: Beata Biernacka

Dear Mr. Lister,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take time to read this carefully and to understand the accompanying information.

As you are aware, I am a Ph.D. student in the Faculty of Education at the University of Manitoba. I am writing to you because, as we discussed over the phone, I am interested in conducting a research project with you and your science students. Although we have already talked about this project, I would like to provide you with more information.

For this project, I would like to visit your grade five science class on daily basis for a period of six weeks, starting on April 7th. I am interested in documenting how you translate the nature of science addressed in your Science Curriculum and Instruction class at the University of Manitoba into your classroom teaching. Hence, the science class conversations happening in your classroom will be audio-taped. However, please be informed, that only those students who give consent will be audio-taped. In addition, I would like to analyze selected pieces of written work done by your students, for example: science notebook, science journal, science assignments and tests. Thus, chosen pieces of your students' work might be photocopied.

As we discussed earlier, this project would involve both of us planning the science unit together and then you teaching it to your students. Since scientific inquiry is a natural part of the learning of science concepts, I do not anticipate any disruptions to normal class routines. There will be no class time lost because the inquiry will be incorporated into the units of study as recommended by the science curriculum documents.

During the process of data collection, the information obtained from you and your students will be available only to myself and my research supervisor, Dr. Jazlin Ebenezer. After the data have been collected and analyzed, I would like to use the excerpts of the audio-recordings and fragments of your students' work in my Ph.D. dissertation. Hence, I wish to obtain permission from you to use the excerpts of the audio-recordings and fragments of your students' written work in my Ph.D. dissertation. Neither your nor your students' names, however, will be identified in my dissertation. The audio-tapes taken in your classroom will be erased as soon as they are transcribed for later analysis. Also, the photocopies of your student's work will be destroyed as soon as I am finished with analyzing them.

I would like to assure you that confidential records, such as: students' marks, health records, and personal records will not be consulted for the purpose of this study. Furthermore, I would like to emphasize that this study is looking very specifically at curriculum and instruction, not student performance. It is anticipated that the results of this proposed study will contribute knowledge to the improvement of school scientific inquiry. Classroom findings may be used by science teacher educators for curriculum development and pedagogical decisions.

Throughout the course of this project, a summary of study results as well as a final summary, will be available to you, upon request, from me at the address provided in this letter. Please be informed that both yours and your students' participation in this study is completely voluntary, and that both you and your students will have a chance to withdraw from this project at any time. If a student wants to withdraw from the study he/she or his/her parent should inform you. After you have been informed the student will no longer be audio-taped and his/her written work will not be collected and analyzed. If you would like to withdraw from the study you need to inform me.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. You may obtain further information either from me, Beata Biernacka, at or my supervisor, Dr. Jazlin Ebenezer,

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-mentioned persons or the Human Ethics Secretariat A copy of this consent form has been given to you to keep for your records and reference.

....	....
Teacher's Signature	Date
....	....
Researcher's Signature	Date

My address: Beata Biernacka
The University of Manitoba
230 Education Building
Winnipeg, Manitoba

March 26, 2003

Principal consent form

Research Project Title: Nature of scientific inquiry in a grade five science class.

Researcher: Beata Biernacka

Dear Ms Thiry,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take time to read this carefully and to understand the accompanying information.

I am a Ph.D. student at the Faculty of Education, University of Manitoba. I am writing to you because I am interested in conducting a research project with one of the teachers, Mr. Adam Lister, and his grade five science students in your school. The title of this project is: Nature of scientific inquiry in grade five science class. I am planning on collecting data for six weeks, starting on April 7th, 2003. I have chosen your school because Mr. Lister was a student of mine at the University of Manitoba and I am interested in documenting how Mr. Lister translates the nature of science which was addressed in his Elementary Science Curriculum and Instruction class at the university into his classroom practice.

To fulfill this project, I will visit grade five science class and document the interactions and dialogues that will be taking place between Mr. Lister and his students and among the students themselves. Consequently, the dialogues happening in the science class will be audio-taped. All the students will be organized into small groups to conduct scientific inquiry. However, only those students who have consented to participate in this study will be audio-taped. In addition, I would like to analyze written work done by the students, for example: science notebook, science journal, selected science assignments and tests. Thus, some of the students' written work might be photocopied. However, I will photocopy only the participating students' work and return the original to them.

Since the scientific inquiry will be a natural part of the learning of science concepts, I do not anticipate any disruptions of normal class routines. There will be no class time lost because the inquiry will be incorporated into the unit of study as recommended by the science curriculum documents. It is anticipated that the results of this proposed study will contribute knowledge to the improvement of school scientific inquiry. Classroom findings may be used by science teacher educators for curriculum development and pedagogical decisions.

I would like to assure you that confidential records, such as: students' marks, health records, and personal records will not be consulted for the purpose of this study.

Furthermore, I would like to emphasize that this study is looking very specifically at curriculum and instruction, not student performance.

During the process of data collection, the information obtained from the students and their teacher will be available only to myself, the teacher, and my research supervisor, Dr. Jazlin Ebenezer. After the data have been collected and analyzed, I would like to use the excerpts of the audio-recordings and fragments of students' work in my Ph.D. dissertation. Hence, I wish to obtain permission from you to use the excerpts of the audio-recordings and fragments of students' written work in my Ph.D. dissertation. Neither teacher's nor students' names, however, will be identified in my dissertation. The audio- tapes will be erased as soon as they are transcribed for later analysis. Also, the photocopies of students' work will be destroyed as soon as I am finished with analyzing them.

Upon request, throughout the course of this project and at the end, a summary of study results as well as a final summary, will be made available to you, students, parents/guardians, teacher, and superintendent at the address provided in this letter. Please be informed that both the students' and the teacher's participation in this study is completely voluntary, and that they will have a chance to withdraw from this project at any time. If a student wants to withdraw from the study he/she or his/her parent should inform the teacher. After the teacher has been informed the student will no longer be audio-taped and his/her written work will not be collected and analyzed. If a teacher wants to withdraw from the study he needs to inform me.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. You may obtain further information either from me, Beata Biernacka, or my supervisor, Dr. Jazlin Ebenezer,

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-mentioned persons or the Human Ethics Secretariat at A copy of this consent form has been given to you to keep for your records and reference.

....

Principal's Signature Date

....

Researcher's Signature Date

My address: Beata Biernacka
The University of Manitoba
230 Education Building
Winnipeg, MB R3T 2N4

March 26, 2003

Superintendent consent form

Research Project Title: Nature of scientific inquiry in a grade five science class.

Researcher: Beata Biernacka

Dear Mr. Weston,

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take time to read this carefully and to understand the accompanying information.

I am a Ph.D. student at the Faculty of Education, University of Manitoba. I am writing to you because I am interested in conducting a research project in a grade five science class at Brooklands School. The title of this project is: The nature of scientific inquiry in a grade five science class. I am planning on collecting data for a period of six weeks, starting on April 7th, 2003. I have chosen the school from your division because the science teacher, Mr. Adam Lister, was a student of mine at the University of Manitoba and I am interested in documenting how Mr. Lister translates the nature of science which was addressed in his Elementary Science Curriculum and Instruction class at the university into his classroom practice.

To fulfill this project, I will observe grade five science class and document the interactions and dialogues which will be taking place between Mr. Lister and his students and among the students themselves. Consequently, the dialogues happening in the science class will be audio-taped. All the students will be organized into small groups to conduct scientific inquiry. However, only those students who have consented to participate in this study will be audio-taped. In addition, I would like to analyze written work done by the students, for example: science notebook, science journal, selected science assignments and tests. Thus, some of the students' written work might be photocopied. However, I will photocopy only the participating students' work and return the original to them.

Since the scientific inquiry will be a natural part of the learning of science concepts, I do not anticipate any disruptions to normal class routines. There will be no class time lost because the inquiry will be incorporated into the unit of study as recommended by the science curriculum documents. I would like to assure you that confidential records, such as: students' marks, health records, and personal records will not be consulted for the purpose of this study. Furthermore, I would like to emphasize that this study is looking very specifically at curriculum and instruction, not student performance.

During the process of data collection, the information obtained from the students and their teacher will be available only to myself, the teacher, and my research supervisor, Dr. Jazlin Ebenezer. After the data have been collected and analyzed, I would like to use the excerpts of the audio-recordings and fragments of students' work in my Ph.D. dissertation. Hence, I wish to obtain permission from you to use the excerpts of the audio-recordings and fragments of students' written work in my Ph.D. dissertation. Neither teacher's nor students' names, however, will be identified in my dissertation. The audio- tapes will be erased as soon as they are transcribed for later analysis. Also, the photocopies of students' work will be destroyed as soon as I am finished with analyzing them.

Upon request, throughout the course of this project and at the end, a summary of study results as well as a final summary, will be made available to you, students, teacher, parents/guardians, and principal at the address provided in this letter. Please be informed that both the students' and the teacher's participation in this study is completely voluntary, and that they will have a chance to withdraw from this project at any time. If a student wants to withdraw from the study he/she or his/her parent should inform the teacher. After the teacher has been informed the student will no longer be audio-taped and his/her written work will not be collected and analyzed. If a teacher wants to withdraw from the study he needs to inform me.

It is anticipated that the results of this proposed study will contribute knowledge to the improvement of school scientific inquiry. Classroom findings may be used by science teacher educators for curriculum development and pedagogical decision making.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. You may obtain further information either from me, Beata Biernacka, , or my supervisor, Dr. Jazlin Ebenezer,

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-mentioned persons or the Human Ethics Secretariat at A copy of this consent form has been given to you to keep for your records and reference.

....
Superintendent's Signature Date

....
Researcher's Signature Date

My address: Beata Biernacka
The University of Manitoba
230 Education Building
Winnipeg, Manitoba R3T 2N4

Appendix C

Student-parent interviews

Parents' ides on how people predict and measure weather

Conversation Excerpt 1: Ian interviewing his father

Ian: How do people predict the weather?

Father: O.K. when it is really cloudy it will rain, and when the geese are migrating the weather
is going to be warm.

Ian: How do you think people measure the weather? Like see how cold it is or how hot it is.

Father: They are using ***barometer****.*

Ian: Thermometer?

Father: Yeah, ***thermometer*** *too, yes. Like the meteorologist*

Ian: Yeah meteorologists. But, how do they do it? How do they figure it out?

Father: ***They have the instrument.***

Ian: What is the instrument?

Father: The instrument...(pauses). The name I do not know.

Ian: Right but....

Father: It will be like a thermometer. They also have a ***map like a computer map****.*

Ian: And how do they figure out the weather by a map? Like what the weather is going to be

Father: They see in the computer map that there are ***the clouds and if it is more cloudy*** *in there*
it is going to rain. I mean they see a dark cloud. When it is sunny, there are the clouds are so white like a snow white and it will be sunny.

Conversation Excerpt 2: Dorothy interviewing her mother

Dorothy: How do you think people predict weather?

Mother: By the aches in their bones. If their bones ache it means it is going to rain or there is going to be a bad weather. The older the people get the worst aches in their joints.

Dorothy: I do not know what you are talking about. But,...I, we do not know about that. Like can you make it better so I can understand you?

Mother: O well that is how older people predict weather if their joints are hurting.

Dorothy: No how people for news like news people how do they know if it is gonna rain or not.

Mother: ooooo....O.K., O.K. I get it now. They have a weather channel where they go and look on the map and they see different weather patterns they see the wind, they see different patterns to winds and weather, and this is how they are able to tell what kind of weather we are having today.

Dorothy: O.K. So, next I am gonna ask you how do you think that they measure weather? Like how long is it gonna rain.

Mother: Hm. I really do not know. I think they can tell by the type of clouds that they have up in the sky. I can not remember what types they are but, there is certain clouds that there is more rain that comes out of them. And other **clouds** *there is not that much rain. So they are able to predict just by the type of cloud and how much rain they are gonna get.*

Dorothy: O.K.

Conversation Excerpt 3: Timothy interviewing his parents

Timothy: Well how do you measure weather?

Father: Well, we measure weather by the thermometer we have outside our garage. Otherwise we go by what the newspaper and the T.V. tells us.

Timothy: Mom, How do you predict weather?

Mother: Well, a lot of times when there is a red sky at night there is an old saying that red sky at night sailors delight that means that there is going to be a very niece day the next day or a lot of times when the sky is red first thing in the morning it means that there *is rough weather coming our way. So that is one way how we predict the weather. Another way, you know, your grandpa tends to say that his bones are cold or his bones are aching. So, that is the way people usually predict bad weather or damp weather. But, there are also other ways to predict weather.*

Timothy: So that was my mom and dad predicting and measuring weather. Thank you and have a niece day.

Conversation Excerpt 4: Jessica interviewing her mother

Jessica: Mom, how do you think people predict weather?

Mother: Well, I think people predict weather by ...well depends who it is. There is a lot of old wise tales where like for instance growing up on the farm when the cows all huddle together there is gonna be a storm. It can become really, really calm where everything seems to be quiet, no wind or whatever and there is gonna be a storm. I just look at the clouds and if they look bad there is gonna snow or something depending on the color of the cloud and everything. There is your meteorologists they do all their satellite images, and that is how they predict it. They can see the direction of the wind, the clouds and the highs and the lows. They know what they are looking at, I do not, and the weather channel predicts it for me. So that is all I have to say about that one.

Jessica: Well, how do you think people measure weather?

Mother: They look outside and see how **much rain was in a bucket***. I do not know.*

Jessica: That is exactly it, the rain gauge.

Mother: Look I do not know that is how I measure it. Look outside the next day and see how much did it snow. It snowed four inches. I do not know how they, they have their special equipment to measure it.

Jessica: Instruments

Mother: Be technical

Jessica: What that is what they are called instruments.

Mother: O.K. What else do you need to know.

Jessica: That is it.

Mother: O.K. we are done I do not like being recorded here.

Conversation Excerpt 5: Yolanta interviewing her mother

Yolanta: How do people predict weather?

Mother: Some people read Farmers Almanac.

Yolanta: How people measure weather?

Mother: I do not know

Yolanta: You do not. Please mom, I need this for school
Mother: Some people predict the weather by where they live. If you are in the south, it is going to be warmer then if you live in the north.

Yolanta: Do you know anything about measuring?

Mother: No, I do not.

Conversation Excerpt 6: Sammy interviewing his mother

Sammy: How do people predict the weather?

Mother: I really do not like being recorded here but, for you Sammy I will do it and I will give it my best shot. People predict weather in ***many different ways****. When I was a little girl growing up on the farm in Saskatchewan my parents made us look at the weather. My mother for example looked at the* ***clouds,*** *if they were certain shape, then the weather would be sunny and hot. These clouds were usually fluffy and white looking. If they were sort of rainbows on each side of the sun, they were called sun dogs and in the winter they would mean a very cold weather. If the* ***animals*** *were seen storing away food, it would mean that it will be a very early winter. In the spring if the birds returned earlier, they everyone knew that the spring is just around the corner. Other people who suffer from arthritis can predict the rain and snow by the* ***pain and discomfort in their joints****. And, people who predict the weather for living are called the* ***meteorologists****. They use* ***computers and other high-tech equipment*** *and certain types of* ***weather maps to predict*** *storms. Weather can change from hour to hour depending on where you live, no one can accurately predict weather all the time. Today we have a prediction at our finger tips by* ***going on line*** *or watching a* ***weather channel****, we can get it in the matter of seconds. Technology has come a long way since I was a little girl.*

Sammy: And how do you measure the weather?

Mother: In terms of measuring the weather, people can use a different types a gages. For example, ***a yard stick*** *could be stack into the snow to measure the amount of snow fall.*

*An **anemometer could be used to measure the wind velocity**, some farmers have a **mill that tells them the wind direction.** There are **thermometers** to measure how hot it is. Almost every house has one inside and out. Weather stations use **barometers** to measure the **barometric pressure** in the air. There are **certain figurines that change colors** for rain, sun, but they are not very reliable, etc.*

Conversation Excerpt 7: Peter interviewing his mother

Peter: How do people predict the weather?

*Mother: They use the **radar, satellite**, they watch **TV** for the weather information. They can look outside, if it is cloudy, sunny, windy, just by going outside.*

Peter: And, how people measure the weather?

*Mother: They use some sort of device. Like in the old days, they used to do a **rain bucket** to know the amount of snow or rain. Now there are **more sophisticated things to track weather**.*

Conversation Excerpt 8: Joey interviewing his mother

Joey: How people predict the weather?

Mother: I have no idea how the weather is measured. You mean snow and rain.

Joey: Ya stuff like that.

Mother: I think they use some sort of measuring thing when precipitation falls in it they know how much it was snowing.

Conversation Excerpt 9: Kathy interviewing her cousin

Kathy: How do you think people predict the weather?

*Cousin: I think they just **go outside and feel** how the weather is going to be like? I think they use **computers and stuff like big things.***

Kathy: Do you thing that they use big instruments or just home made products?

Cousin: I think that they use big home made instruments.

Kathy: Do you have an example, like any example at all?

*Cousin: I think that **satellites send information to the computers and stuff.***

Kathy: Very good. Do you have any other ideas.

Cousin: No

Conversation Excerpt 10: Kathy interviewing another cousin

Kathy: How do you think people predict the weather?

Cousin. I think they go ***outside and feel the weather*** *and they experiment with the big things,* ***like big machines.***

Kathy: Do you think they use big mechanical instruments or home made products?

Cousin: I think they use big mechanical instruments.

Kathy: Do you have an example?

Cousin: I think they use ***big computer.***

Kathy: How do you think people measure the weather.

Cousin: I think they use a ***big thermometer*** *and take the temperature.*

Kathy: How do you think people use the thermometer? Like what I mean is where they put this thermometer. Do they put it in the air, or grass, or do they leave it somewhere. What do you think.

Cousin: I think they just stick it in the air.

Kathy: What about measuring the amount of rain?

Cousin: I think they have a special ***instrument*** *that they can use to see how much it has rained.*

Kathy: O, it is very good. It is almost like a real thing. I am impressed with you. So do you maybe know how people measure how fast wind is going?

Cousin: Well, I think they have a ***wind tracker*** *and when the wind goes by it takes speed.*

Kathy: Ok, that is a really good guess. Good imagination.

Conversation Excerpt 11: Anthony interviewing his mother

Anthony: How do you think people predict the weather?

Mother: It depends on the day. If the day is windy, and cloudy, we can expect to have a thunderstorm. This is how I predict it.

Anthony: How people measure weather?

Mother: They measure the temperature. The weather man have the instruments. On the sunny day, they have degrees Celsius. If it is 25 degrees, it is going to be quite warm. And, if it is 45 degrees, it is going to be very warm.

Conversation Excerpt 12: Matthew interviewing his brother

Matthew: How do you people predict the weather?

Brother: They are ***meteorologists*** *and they go and check what the weather is going to be like and then when they are done, they go and post if on the* ***computer****. And people can go and check on the computer weather chanel.com. If people do not have computers, they can check on* ***T.V.***

Matthew: How people measure weather?

Brother: They use ***thermometer****,* ***barometer****, and* ***anemometer****.*

Conversation Excerpt 13: Emillio interviewing his mother

Emillio: How do people predict weather?

Mother: Some people can smell that the rain is coming?

Emillio: Like the moisture you mean.

Mother: And they can also predict if it is going to be a long shower or not. And does not rain in one spot. Sometimes it rains in different spots, especially here in Manitoba.

Emillio: Ya. Do you know how people measure weather?

Mother: Just like what I told you. Sometimes they use these ***practical items****, like a* ***bucket****. They put it outside and measure.*

Emillio: That is called the rain gauge mom.

Mother: Yes, the rain gauge. And, they will use some kind of wind.

Emillio: That is called anemometer mom.

Mother: Something like ***a fan****. And they put them up on the trees and stuff.*

Emillio: That is called the weather wane.

Mother: And they see the horizon, and they can ***only predict not be very sure****. Like they have a special* ***gadget*** *not even in the city, but, also on the outskirts.*

Emillio: So what you are saying is that they use a special kind of instrument, like a thermometer

Mother: I do not know the names of those things

Emillio: Ya, I understand, I know some. So what you are saying is that the meteorologists predict it by using computer.

Mother: Ya, it is ***computer*** *based now and the special instrument is sending it to the computer.*

Emillio: So you are saying that meteorologists measure weather with different instruments

Mother: Yes, even as simple as the weather wane or buckets to put outside, maybe three or four of them in different areas and maybe the bucket that has more water will have more rain in the area. Or the one that has nothing at all must be sunny. So ***I think that is my generations knowledge.*** *Thank you.*

Emillio: Thank you.

Conversation Excerpt 14: Hanna interviewing her mother

Hanna: How do you think people predict the weather?

Mother: People who predict the weather on ***T.V look at the weather****, they can see a* ***weather front coming from different country or different province****. They can kind of predict that it will be coming this way or something like that.*

Hanna: How do you think people measure weather?

Mother: Measure weather, Hm, What do you mean by that?

Hanna: <u>I am not talking about something like sticking the broom in the snow and measuring how much it equals</u>. I am talking about something like how people measure weather with the thermometer. So, I am asking you to tell me what kind of instruments people use to measure weather with.

Mother: ***Thermometers, barometers****. Just looking outside you can tell what the weather is going to be like, on the computer* ***watching the weather patterns****. That is it.*

Hanna: O.K. Thank you.

Conversation Excerpt 15: Isabella interviewing her mother

Isabella: How do you think people predict the weather?

Mother: I think people predict the weather by ***watching T.V. radio, computers, dark clouds means that it is going to rain.***

Isabella: How do you think people measure the weather?

Mother: They use ***thermometer, barometer****, and they* ***look outside****, high temperature and low temperature.*

Conversation Excerpt 16: Alek interviewing his father

How come they have satellite weather maps?

How come there is such a thing as a weather gage?

What do they mean by humidity?

What do they mean by visibility?

What does a barometer do?

Alek: Do you believe in folklore?

Father: Yes, I do believe in it to a degree. Like red sky at night sailors delight, red sky in the morning sailors take warning means that the storm is coming.

Alek: How come the weather stations are not always right when they predict the weather?

Father: Because it is not an absolute science predicting the weather, that is why it is called predicting.

Conversation Excerpt 17: Rose interviewing her father

Rose: How do you think people predict weather?

Father: By using a ***thermometer*** *and they also* ***review the weather of the past*** *year on the same day.*

Rose: How do you think people measure the weather?

Father: People measure the weather through a ***barometer.***

Conversation Excerpt 18: Bonny interviewing her mother

Bonny:

Mother: Satellite imagery, Doppler radar, maps,

Bonny: People measure the weather by sending the balloons up and weather station which measures the humidity, wind speed and precipitation.

Conversation Excerpt 19: Kristofer interviewing his mother

Kristofer:
Mother: Satellite, radar, watch T.V. Looking outside to see if it is cloudy, sunny, and windy.

Kristofer: ***Some sort of device. In the old says, they used a rain bucket to see how much snow or rain fell.*** *Now there are more sophisticated things.*

Appendix D

Aboriginal legend

Mr. Birdie: He is telling another story about the same little guy, "Chakapish" means midget okay, Chakapish. I will tell you a little bit about this guy because he lived a long time ago. He had many, many events, many things happened to him over time, so I will only tell you a little bit about him. Now Legends are stories, they make up stories, they don't really happen, but they make up these stories. We know they are not true but it is nice to listen to them anyway. Legends it happened sometimes in real. The stories tell us to obey, obey your parents, obey your grandparents. They made up the stories and little guy, the midget. Sometimes I mean he did not listen and he had to be rescued by his sister. I am going to speak to you about just this one guy and his sister. At one time they had two parents, they lived in the wilderness and their parents were young and they were very happy together, and there was a little girl first and then the little one. The little girl was about 4 years old when the boy was born and he used to be known as "Chakapish". So when he was about 5 years old his parents were killed by the, by the giants. There were bad giants on their and they came out and killed their parents. They ran away, the sister and the little boy, they escaped to hide, so they hid and they survived and lived on their own in the wilderness. The sister who was 8 year old, she had lessons she had learned from her mother how to live, how to do things and she knew how to take care of the little boy. So they lived in the wilderness by themselves away from the giants who scared them away. And so because they are by themselves, they were protected by the great spirit, god, you know god,

O.C. Mr. Birdie points at the ceiling/sky.

Mr. Birdie: God, he protected them. No many how dangerous it was in the wilderness they always knew a little girl who looked after the little boy was given all the knowledge and inner strength to look after the little boy. Many years later the sister became to be a lady and the little boy remained 5year old, the size of a 5 year old but he was 15, 18 and then a young man, but he remained small and he behaved like a little boy, too. Sometimes he didn't listen to his sister when his sister said don't do that. And he said O.K. sister I won't do that and then he goes and he would do all of that and get in trouble, and then he would call his sister to help him, to come and save him, and it happens all the time. There was this one day, he just walked into the wilderness he found a large lake and, a pond, you know, and the river that runs out of it and he started to wonder if there were any fish in it and if they are big, and he wondered what kind of fish they were. So he went back to tell his sister that he saw a lake with fish and he didn't know what kind of fish. So his sister says don't you ever go into that lake because that lake is very bad and the fish there are big and they will swallow you. So, he said ok, ok sister I promise, but he was very curious to know how big there were so he went back to the lake. In the morning, turned right there. So when he got there he was wondering how he was going to get those fish to jump. So he had this little ball and he started throwing it in there and the fish started jumping up and a big splash came up and a giant fish had

jumped and finally it pops up and he decided he should swim with the fish even though he was told not to. So, he jumped right in. As he was swimming, he was teasing the fish, he said here fishy, fishy, come and swallow me. He was teasing the fish even though his sister did not approve. Then all of a sudden the big fish came up, big splash and he was swallowed, the whole body went right in. And he called for his sister to save him. Sister I have been swallowed by a fish. At the same time, his sister was sitting at home, she could hear her brother yelling for help. So, she started walking towards the lake and then she made a hook with bait and she throws it towards the fish and she tried three times and finally the fish grabs it. Then, she started pulling and pulling and the big fish came to the shore. Then, she took a big knife and started cutting the fish. As she was cutting, she heard a voice: do not cut me, do not cut me, hi, hi, hi. By this time the sister is very mad. Why did you have to go to the lake. I told you not to go to the lake and she was very mad. Why did you have to do it? I am sorry, I promise I will not do it again. Promise. Promise. So he was very shameful and they went home again that night. But, he forget and he went into trouble again and the sister had to rescue him again. So that is the end of this story okay, about the fish. But the story goes on for 15 sections, O.K. I can sit here the whole day to tell you about it. There are five other stories like that so they call them legends. We listen to those stories again and again and we memorized them and that is why I am able to tell you this story again. Sometimes we told the stories to each other, of course we forget. And this is what I have done I remembered those stories so now I travel places with those stories.
I go to the big cities and talk to the little children like you. Sometimes they sit around me. Sometimes they are really good and sometimes they fight with each other so I stop for a while and they listen again. Sometimes I put the kids to sleep. But this is what the stories are supposed to do they are supposed to calm you down and to relax you and take your mind to another time and place that happened a long time ago. So, our stories are like books, like a history book or any other book, our stories are like that. Because our people, our people long time ago when I was young, they did not live in the cities, they did not live in towns. They lived in wilderness and every day they moved to learn something new, and they did not carry the books so we had our grandparents' stories. O.K. stop for a while. At least for a while.

Scott: Sure

O.C. Mr. Birdie pauses for a while after finishing the story about "Chakapish".

Mr. Birdie: O.K. If you want to ask questions that is fine with me.

Shane: How strong was this little guy?

Mr. Birdie: Chakapish

Shane: In the story, he, he is very strong.

Danny: Are some of the legends true?

Mr. Birdie: Not really, just part of them they make them sound so ridiculously untrue that is for you to laugh, and some part it is true. They made them that way so we could listen to them. We did not have anything like you, like radio or music. All we had are our grandparents to listen to them. Our entertainment, we did not have anything

Hanna: What language do you speak?

Mr. Birdie: That language that you heard is the Cree language. I speak just two languages.

Shane: What was the name of that boy?

Mr. Birdie: The boy in the story I just told you? That Chakapish, Chakapish story.

Weather station-to-station test

Name ________________________.

Mark ________________________.

Station 1

Questions

1) What weather saying do you know that this picture represents?

____

2) Do you believe in Folklore? Explain why or why not.

Station 2

Questions

1) On this webpage you can see that scientists have take pictures of weather. What instrument did they use to get these photographs?

2) Look at how the weather is moving in the picture. What kind of weather do you expect here in Winnipeg in the near future?

Station 3

Questions

1) Name the weather instrument that you see in the drawing. ________________
2) Explain how this instrument works using pictures and words.

Station 4

Questions

1) What is the name of this weather instrument? ____________________
2) What does this instrument measure? ______________________________
3) What is the current reading on this instrument? __________________
4) There are three things you must do to get an accurate reading when using this instrument. Name 1 of them.

____

Station 5

Questions

1) What is the name of this weather instrument? ____________________
2) What does this instrument measure? ______________________________
3) What is the current reading on this instrument? __________________
4) According to the Beaufort Scale, what would the wind speed be in Km/hr?

____

Station 6

Questions

1) What is the name of this weather instrument? ______________________
2) What does this instrument measure? ______________________
3) What is the current reading on this instrument? ______________________

Station 7

Questions

1) Looking at the bottle, what do you predict will happen if you blow into the balloon?

2) Explain why this will happen. (Use words and drawings)

Station 8

Questions

1) What do you believe would happen to this balloon if you leave it in a freezer?

2) Explain why this will happen. (Use words and drawings)

Station 9

Questions

1) What is the name of the type of cloud in the picture? ________________

2) When you see these clouds in the sky, what kind of weather can you expect?
____

Station 10

Questions

1) What is the current temperature? ____________________
2) What direction is the wind coming from? ___________________________
3) What is the wind speed? ___________________
4) What does the forecast predict for tomorrow's weather?
____

Station 11

Questions

1) What is the name of this structure? ____________________
2) What is this structure used for?

3) Why is it important to use this structure?

Station 12

Questions

1) After looking at the chart provided at the station, do you believe that long-term weather forecasts are accurate? Explain why or why not.

3) Why do you think there is such a difference between what scientists predicted for this day, and what they actually measured?

Station 13

Questions

1) Explain what is happening in this diagram and why it is happening.

2) What kind of weather would you expect when this happens?

Station 14

Questions

1) What do you call a scientist who studies weather? ____________________
2) One major part of a scientist's job is to share what they have found in their studies. Give 3 ways that scientists share the information that they collect about weather.

____

____

____

Station 15

<u>Questions</u>

1) How do people measure and predict weather? Use pictures and drawings.
   (Give as many ideas as you can!!!!)

How People Predict	How People Measure

Appendix F

Long answer test

Science Test
Our Study of Weather

____

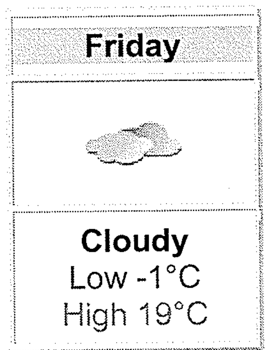
Name

1) How did the work of Sir Francis Beaufort help us to better understand weather? (1 mark)

2) Why do you think that the measurements that we took with our weather instruments were different from those that scientists took? (1 mark)

3) How do floods form, and what should people do to prepare for a possible flood?

4) Look at the weather forecast below.



How would you dress for this day? Why? (1 mark)

What advice would you give to people so that they can plan their day out for this day? (1 mark)

5) Are scientists always correct? Give examples to support your answer. (2 marks)

6) Explain the difference between weather and climate. Give one example of each. (2 marks)

____
____
____
____
____
____

7) Each place on the globe on the next page has a different climate. Explain what the climate would be like would be for each place and why. (2 marks for each one)

a) Winnipeg, Manitoba, Canada

What is the climate like here?

____
____

Why is it like this (What causes this change in climate)?

____
____

b) Vancouver, British Columbia, Canada

What is the climate like here?

____
____

Why is it like this (What causes this change in climate)?

____
____

c) Peurto Plata, Dominican Republic

What is the climate like here?

____

____

Why is it like this (What causes this change in climate)?

____

____

8) How do you think working in groups has improved your learning and understanding in science?

____

____

____

____

____

____

Appendix G

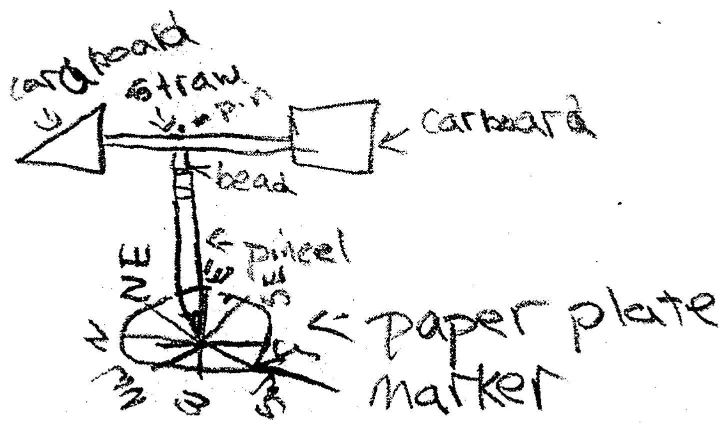
Weather instrument brochure

Weather Instrument Brochure

Name: [redacted]

For this assignment you must draw and label your instrument in the box below, and then provide step by step instructions on how to use it.

Weather Vane



- step 1, make it face north by the compass,
- step 2 wait until the wind picks up,
- step 3 wait until the arrow stops.
- step 4 look were the arrow is pointing.
- step 5 tells you were the wind is coming from.

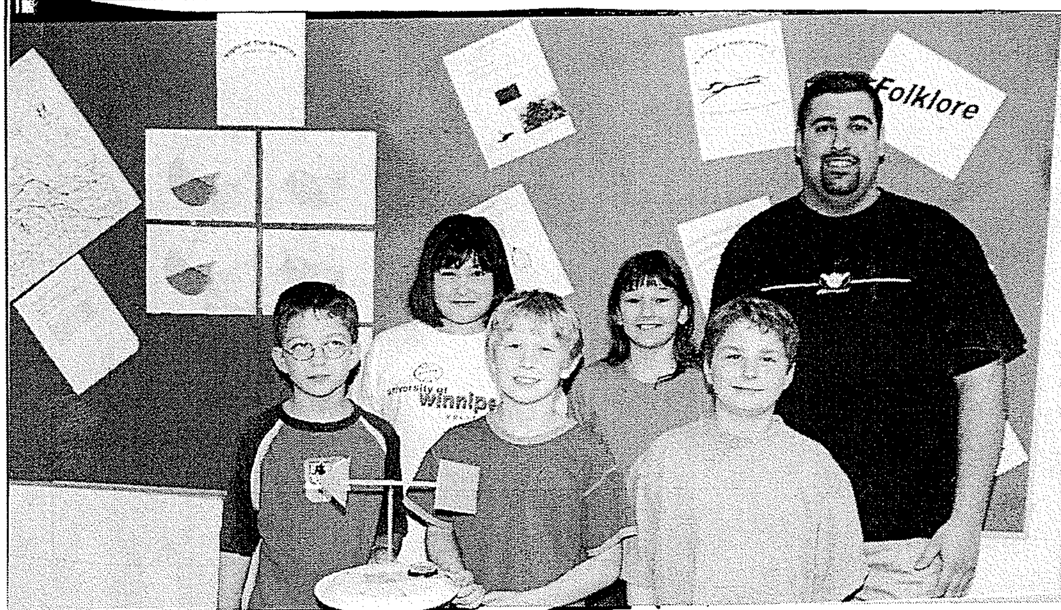
My Design Journal

Write a detailed description about how you and your group made your instrument from beginning to end. (Include research and planning)

First we designd a type of weather what we would use. Next we made sure who brings what types of things for the weather vane. Next day we started to make a weather vane and finished it in 15 to 20 minutes. After we were finished we worked on our activity books.

What did you learn about weather, through building this instrument?

I learned about weather that you cam make weather things to help predict the weather. Another thing is I learned that you can use the things to set up your weather station.



My Weather Instrument

Our instrument is called the weather vane, it spins around, and if it points on north the wind is coming from north. We use card board for the tail, and the front arrow because paper would be to light. We used a straw with cuts at the ends of the straw for the arrow, and the tail. Next you get a sharp pencil and put it in the middle of the paper plate. After you make lines with a ruler, and mark North, NE, East, SE, sorth, SW, west, and NW. When done that you put a bead on top of the eraser on the pencil, then you put the straw with the arrow, and the tail on top of the bead. After you finish by puting the pin though the straw and into the eraser, and put tape for the arrow, and the tail to stay on.

Appendix H

Letter to a Kindergarten Class (by Sammy)

Your letter must be written like an actual letter, because the teacher in that room will choose the best letter to read to their class as a lesson.

Dear Kindergarten class,

I'm here to tell you about floods. We have to look out for floods, because they can kill you if you don't know what to do. Thats why I'm writing this letter. floods occur when it is raining for a long time. It can also happen when it snows. When the snow melts, it turns into water. Floods are when to much water comes to a place and drowns that place. People can lost their hauses. The flood will break them down. The way you can prepare for a flood is to start sandbagging going to a high place. You can make a survival kit to prepare for a flood. It should include a rope, life jacket, extra clothes, food that dosn't rot and medicine. A flood can ruin peoples lifes.