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University of Alberta

Elementary Science and Teacher Development: Examining a Situation

by

Sandra Lee MacNey Guilbert ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Department of Elementary Education

Edmonton, Alberta
Spring 2002

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Elementary Science and Teacher Development: Examining a Situation* by Sandra Lee MacNey Guilbert in partial fulfillment of the requirements of the degree of Doctor of Philosophy.

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ABSTRACT

In the mid-1990s, the Alberta government cut provincial spending substantially. A Three-Year Business Plan to restructure education and a Quality Teaching initiative were also issued by the provincial government. In 1995 a revised provincial elementary school science curriculum was released. I was concerned with the number of changes being made in a fairly short period of time, but uncertain if these changes posed any problems for teachers or students. To ascertain if a problem or problems did exist, I undertook this study.

Through my examination of elementary science curriculum documents, teacher professional development in six Alberta school districts, and perceptions of exemplary science lessons described by selected Albertans, the situation gained clarity. My analysis, using the Dewey/Schwab theory of levels of intellectual space, indicated that problems did exist. First, an analysis of the curriculum documents (the Program of Studies, provincially-prepared assessment materials, and provincially-authorized teaching resources) indicated a strong provincial emphasis was placed on students acquiring Correct Explanations (Roberts, 1982). This is a problem as such lessons involve students predominantly in procedural science, in activities located in the first and second levels of intellectual space. Additionally, the science lessons described as exemplary by many study participants would involve students predominantly in the first and second levels of intellectual space. Finally, the professional development being offered to teachers was also primarily procedural in nature, involving teachers, too, in activities located in the first and second levels of intellectual space.

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Through this research, problems and a desirable goal (support for students and teachers to commonly operate in the third and fourth levels of intellectual space) co-emerged. In order to help ameliorate the problematic situations identified, I conclude with recommendations for conducting future deliberations on why science should be taught in elementary schools, what science should be taught, and how best to teach that science, "a process in which all pool their ingenuities, insights, and perceptions in the interest of discovering the most promising possibilities" (Schwab, 1983, p. 255).

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Part III Clarifying the Problems and Recommending Future Deliberations

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PART I

INTRODUCING

THE

STUDY

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CHAPTER ONE

INTRODUCTION

"Science is all the wonder things - all the things you wonder about. A scientist studies everything almost, like all the wonder things. Like you wonder, 'Is there an end to space?' It's probably a scientist who discovered there's no end to space" (McNay, 1985, p. 375). These are the views of eight year old Martin who is himself a wonderer. Characteristically, young children start school curious and full of questions about their natural world. At the end of elementary school they may be more fascinated, more knowledgeable, and more capable of exploring this world, or, conversely, convinced that science is dull, uninteresting, and difficult to learn.

In elementary school science children can be offered opportunities to explore and make sense of aspects of their natural and technological world. Through their own scientific explorations students can learn about the nature of science; that is, about how science is done and how communities of scientists negotiate knowledge in their areas of expertise. Science lessons of this type have been described by Reardon (1996) as meeting the criteria of real (the problem is a real one for the students), relevant (the lessons is relevant to the experiences of the students), and rigorous ("the children are doing what real scientists do – asking questions, talking, writing, challenging each other, explaining, testing, comparing, thinking, confirming, revising, planning" [p. 18]).

Through investigating science topics related to their natural and technological world, students come to better understand how science is related to their lives and to issues of importance in that world (American Association for the Advancement of Science [AAAS], 1994; Council of Ministers of Education, Canada [CMEC], 1997; National Research Council [NRC], 1996). Reading about and discussing historical developments in science also help students develop knowledge of both the nature of science and of science concepts.

Elementary school science, thus, lays a foundation for future science learning and can strongly influence children's view of science and their future interactions with this subject.

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This is a view of what science can be, and is in some elementary school classrooms. I live in Alberta; I am interested in the science education received by children in the elementary classrooms in this province. I am also interested in the provincially written and mandated science curriculum and its effects on science education in the province. It is this curriculum I will discuss briefly in the following section to help set the context for this study.

Elementary School Science in Alberta

In Alberta the Minister of Education "may prescribe courses of study, including the amount of instruction time, and authorize education programs and instructional materials for use in schools" (Province of Alberta, 1988, p. 19). And, in fact, the Minister does prescribe courses of study for all subject areas in grades one to twelve, and orders revisions to these programs in a rather regular cycle. As part of this regular cycle, in 1991 the Minister approved a proposal to revise the elementary school science curriculum, leading the Curriculum Standards Branch of the Department of Education to undertake a rewrite of the then current elementary school science curriculum, a curriculum that had been developed in 1980 and revised in 1983[1].

Four years later, after writing and circulating for comment a number of draft elementary science curricula, the Alberta Department of Education sent a copy of a final draft of the revised *Elementary Science Program of Studies* (Alberta Education, 1995a) to all elementary schools in the province. In a slightly-modified form, this became the official program in 1996 with full implementation mandatory in the 1996-1997 school year. Hereafter I will refer to the 1996 elementary science program.

Comparing the new science curriculum to the old, teachers would have noted a number of obvious differences. The 1980 elementary science curriculum (with minor revisions in 1983) repeatedly stated that "The major emphasis of the Elementary Science program is on the development of the process skills within the framework of an inquiry approach to teaching science" (Alberta Education, 1983, p. 20). Skills development was

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[1] While the term revision is used in government communications to describe a change in curriculum, new curricula are often very different from the curriculum they replace, both in form and in feature.

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also acknowledged as one of the three overarching goals of science education in the 1996 document, but much more emphasis was placed on the development of scientific content knowledge, "building a foundation of experience and understanding upon which later learning can be based" (Alberta Education, 1996b, p. A.1).

The 1983 curriculum document specified core topics to be taught in Division One (kindergarten to grade three) and in Division Two (grades four to six) and, in a brief paragraph, outlined the major conceptual underpinnings of each topic. Suggestions were also given for elective components, meant to comprise 20-30% of the science program, "to provide teachers with greater flexibility in planning their programs to meet student needs and interests and to utilize local resources" (Alberta Education, 1983, p. 13). In contrast, the 1996 science program, in response to educators' suggestions gathered in a Department of Education-sponsored Needs Survey, was a grade specific program listing five topics to be taught at each grade level. Specific learner expectations were listed for each of the 30 mandated topics, a list of between 4 and 14 statements of what students will do while engaged in the prescribed studies.

Although science process skills had been emphasized in the older curriculum, the list of authorized learning resources included three sets of textbooks that could be used to teach the science curriculum. In 1996, however, no student textbooks were included in the list of authorized resources.

These differences represented a considerable change for teachers. All teachers would be teaching topics of study they had never taught before, including one topic at each grade level emphasizing "problem solving through technology," topics intended to involve students in designing, building, and evaluating different types of products. There would be no textbooks to rely on; students were to be involved in hands-on inquiry and problem-solving exercises. Such activities meant acquiring materials for students to work with, finding places to store these materials, and finding teaching resources with ideas for activities to teach students the science facts and concepts listed in the Program of Studies. Also, a careful reading of the Program Overview would have revealed a shift from the 1983 process skill orientation toward a more constructivist perspective on children's learning.

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Cutbacks in Spending on Education

During the time the elementary science curriculum was being revised, the provincial government ordered substantial cutbacks in spending in all areas under provincial jurisdiction. This, of course, included education. Then Minister of Education Halvar Johnson wrote, "On January 17, 1994, Premier Ralph Klein announced a four-year-reduction target for education of 12.4%, the lowest of the major spending departments... The following day I announced plans for a major restructuring of the education system to focus resources on students in the classroom, ensure more decision-making at the school level, lower administrative costs, and put in place a fair system of funding for education" (Government of Alberta, 1994, p. 2).

These restructuring plans were released in a *Three-Year Business Plan* (Alberta Education, 1994b) created to provide "direction for the future of education in Alberta" (p. 2). One of the goals stated in that plan was to "improve teaching." The impact on teachers of the strategies taken by the provincial government to "enhance the quality of teaching in Alberta" (Alberta Education, 1996c) was of additional interest to me, a topic addressed in the next section.

Quality Teaching

A 1994 news release by the government of Alberta highlighting details of the recently released *Three-Year Business Plan* for education listed, under the heading of Improve Teaching, three strategies:

- Update teacher preparation and certification requirements.
- Establish competencies for beginning and experienced teachers.
- Provide for flexibility and new initiatives in delivering teacher in-service.

(Government of Alberta, 1994, p. 3)

The last statement, however, did not actually appear in the 1994/95 – 1997/98 business plan, but did surface in the 1995/96-1997/98 plan as "Develop a coordinated approach to the delivery of professional development opportunities for teachers" (Alberta Education, 1995b, p. 15).

Having identified regional professional development consortia as a means "to support the successful implementation of school jurisdiction goals... as well as the goals and strategies of the Alberta Education three-year business plan" (Alberta Education,

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1996a, p. 1), three year provincial funding for up to six regional consortia was announced in June of 1995. The first joint proposal approved by the Minister provided for "in-services to support the implementation of school councils in Alberta" (Alberta Education, 1996a, p. 2), not an initiative for "the delivery of professional development opportunities for teachers" (Alberta Education, 1995b, p. 15), the goal stated in the business plan.

To "establish competencies for beginning and experienced teachers," the second stated strategy to improve teaching, a Quality Teaching Standard and descriptors were prepared and authorized under Ministerial Order. As well, the *Provincial Teacher Evaluation Policy* was amended to require boards to "identify and allocate resources to contribute to individual teachers' professional development" (Alberta Education, 1996c, p. 11) and all teachers with teaching contracts were to "be responsible and accountable for developing, implementing, helping to monitor and reporting on their annual individualized professional development plan" (p. 12), this plan being a new addition to the list of teacher responsibilities outlined in provincial documents.

Approaching the Study

As a parent, as a teacher, and as a teacher educator I was concerned with the number of changes to elementary school science education and to the teaching profession being mandated in a fairly short time period and during a time of province-wide budget cuts. But was there a problem? Seeking answers to that question set the purpose for my study. Schwab's (1978) statement expresses my quandary as I started this study:

> We may be conscious that a practical problem exists, but we do not know what the problem is. We cannot be sure even of its subjective side – what it is we want or need. There is still less clarity on the objective side – what portion of the state of affairs is awry. These matters begin to emerge only as we examine the situation which seems to be wrong and begin to look ... for what is the matter. The problem slowly emerges... (Schwab, 1978, p. 290).

Research Questions

> First we need to decide *why* we want to teach science to our young people; from that we can perhaps work out *what* we want to teach them. Then research, linked closely to the development and evaluation of teaching materials and approaches, may be able to help us discover *how* best to teach these ideas (Millar, 1996, p. 17-18, emphasis in original)

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Guided by a general unease with the environment into which the new science curriculum was being introduced, I wanted to learn more about what was happening to the science curriculum at the school district and school level. To that end the study was designed to be exploratory; my intention was to gather data that could help me better understand if there was a problem with the science instruction being offered elementary students and the science education professional development being offered elementary school teachers.

What was to be taught was quite clear; the provincial curriculum writers had worked to fulfill their responsibility to "establish and communicate clear learning expectations and standards" (Government of Alberta, 1994, p. 3). Less clear were the beliefs held by Alberta educators about "how best to teach these ideas" (Millar, 1996, p. 17-18), an important consideration because educators' beliefs can critically affect the type of science education offered to students (Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996; Yerrick, Parke, & Nugent, 1997). Since schools do not operate in a vacuum, I also wanted to know the views held by other Albertans, those who had taken a leadership role affecting science education policy, direction, or teaching practice in elementary schools, regarding the teaching of elementary school science.

And, in light of the recent provincial emphasis on quality teaching and teacher professional development, I was curious about the help being offered to educators as they prepared to teach the new science curriculum.

These wonderings and concerns led to my formal research questions, questions formed to help me better understand the dimensions of a conceivable problem in elementary school science education in Alberta.

1. *What do study participants believe constitutes an exemplary elementary school science lesson?*
2. *What professional development was available to selected Alberta educators responsible for elementary science education in the two years following the issuance of the Elementary Science Program of Studies (Alberta Education, 1996b)?*

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While analyzing the data I had collected to address these two questions, I realized I needed to set that data into a more detailed understanding of the Alberta elementary science curriculum. The curriculum as defined by the *Elementary Science Program of Studies* (Alberta Education, 1996b), the provincially authorized resource materials, and the provincially-prepared elementary science testing materials would, I reasoned, influence participants' thinking about teaching science and the professional development offered to help teachers implement the new science program.

Therefore, I added a third research question to the original two:

3. *What messages about why science should be taught are contained in provincial documents relevant to the teaching of elementary science?*

Overview of the Thesis

In Chapter Two, I introduce the approach taken in this study and explain how data were collected and analysed.

Using Schwab's (1978) wording, Part Two is entitled "Examining the Situation," as that phrase exactly describes my intent. In Chapter Three I report on my review of the literature, a review undertaken to develop my understanding of recent and current discussions about why and how science might be taught and professional development provided. In Chapter Four provincial documents with potential impact on the teaching of elementary science are analyzed in order to detect the messages about why science should be taught contained therein. Chapter Five is composed of case studies of the formal and informal professional development offered to and sought out by educators in the six school districts in which data were gathered. Chapter Six contains an analysis of the participants' descriptions of an exemplary science lesson. The constructs used for the analyses are elaborated on at the points in the dissertation where they became useful tools for me as one of my goals has been to give some sense of the process and progress of the study as it unfolded for me.

In Part Three, "the desirable" (Schwab, 1978) is identified and problems that block us from attaining that goal are discussed. This leads to the final chapter, a set of

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recommendations to move us toward action based on broad deliberation by those "who must live with the consequences of a chosen action" (Schwab, 1978, p. 319).

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CHAPTER TWO

EXPLAINING THE STUDY

I began this study aware of the existence of a possible problem (or problems) and of a need to gain a better understanding of the possibly problematic situation. Schwab's (1978) statement about the emergence of the problem through an examination of the situation started me thinking about how such an examination might be done; that is, about how I might approach this study.

The Approach

The approach used in this study is best described as eclectic. Because I found limited written guidance for examining a situation as broad as the one in which I was interested, I had to design a flexible approach. That design incorporated aspects of several approaches, as well as processes I had found personally useful in defining and deliberating on problematic situations. The most significant influences are described below.

Systematic Inquiry and Personal Experience

When I became concerned about the teaching of the elementary school science curriculum and decided to examine the situation in more detail to try to determine if I should be concerned (i.e., Was there a problem?), inquiry as I broadly understood it from my past reading, discussions, and experience seemed a logical approach. This approach can be described using terms from the science inquiry standard in the *National Science Education Standards* (NRC, 1996). "To do science inquiry" (I mentally substituted "systematic, intentional inquiry" [Lytle & Cochran-Smith, 1992] for scientific inquiry), one (a) asks a question, (b) designs and conducts an investigation, (c) "uses appropriate tools and techniques to gather, analyze, and interpret data" (p. 145), and (d) develops explanations using evidence.

For this particular study, use of a broadly defined inquiry approach entailed first posing a set of research questions to guide the design of the study and then planning methods of data collection to gather information based on the questions I had posed.

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After data were gathered, data analysis and interpretation required the development of analytic tools appropriate for understanding and explaining the data. Finally, for this study, I prepared a set of recommendations intended to transform the knowledge I had gained into practical knowledge, "knowledge that could be used to do something" (Patton, 1982, p. 24).

Patton

A second influence on my thinking was the writing of Michael Patton. After describing a variety of theoretical perspectives informing qualitative inquiry, he concluded with the observation that

> Not all questions are theory based. Indeed, the quite concrete and practical questions of people working to make the world a better place (and wondering if what they're doing is working) can be addressed without placing the study in one of the theoretical frameworks .... [T]here is a very practical side to qualitative methods that simply involves asking open-ended questions of people and observing matters of interest in real-world setting in order to solve problems, improve programs, or develop policies (1990, pp 89-90).

My conception of examining the situation in order to determine whether a problem existed did not seem far removed from Patton's (1978, 1981, 1982) ideas about utilization-focussed, creative, practical evaluation. In particular, I wanted my study to generate practical knowledge, knowledge that "can be used to do something" (Patton, 1982, p. 24). Furthermore, the study was evaluative, in Patton's (1982) sense of the term, in that it involved the "systematic collection of information" about a topic (aspects of science education and professional development) for use in making decisions for a variety of purposes (in this case, for making recommendations with regard to elementary science education in Alberta) (p. 15). Such evaluation, Patton stressed, requires creativity, which I view as similar to Schwab's (1978) description of the "complex, fluid, transactional" (p. 291) nature of the practical.

Schwab

I have explained how Schwab's statement on the necessity for examining a situation in order to characterize a possible problem served as a guide for initially conceptualizing this study. Schwab wrote, as well, of problems that "arise from states of affairs in relation to ourselves.... They are constituted of conditions which we *wish* were

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otherwise and we think they *can be made* to be otherwise" (Schwab, 1978, p. 289, emphasis in original).

This study grew out of personal concerns about recent events in Alberta related to changes in educational policy and elementary science education. I had concerns about the science education being offered to my elementary school son. I had concerns about the help teachers were (or were not) receiving to help them better teach science. I had concerns about the *Elementary Science Program of Studies* (Alberta Education, 1996b) my university students were mandated to teach and the provincial Science Achievement Tests grade six students had to write.

Furthermore, it has been my experience that, in Alberta, individuals can have an effect on aspects of policy in which they are interested. Holding this belief, I approached my study optimistically, believing that if an indication of problems emerged from the research, there was a possibility that the situation could be made to be otherwise.

Summary

Based on the influences outlined above, I began this study by asking questions I deemed important for examining and evaluating the situation in which I was interested. The questions asked and the initial analysis of the data were not theory driven; however, they did not appear out of nowhere, but were based on my perspective of what was important to know about the science education and professional development being offered. This perspective is briefly explained in the following section, allowing the reader to be better prepared to interpret my interpretation.

Perspective

Research involves interpretation; interpretation involves a researcher's point of view (Peshkin, 2000). As the self as evaluator is necessarily present in inquiry (Guba & Lincoln, 1989), it is important to understand that "acknowledged self" (Greene, 1994), the viewpoint the investigator brings to an inquiry.

One phrase in particular grounds my perspective on education and helps to explain the stance I took in this study. Dewey's (1938/1967) phrase "educative

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experience" captures, for me, the essence of education as the promotion of intellectual and moral growth, growth which, in turn, creates "conditions for further growth" (p. 36). For Dewey, educators are responsible for using their greater maturity of experience to shape and adjust experiences to meet these growth criteria for their students.

I view educative experiences as involving both the introduction of possibilities, alternative ways of thinking about concepts and phenomena, as well as time and support for a serious consideration of those alternative possibilities. This process may also be thought of as being deliberative since it involves examining, comparing, and evaluating alternatives. It is, in addition, an interactive process, one which may be inter- or intra-personal. Thus, an educative experience involves active participation in a deliberative process. Collaborative interactions with others can enhance a deliberative process by allowing for, and encouraging, the introduction and consideration of additional information and perspectives.

A second, more contemporary phrase illustrates what education as a consideration of possibilities should accomplish. Cobb (1988) maintained that "A fundamental goal of … instruction is or should be to help students build structures that are more complex, powerful, and abstract than those that they possess when instruction commences" (p. 89). This, too, suggests growth. Additionally, it implies that different students will construct different understandings, dependent on what they believe at the onset of instruction.

With Dewey (1938/1967), I believe that the role of the educator is to fashion instruction that progressively develops experience "into a richer and more organized form" (p. 74). Dewey wrote of form, Cobb (1988) of structures. Both terms imply that learning involves the development of complex cognitive structures. Engagement in educative experiences may, at times, also lead to a reorganization of those cognitive structures, a process Piaget (1976) referred to as accommodation. Learning, so explained, is a much more complex process than accrual of "knowledge bits."

I am reminded, too, of the conditions Posner, Strike, Hewson, and Gertzog (1982) suggested were necessary for major conceptual change (accommodation). Conceptual change, they theorized, required that there be dissatisfaction with a current conception, and that new conceptions must appear to be intelligible, plausible, and "have the potential to be a productive tool of thought" (Strike & Posner, 1992, p. 149). That these conditions

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will not be the same for all students in a classroom adds even more complexity to a teacher's choice of educative experiences.

Education considered in these terms places the teacher in a position of great responsibility. Dewey's (1938/1967) writings remind us that teachers' decisions, based on the teacher's knowledge of subject matter and individual students, affect the quality of the educative experience for each of their students.

For me, knowledge is "objectively reasonable belief" (Fenstermacher, 1994) which entails belief in a proposition and "evidence to establish its reasonableness in relation to other, competing claims" (p. 24). This again indicates the importance of examination and evaluation of alternative possibilities in knowledge growth.

The role of the creator of educative experiences is one Schwab (1959) referred to as "impossible." Made less impossible, in my opinion, when teachers are introduced to the possibilities developed through educational research. I believe that research generates theories and studies of importance to the development of more complex pedagogical understanding. I know that a considerable amount of research on teaching and learning in science has occurred in the last two decades. However, just as we do not expect children to spontaneously construct powerful understandings of complex phenomena and situations, neither can we expect teachers to spontaneously understand new concepts about teaching and learning, concepts which may be counterintuitive to their views of education.

Thus, professional development, too, can be considered as educative experience – introducing possibilities and providing support for teachers while they build understandings of teaching and learning "more complex, powerful, and abstract than those that they possess when instruction commences" (Cobb, 1988, p. 89) that will help them grow in their ability to provide educative experiences for their students.

Details of just how this exploratory, practical, qualitative study was conducted – how the data were collected and analyzed – are explained below.

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Data Collection

To help me better understand the situation as it existed in selected Alberta school districts and the policy and resource context educators were operating in, I chose to collect data from a number of different sources. First, I decided to interview educators and others interested in elementary science education in Alberta. Field notes were also taken at the time of the interviews. In addition, I collected documents related to provincial elementary school science education policy with a potential impact on the teaching of elementary school science. Data collection methods are first discussed, followed by an explanation of the content analyses of the collected data.

Interviews

To collect data concerning beliefs about the constituents of exemplary science lessons and the professional development available to educators in selected school districts, I had a choice between developing and mailing questionnaires or conducting interviews. Semi-structured interviews were chosen for several reasons. First, semi-structured interviews allow flexibility and sensitivity to one's informants (Arksey & Knight, 1999). Participants differ; even within a category of participants such as principals there was considerable diversity. Through semi-structured interviews, one can capture that diversity and tap the expertise of the individual respondent. It is also possible in interviews to clarify and restate questions and ask for details (McMillan, 1992).

Interviews also allow for selection of participants meeting criteria established for specific studies and afford a better response rate than surveys (Keats, 2000). For my study, this meant that in the selected schools a high response rate of principal/teacher pairs could be obtained. Almost every one of my participants was a very busy person who made time for me. That time would likely not have been found to fill out a survey form from an anonymous researcher, making the possibility of obtaining multiple sources of data from the same schools also unlikely.

Third, interviews allowed me to become acquainted with people and their contexts, important for developing a fuller understanding of the Alberta situation in these districts. Furthermore, I had done a number of semi-structured interviews in past

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research projects and felt confident in my ability to conduct an interview; I am able to set most people at ease and encourage them to respond to my questions, important interviewing traits (Arksey & Knight, 1999; Keats, 2000).

For these reasons, semi-structured interviews were chosen for primary data collection. Questions varied somewhat depending on the individual participant I was interviewing; (e.g., the questions I asked professional development providers varied somewhat from those I asked teachers and principals). Examples of the interview questions asked the teachers are located in Appendix C. As the interviews were *semi-*structured, questions different from the written protocol were asked whenever it appeared that a somewhat different line of questioning would elicit information of greater use in understanding the Alberta situation.

Because I had identified a number of topics as important for understanding the situation (e.g., the participants' professional background and current duties, their professional decision-making practices, their views on why science should be taught in elementary schools and the constituents of exemplary science lessons, and their views on exemplary professional development), the interviews were designed to talk with the participants about these topics, rather than to probe any one topic in depth. Thus, to some extent, the interviews served as oral questionnaires reflecting the intent to survey opinion and gather information rather than uncover in depth participant-held meanings about science education and professional development.

Based on my previous experience interviewing educators, I designed an interview that could be completed in approximately half an hour, the length of time I had previously found educators generally were willing and able to take out of a school day. An interview protocol was written, piloted, and non-substantive changes made in the wording to better reflect the language used by the educator in the pilot interview. When I started interviewing I made a few more minor changes in question wording to better communicate the intent of the question.

Participant Selection

As I was interested in obtaining data about the elementary science education situation in a variety of Alberta localities, I decided to interview in six school districts:

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two urban (located in one of the two major cities in Alberta), two rural, and two suburban (defined as a school district adjoining a major city). To better understand perceptions of science education and the professional development available in each school district, I chose to interview a principal and a teacher in two different schools in each of the districts. Interviewing this number of educators, I reasoned, would be both possible to do and give me the data necessary to identify possible problems and, ultimately, to suggest considerations potentially useful in future decision-making processes.

Three districts, one urban and two suburban, were chosen for their physical accessibility. The second urban school district was chosen to contrast with the first; it was in the second major urban area in the province and differed in religious affiliation. The rural districts had to be, first, at least three driving-hours away from a major city. Secondly, I needed the name of someone to contact, an administrator or teacher, working in the possible districts.

Having contacted and received permission from school district personnel to interview a district curriculum facilitator, principals and teachers, I started the participant-selection process. School names were suggested by an administrator in three of the school districts when I requested help locating a specific type of school (a smaller rural school and a town school in the rural and suburban school districts, an inner city and a middle-class neighbourhood school in the urban districts). In Spruce School District this request was met with the names of two principals and two teachers working in four different schools, one of them in an inner city neighbourhood. In the other two school districts, I was able to achieve my goal of locating a principal and a teacher in each of two different schools serving different types of student populations. I requested names of possible participants working in schools that met my specifications from a teacher or principal in the last three districts.

After receiving the names of possible schools, I contacted the principal, explained my study and requested an interview with him or her and with a teacher on his or her staff who would be willing to be interviewed for this study. Principals then asked their staffs if there were any teachers who would be willing to volunteer; there was no indication during the interviews that any teacher was not a willing participant. No criteria other

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than willingness to be interviewed were used. A copy of the letter sent to potential participants is found in Appendix A.

A number of other Albertans outside the school system but with an interest in elementary science education were first identified by their inclusion on a provincial mailing list for circulation of elementary science education curriculum materials. Three participants were chosen from this list – one working for industry, one for a provincial science organization, and one doing outreach in schools for a professional organization – because they were reported to have responded to the invitation of Alberta Education to critique draft copies of the elementary science curriculum as it was being developed (B. Galbraith, personal communication, January 20, 1998). As well, elementary science education instructors at two universities in the province, an elementary science curriculum writer, the director of a regional professional development consortium, and an Alberta Teachers' Association professional development specialist were asked to contribute their views on elementary science education and professional development.

A list and brief description of the participants who volunteered to be interviewed is located in Appendix B. There were, in all, 37 participants: 6 curriculum facilitators, 11 teachers and 1 teacher/principal, 11 principals, 2 university instructors, 1 curriculum writer, and 5 people involved in providing professional development or other science services to educators. School district personnel are described in more detail in Chapter Five.

Interview Transcription

The semi-structured interviews were audio-taped and later transcribed (by me). As the sense of an utterance, not an exact rendering of it, was of greatest concern, uh's, er's and short repetitions were omitted during the transcribing. This resulted in a better flow of thoughts and reasoning. However, when the sense of a sentence was not clear, the original wording was transcribed verbatim. Meaningful features such as pauses of any length were also included in the transcripts.

A transcript of the interview was returned to each participant and participants were invited to add comments and clarifications if they wished. Desired changes were made to the interview transcripts before the data analysis process began.

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Elimination of unnecessary verbiage may also make the transcription of an interview more acceptable to those interviewed. Even after I had made the described adjustments, two principals reported that while the transcript was an accurate representation of their views, they feared that they had sounded very inarticulate. An exact transcription, thus, might cause some people to be less willing to be interviewed in the future if that interview is to be transcribed. Sample transcripts of two of the interviews are found in Appendix D.

Field Notes

Following each interview, a short set of field notes was written to describe the context of the interview. For example, I was interested in the books on office shelves, and the contents of staff rooms – the notices on the bulletin board and the books selected for teacher use. Teachers most often chose to meet with me in a conference room, so I seldom had a chance to see their classrooms. I also noted signs of enthusiasm and fatigue and circumstances that cut the interviews short.

While in the field I also collected, if available, copies of professional development bulletins issued by the district or institution.

Documents

Guba and Lincoln (1981) wrote that the inclusion of data from documents "lends contextual richness" (p. 234) to a study, as well as serving to extend the larger body of research. These two purposes describe why I chose to collect, and then analyze, a set of documents.

First, to better understand the elementary school science teaching context that study participants operated in, it was necessary to be acquainted with the contents of the documents outlining provincial elementary science education policy. These documents, I reasoned, might also affect participants' beliefs about exemplary science instruction. Second, my third research question asked, "What messages about <u>why</u> science should be taught are contained in provincial documents relevant to the teaching of elementary science?" An answer to that question necessitated collecting and analyzing the content of those documents.

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The *Elementary Science Program of Studies* (Alberta Education, 1996b) was an obvious first choice. As educators had referred to the grade six science achievement tests and the Classroom Assessment Materials Project (CAMP) tests in the interviews as having an impact on their teaching, samples of these tests were also collected. The Curriculum Standards Branch of Alberta Education had also authorized a number of teacher and student resources for teaching the mandated topics. As I believed that these resources could have a potential impact on the teaching of elementary school science, I also collected a sample of the authorized teacher resources.

To ascertain if this collection of documents was complete, I contacted a program manager at Alberta Education to ask if there were any other provincial documents educators would have received or had ready access to that represented Alberta elementary science policy. I was told that the list of documents described was complete (B. Galbraith, personal communication, July 2000).

Data Analysis

This study was not initially guided by a designated theory; data analysis was, as Schwab (1978) described, fluid and deliberative. Analysis of the data gathered to address the three research questions can also be characterized, using Erickson's (1984) term, as "analytic detective work" This detective work will now be described in more detail. The concepts I used for analysing and interpreting the data (the components of an exemplary science lesson, principled or procedural knowledge development, curriculum emphases, and intellectual space) will be further elaborated on in later chapters.

What do study participants believe constitutes an exemplary elementary school science lesson?

To analyze the interview data I had gathered to address this research question, I turned to the participants' responses to the interview questions asking them to describe the most important elements of an exemplary science lesson and the teacher's role at the beginning, during, and at the conclusion of such a lesson.

The responses of each participant were listed under their identification (ID) code. The listed responses were read and reread, abbreviated to phrases, and these phrases combined into a long list. Typical phrases on this list included:

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- teacher gathers and organizes student material
- teacher decides on ways to involve/interest students
- teacher provides background information for the students when necessary
- teacher leads a discussion of what was done and what students found out; What worked? What didn't work?

Ambiguous phrases such as "the teacher guides the students" or "the teacher facilitates learning" led to a rereading of individual transcripts to try to add clarity and meaning to these phrases.

A final list of phrases describing teacher actions in sufficient detail to delineate one action from another, or phrases lacking clarity but frequently used, was prepared. This process corresponds to Huberman and Miles' (1994) description of data display, reducing data as an aid to finding meaning in the data. Next the ID code of each participant whose statements appeared to support the action described in a phrase was listed after each phrase.

Looking more closely at the descriptions of exemplary teaching practices over the course of a lesson, I started to note consistencies in responses. These are described in more detail in Chapter Six. Of importance to this explanation of data analysis, the patterns discerned emerged out of the data after multiple readings of the transcripts, reduction of the discourse to phrases, and a growing awareness that combinations of these phrases described three different perspectives on the teaching of an exemplary science lesson.

To check that the relationships discovered in the data display were an accurate reflection of the meaning of the participants, I returned to the full transcripts. These I read blind, then categorized each using the patterns I had discerned in the reduced data display. After this categorization, I again returned to the interview data and prepared a sheet for each participant (with each person's code number listed on the back of the page) on which I listed the interview statements I had previously judged to be relevant for this classifying task. I then classified those sets of statements using the designated categories. The views of most of the participants were consistent enough and in adequate detail to allow easy and replicable classification. For those few participants whose statements were not as easy to consistently fit into a single category, I reread the entire interview,

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looking for any additional insight into their views on exemplary science teaching. I used this additional data to try to come to a conclusion on the person's views. After this exercise, I put the sheets aside while I worked on other aspects of my research, then returned to this reduced, blind data, and reclassified the statements. When I was still not satisfied that a participant's responses allowed a clear distinction to be made between one pattern and another, the participant was placed in the second pattern in alphabetical order. That is, if there was a doubt about whether responses represented an A or a B-patterned outlook on science lessons, the responses were judged to be representative of a B pattern.

There was, thus, a "multiple iterative set of tactics in play .... In this sense we can speak of 'data transformation' as information is condensed, clustered, sorted, and linked over time" (Huberman & Miles, 1994, p. 429).

Placing the interpreted patterns of participants' perspectives into a figure, a more powerful display, did, as suggested by Huberman and Miles, beget further analysis. The explanations developed from this analysis are presented in the Discussion.

What professional development was available to educators responsible for elementary science education in the two years following the issuance of the *Elementary Science Program of Studies* (Alberta Education, 1996b)?

Interview data were gathered from five educators in each school district (four in Clover School District as one participant was both an elementary school teacher and the principal of a very small school). These multiple sources of data and the professional development bulletins that I collected helped me write the descriptions of the professional development available in each school district.

Again, interpretation was based on multiple readings of the interviews. Topics that framed the descriptions of professional development in the six school districts were suggested through these readings and were expanded on in writing the descriptions – a lengthier and denser example of data display than that described for analyzing perceptions of exemplary teaching practice. In a similar fashion, however, the narrative data display suggested comparisons and relationships that required a return to the interview texts and resulted in confirmation, elaboration, or elimination of certain display items.

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Analysis of the narrative displays indicated that professional development had been predominantly focused on an immediately practical goal – informing teachers about resources and activities that they could use to teach the new science program of studies. There were examples, however, of teachers being introduced in professional development sessions to more theoretical concepts of science teaching and learning.

I differentiated these two different orientations to professional development on the basis of the apparent focus of that professional development; i.e., by the type of teacher knowledge development that appeared to be emphasized in the activities chosen. To label the differences I chose the terms principled and procedural knowledge development. Briefly, Spillane and Zeuli (1999) distinguished between procedural knowledge, knowledge of structured ways to proceed, and principled knowledge, the "key ideas and concepts that can be used to construct procedures" (p. 4). Edwards and Mercer (1987) made a similar comparison. Procedural knowledge, which they referred to as ritual knowledge, was defined as "knowing how to do something" (p. 97). This they contrasted with principled knowledge, knowledge that is "essentially explanatory, oriented towards an understanding of how procedures and processes work, why certain conclusions are necessary or valid" (p. 97). (A more complete examination of the origins of these terms is found in the review of the literature on professional development. The terms are, as well, further elaborated on in Chapter 5 when I use them to analyze the professional development described by study participants.)

I used these two concepts of procedural and principled knowledge to label the kinds of professional development that had been available to study participants. Through this analysis, I also started to clarify a possible problem. If, as I assume, principled knowledge is necessary in the planning of educative experiences, how do teachers develop the key ideas and concepts necessary for constructing teaching procedures if professional development is focused instead predominantly on procedural knowledge?

Returning to the interview data, I looked for further indications of learning interactions that might have affected beliefs about science teaching and learning at the time of the science curriculum change. I thought of these interactions as conversations, "in its largest sense…[involving] readers and writers as well as speakers and listeners" (Applebee, 1996, p. 40). To better understand ideas about science teaching and learning

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being exchanged, I asked, "Who was talking to whom about what?" and analyzed the answers according to the criteria of procedural or principled knowledge exchange.

What messages about why science should be taught are contained in provincial documents relevant to the teaching of elementary science?

The rationale stated in the *Elementary Science Program of Studies* (Alberta Education, 1996b) reads: "The purpose of the program is to encourage and stimulate children's learning by nurturing their sense of wonderment, by developing skill and confidence in investigating their surroundings and by building a foundation of experience and understanding upon which later learning can be based." (Alberta Education, 1996b, p. A.1). In this statement, I recognized a goal statement common to many Alberta curriculum programs: student development of knowledge, skills, and attitudes. "Knowledge, skills, and attitudes for what purpose?" was my next question.

For analyzing the reasons for knowledge development, I chose to adapt Roberts' (1982, 1998) curriculum emphases categories. As well as being an often cited means of thinking about the knowledge base being developed in science education, Roberts' emphases have also been used by Alberta curriculum developers in their own conceptualization of science curriculum (B. Galbraith, personal communication, April 8, 1998; Jenkins, 1990).

As Roberts defined it, a curriculum emphasis "is a coherent set of messages to the student about science… which provides answers to the student question: 'Why am I learning this?'" (1982, p. 245, emphasis in original). The concept of curriculum emphases serves, as well, to provide answers to the teacher question: "Why am I teaching this?" I found four of Roberts' seven emphases useful for analyzing and describing knowledge outcome statements in the elementary science program (Roberts' work was based on an analysis of secondary science): Solid Foundation, Correct Explanations, Everyday Coping/Practical Applications, and Science, Technology, and Decisions.

As defined by Roberts (1982, 1998) a **Solid Foundation** emphasis stresses the importance of a cumulative development of propositional knowledge. The message here is that it is necessary to learn a particular concept because it forms the foundation for

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future learning and "that learning fits into a structure which has been thought about and planned" (Roberts, 1982, p. 249).

Correct Explanations also stresses propositional knowledge, but the focus is more on learning a certain body of knowledge because "science presents a correct interpretation of the world" (Roberts, 1998, p. 10). Curriculum statements were placed in this category when there was no obvious indications of how the science content outlined would help children make sense of their everyday world, but had more the sense of science facts and concepts being learned, in the words of a student, "because the teacher says we have to learn this."

An **Everyday Coping/Practical Applications** emphasis puts stress on science being "an important means for understanding and controlling one's environment – be it natural or technological" (Roberts, 1982, p. 246) and values an "understanding of scientific principles as a means for coping with individual and collective 'problems.' The student must apply, indeed must learn how to apply, the principles and generalizations learned in the science classroom, if the message is to get through" (p.246, emphasis in original). In this emphasis, the student is socialized "to grasp science as a way to make sense of objects and events of fairly obvious everyday importance, and therefore to understand them better by understanding them scientifically" (Roberts, 1998, p.8).

Knowledge is also important for **Science, Technology, and Decisions,** preparing students to "critically address science-related societal, economic, ethical and environmental issues" (CMEC, 1997, p. 5). That is, students will learn to "engage intelligently in public discourse and debate about matters of scientific and technological concern" (NRC, 1996, p. 13).

Statements in the *Elementary Science Program of Studies* (Alberta Education, 1996b) pertaining to **skills** appeared to refer to two levels of skills: basic skills such as measuring, observing and comparing, and more complex skills often referred to as critical thinking skills. I included both in the skills category of curriculum emphases.

While both "positive **attitudes** toward the study of science and for the application of science in responsible ways" (Alberta Education, 1996b, p. B.2) are to be developed, I was unable to clearly differentiate between these different purposes for developing attitudinal goals in the statements found in the *Elementary Science Program of Studies*

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(Alberta Education, 1996b). Therefore, any reference to attitude was simply categorized as attitude.

Discussion

When the time arrived to discuss the findings revealed through a use of these various analyses, I found Schwab's (1959) theory of intellectual space to be a valuable interpretive tool. As this theory is not relevant until much later in this dissertation, I have chosen to detail intellectual space in Chapter Seven in closer proximity to my use of the theory for interpreting the study findings.

Systematic and Rigorous Investigation

After reviewing numerous texts addressing the issue of research criteria, I considered entitling this section, "Research in a Postmodern Era." Positions taken over the last two decades by Guba and Lincoln illustrate my dilemma. Guba (1981) and Lincoln and Guba (1985) proposed that criteria of credibility, transferability, dependability, and conformability be used to judge the *trustworthiness* of an inquiry. In 1994 they wrote that "although these criteria have been well received, their parallelism to positivist criteria makes them suspect" (p. 114) and concluded that the issue of quality criteria in constructivist research was not yet well resolved. By 2001, Lincoln and Guba were asking, "Whither and Whether Criteria" (p. 179) and noting changes that they had made, and were making, in their thinking about research criteria "with many miles under our theoretic and practice feet" (p. 180).

Despite the fascinating debate going on related to "the problem of criteria in the age of relativism" (Smith & Deemer, 2001, p. 877), my immediate need was a practical one: choosing terms for explaining the measures I had taken to collect data and construct explanations that made sense and enhanced understanding. In the end I chose Bogdan and Biklen's (1998) statement that research involves "rigorous and systematic investigation." Under that banner I will explain the measures I took to collect data and to analyze them.

To aid in the collection of data, I had a colleague preview the questions on the semi-structured interview protocol I had written and comment on their perceived

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adequacy for eliciting responses useful for the study. Following a pilot interview, the questions and responses were critiqued with another colleague to ascertain if the interview questions and probes for further information appeared to elicit information that was plausible, in that it made sense, and was dependable; that is, a similar answer would probably be received by anyone else asking that question. Several questions were rephrased to more accurately reflect the language used by principals and teachers.

I chose to collect data from several participants in each school district and I succeeded in interviewing both a teacher and the principal in most schools I visited. These actions were taken to gather multiple sources of information to help me better understand and explain the local situations.

During the data analysis phase, I was in contact with a number of educators who were willing to listen and comment on the plausibility of my developing arguments. When questions were raised, I returned to the interview data to check if my analyses and interpretations appeared to be true to that data. In addition, questions and notes I made to myself while working with the transcripts and documents were used to guide further readings of the data. Plausibility was also checked against personal experience as I continued to work with teachers and visit in their classrooms.

To check if my analysis of the interview data related to the participants' perceptions of exemplary science instruction made sense and was replicable by others, I had three colleagues review the descriptions of patterns of science instruction discerned in the interview data. Each of them then used the pattern descriptors to categorize a set of four different interviews. There was agreement with my categorization of 9 of the 12 interviews. Discussions easily resolved the differences, as these differences were based mainly on my colleagues' categorization of the data according to conditions and practice reported on by the participants, rather than on their descriptions of exemplary instruction. For example, a teacher described both what she did in her grade six classroom to prepare her students for the provincial achievement tests and how she thought science should be taught. It was the latter description that was focussed on in this study.

Conclusions, in a qualitative study such as this one, are impacted by the perspective of the researcher; that is, by that person's experiences, beliefs, and epistemological and ontological lens. In the end, the papers and books I have collected

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over the past three decades; my beliefs in participatory democracy; my experiences as a teacher, parent, and researcher; and my involvement in both deliberative and non-deliberative situations influenced my choice of analyses and the messages I perceived in the data I had chosen to collect.

Limitations and Delimitations

As previously stated, this study was intended to be exploratory; I hoped to gather data that could help me better understand and offer possible explanations of how a group of selected Albertans conceptualized exemplary elementary science instruction and how educators were being helped to understand science teaching and learning. Such a broad goal necessitated the asking of many different questions during the interview, questions focused on both science teaching and professional development, and on gathering professional information about the participants.

I was aware, as well, that the interviews needed to be limited in length as I would be interviewing professionals with very real time constraints. This awareness of time constraints was substantiated on several occasions; once, for example, a principal had to curtail the interview in order to carry out his playground duties. Unscheduled meetings with parents shortened the time allotted for interviews with two other principals. A limited amount of teacher preparatory time abbreviated one interview when a teacher had to return to class. After-school interviews often found teachers tired and not very talkative. Two teachers, though, obviously enjoyed the chance to talk to someone about their science teaching, and the joys and frustrations they had encountered in introducing the new program. These interviews lasted more than 45 minutes, much longer than the average teacher interview. And while I had indicated in an introductory letter that the interview could last as long as an hour, most participants had set aside no more than half that length of time for the interview.

Assertions in this dissertation are based, too, on data gathered in but 6 of the 63 school districts in Alberta. Furthermore, only 12 teachers and 11 principals were interviewed. Additionally, this was not a random sample; participants volunteered to talk to me about their views on science education. I assume that some educators who were not interested in or were uncomfortable talking about science education simply did not

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offer to share their ideas with me. The sources of the interview data are, then, limited and I do not claim they are representative of other Albertans. Therefore, analyses and interpretations of these data can only indicate possible dimensions of the problematic situation.

I agree, too, with Schwab (1978) that views and situations and problems "cannot be taken as fixed" (p. 290). Thus, the interview findings are delimited to the situation at the time of those interviews (1998), to elementary science education, and to the views of the participants in this study.

For the reasons stated above, this study should be considered an exploratory examination of a situation that is intended to provide a perspective on elementary science curriculum, professional development, and views of exemplary elementary science teaching practice in Alberta.

Researcher Bias

As qualitative methodologies became more commonly used in research, increased attention was given to the role preconceptions held by a researcher might play in the gathering and interpretation of data. Exploring this theme, Denzin (1989) wrote, "Value-free interpretive research is impossible. This is the case because every researcher brings preconceptions and interpretation to the problem being studied" (p. 23). Greene (1994) questioned, "Is neutrality or lack of bias ever conceivable? Is disembodied inquiry, or inquiry devoid of prejudgement, possible or desirable?" (p. 425). Bogdan and Biklen (1998) attribute a shift from the assumption that it is possible to learn "what is true" (p.20) if reason is properly used to a focus on the nature of interpretation and the position of the qualitative researcher as interpreter to the growth of postmodernism. Denzin and Lincoln (2001) also relate this shift to postmodern influences, writing that only by embedding descriptions of research in reflexivity, "the process of reflecting critically on the self as researcher" is there any possibility of "achieving a voice of (partial) truth" (p. 18).

Reflecting on my initial unease with the situation that existed reveals a number of the assumptions with which I approached this study, assumptions certain to have affected

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the data gathering, in the field and in the literature, and the interpretations made during the course of the study.

I was concerned, first, about the limited professional development I saw being made available to the teachers with whom I was acquainted. This troubled me as I believe that teaching is very complex and requires an extensive knowledge of content, pedagogy, and learners if students are to have the "best opportunity to learn" (Alberta Education, 1996c, p. 18), the last phrase coming from the standard set by the province for quality teaching. I believe that professional development can offer teachers opportunities for enhancing their professional knowledge base and for learning more about new approaches and strategies; that is, about possible ways to help their students learn better. Additionally, I believe that research is continually adding insights into teaching and learning that can help teachers teach and students learn. Whether or not research findings do help is dependent on teachers being aware of these findings and giving consideration to them; that is, they need to enter teachers' conversations and activity. And this, from my experience, does not just happen spontaneously.

Through reflecting over the years on how I learn and observing the processes used by my children, I have come to believe that people learn best when they are actively engaged in making sense of events and phenomena they find of interest. (Active engagement does not connote physical activity; activity over time is more likely to be mental.) Because of these conceptions, I have been drawn to the explications of learning through inquiry found in both the science education and teacher research literature.

Reflecting further on my initial unease, I hear my mother saying, "If you're going to do something, do it well" (G. MacNey, personal communication, ca. 1947-1973). I realize that I expect actions, especially when these have the potential to affect the lives of others, to be "done well." Here personal experience has contributed to an understanding of what "doing it well" means. Having been involved in a number of clashes with public institutions that colleagues and I did not believe were making well-reasoned decisions, I have come to believe strongly that long-term, deliberative processes are needed for making the best decisions possible (Schwab, 1978). Only then, in my experience, is it likely that the most important issues for all the parties affected by the decisions have been identified and that actions and consequences have been adequately considered. When

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this reasoning is applied to making changes in provincial educational policy likely to have a substantial impact on school district personnel and/or students, it means that potentially affected parties would be invited to take part in meaningful deliberation early in the change process. Consulted at that time, their expertise can help in the development of the principles under girding the revisions. Being involved in on-going deliberation will also enable the affected parties to contribute to discussions of alternatives and their consequences.

While I was aware at the start of this examination that the assumptions about teaching and learning that I brought to the study were likely to have an impact on my choice and interpretation of data, it was only as I pursued the study that I started to realize how much these and other personal experiences might colour my viewpoint and conclusions. For, as Peshkin (2000) has observed, "phenomena associated with personal perspective, dispositions, and feelings ... bear on the interpretive process" (p. 6).

Recognizing that these biases could affect data collection and interpretation allowed me to build tactics "meant to ward off the most obvious biases" (Huberman & Miles, 1994, p. 438) into my research effort. These tactics included, first, a search for disconfirming evidence. For example, knowing my bias toward learning through inquiry, when reading policy statements and the literature on science education and professional development, I searched for evidence of principled knowledge development in activities that did not meet inquiry learning criteria. In a similar fashion, I looked for evidence that teaching elementary school science was really not as complex as I believed and of simple ways that teachers had been helped to enhance their teaching practice.

A search for disconfirming evidence was also a tactic I used when analyzing the interview and document data. After identifying possible themes from that data, I returned to the transcripts and documents seeking evidence that the emerging themes did not adequately represent the data. That is, I asked myself if the themes appeared to be too broad, too narrow, inexact, or skewed to a particular point of view. Through this further analysis, I was also able to adjust and more clearly specify the parameters of the developing themes.

A too ready acceptance of one's initial conclusions may also bias the conclusions drawn from a study. To guard against this possible bias, researchers need to be sceptical;

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that is, they need to constantly question their own analyses. An example of the efforts I made to check and recheck my own analyses is described on pages 21 and 22. I followed a similar procedure in my analysis of the curriculum documents.

Overconfidence in some data and/or reliance on a limited amount of data can also allow "insidious biases to steal into the process of drawing conclusions" (Huberman & Miles, 1994). To help counter this form of bias, I have explained how I interviewed several educators in each of the six study school districts in order to gather multiple perspectives. This was done both to optimize the probability of identifying professional development activities educators felt had helped them enhance their knowledge of teaching and learning science and to be able to write a credible account of the professional development made available to teachers in the six study school districts.

These, then, are some of the measures I took to reduce researcher bias, measures necessary when one is trying to produce an interpretive account that will be judged "useful, fitting, and generative of further inquiry" (Schwandt, 1994, p. 130).

Significance of the Study

The primary intent of this study was to "examine the situation" (Schwab, 1978) in six Alberta school districts to gain a better understanding of the participants' perceptions of exemplary science instruction and of the science education professional development being offered to elementary school teachers. The motivation was a desire to contribute to the development of exemplary science education in Alberta elementary schools; I hoped the data I gathered and interpreted could help inform future elementary school science policy and professional development deliberations in Alberta. The extent to which the problems and the desirable goal that I have identified and the recommendations for future deliberations that I propose affect the process and discussions leading to the revision of the elementary science program of studies (expected to begin in 2003), will mark, for me, the significance of the study. Findings from this study can be used to promote discussions among Alberta educators when preparing for curriculum revision, a time when alternative actions will need to be envisioned, possible consequences considered, and cost and feasibility estimated (Schwab, 1978) -- a deliberative process aimed at

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making the best curriculum and professional development decisions possible to guide the science teaching of Alberta's elementary school children.

Guided by Millar's (1996) statement (see page 6), I focussed first on why science should be taught, on the literature defining and discussing scientific literacy. As an in-depth consideration of why science should be taught does not appear to have been a major consideration in recent Alberta curriculum consultative efforts (Panwar & Hoddinott, 1995), my literature review and the deliberations I propose on this topic can help initiate, as indicated above, future curriculum discussions in Alberta regarding scientific literacy.

My analysis of the current *Elementary Science Program of Studies* (Alberta Education, 1996b) and provincial test items indicates there are problems, when these data are compared to studies in the literature, with some of what is being taught. Deliberations on what is taught might help ameliorate this situation, and I propose a process by which this can proceed.

As regards how science is taught, approaches and strategies for teaching science form much of the science education literature. However, as Millar (1996) and Millar and Osborne (1998) have written, this how research needs to be adapted to local circumstances. Again, I propose a deliberative process that can help us in Alberta plan, test, and evaluate the efficacy of different methods for achieving provincially designated science literacy goals.

The data and analyses that form this study also contribute to the growing body of literature on the implementation of science education programs. Federal funding in the United States for research into efforts to reform science education is resulting in a growing literature on science teacher preparation (Simmons, et al., 1999), science teaching practice and student outcomes (Kahle, Meece & Scantlebury, 2000; Vellom & Anderson, 1999), teacher professional development (Radford, 1998; Supovitz & Turner, 2000), and implementation of the standards at the classroom (Roychoudhury & Kahle, 1999) and district (Spillane & Callahan, 2000) levels. From my examination of the situation, interconnections among teacher beliefs, the teaching of inquiry science, professional development, and policy emerged. The data and analyses produced in this study add, then, to the knowledge base discussed above, most notably to a better

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understanding of aspects of teacher professional development (e.g., of educators' beliefs about exemplary science education that need to be taken into account in designing professional development and of the challenges to science education reform faced by teachers, principals, and school districts). Furthermore, analytic tools used in this study to assess professional development (procedural and principled knowledge designations) and learning activities (levels of intellectual space) are potentially useful to researchers, administrators, professional development providers, and teachers.

Last, as I have indicated, I was able to locate only very limited written guidance for designing a study of this nature. My study was obviously qualitative, but just what kind of qualitative was not well documented in the educational research methodology literature.

Eisner (1984), commenting on Schwab's contribution to curriculum, wrote,

> One of the persistent and nagging problems in the preparation of doctoral students is the difficulty they have formulating significant and educationally interesting questions germane to curriculum for their dissertation research. The kind of eclecticism and organicism that questions of curriculum policy and practice have are extremely difficult to couch within conventional models of social science research (p. 206).

The questions I asked were, I believe, significant and germane to elementary science education in Alberta. The "eclecticism and organicism" of the process was fascinating to me. Data analysis and interpretation unfolded like a mystery; each day promised the possibility of gaining a more complete understanding of the situation which would enable me to contribute insights and alternatives to future discussions in Alberta on elementary school science and professional development. A characterization of the research process outlined in this dissertation offers insight into practical graduate research nearly 20 years after *Curriculum Inquiry* published a "dialogue" series of articles commenting on Schwab's contribution to educational theory and practice and the use of a practical approach in curriculum development.

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PART II

EXAMINING

THE

SITUATION

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> We may be conscious that a practical problem exists, but we do not know what the problem is. We cannot be sure even of its subjective side – what it is we want or need. There is still less clarity on the objective side – what portion of the state of affairs is awry. These matters begin to emerge only as we **examine the situation** which seems to be wrong and begin to look, necessarily at random, for what is the matter. The problem slowly emerges, then, as we search for data, and conversely, the search for data is only gradually given direction by the slow formulation of the problem (Schwab, 1978, p. 290, emphasis added).

In Part II of this thesis I examine the situation, first through a review of the literature and then through an analysis of the collected data.

Although I have placed the literature review before the data analysis, this does not reflect the fluid, transactional character of my examination. In actuality, data analysis and a review of the literature occurred simultaneously, each contributing to a fuller understanding of the problematic situation.

A personal need to understand the reasons given for teaching science in elementary schools led me first to explore the literature pertaining to that topic. Following that, I analyzed the participants' descriptions of exemplary science lessons and the professional development made available to educators following the release of the elementary science program of studies. Over time, discrete strands of the investigation began to merge and to indicate both the outlines of the desirable and of the problem.

In reviewing the literature, I identified a desirable goal for science education, scientific literacy through inquiry, as well as one for teachers, "better teaching" (Baird, 1992). Means for achieving those goals were sought in the literature and the studies influential in furthering my understanding are presented.

The data analyses consider the Alberta elementary science education and teacher professional development situation in more detail.

Thus, in Part II of the dissertation, I examine the situation in order to clarify what portion of the state of affairs might be awry and to identify desirable goals and alternative solutions useful in future decision-making processes concerned with elementary science education and teacher professional development.

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CHAPTER THREE

REVIEW OF THE LITERATURE

To help my examination of "the situation which seems to be wrong and to look … for what is the matter" (Schwab, 1978, p. 290), I turned to the literature on elementary school science and teacher professional development. In particular, I wanted to know more about current discussions and proposed theories regarding why and how science might be taught and professional development provided. This search was not bound by a particular theory nor intended to justify a theory or point of view. It was, inevitably, affected by my perspective, described earlier, on educative experiences.

The results of my search of the literature guided by these considerations are presented in this chapter under the headings: Why Teach Science?, Teaching Science, and Professional Development.

Why Teach Science?

> First we need to decide *why* we want to teach science to our young people; from that we can perhaps work out *what* we want to teach them. Then research, linked closely to the development and evaluation of teaching materials and approaches, may be able to help us discover *how* best to teach these ideas (Millar, 1996, p. 17-18, emphasis in original).

Agreeing with Millar's statement, I first reviewed the literature focused on rationalizing the teaching of science; that is, literature answering the question, "Why teach science?"

For the last several decades, the response to the question "Why teach science?" has been, at least in the English-speaking world, "to develop scientific literacy." In his 1983 discussion paper for the Science Council of Canada, Roberts referred to this phrase as a "rallying symbol" allowing for "a diversity of interpretations." At that time he characterized the slogan as having "reached a point of maturity, or, perhaps, exhaustion" (p. 28 emphasis in original). Later in the same paper he referred to it as "an aging

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slogan."[1] This aging slogan, however, is still given primacy in the science curriculum documents and discussion papers being currently prepared to guide science education in the new millennium. To illustrate this, the following examples are taken from recent science curriculum documents published in Canada, the United States, and Britain.

Recent Science Curriculum Documents

Although the term scientific literacy is not used in the Alberta *Elementary Science Program of Studies* (Alberta Education, 1996b), the following program statement gives the justification for students learning science:

> Elementary and secondary science programs help prepare students for life in a rapidly changing world – a world of expanding knowledge and technology in which new challenges and opportunities continually arise. Tomorrow's citizens will live in a changing environment in which increasingly complex questions and issues will need to be addressed. The decisions and actions of future citizens need to be based on an awareness and understanding of their world and on the ability to ask relevant questions, seek answers, define problems and find solutions. (p. A.1)

In the *Common Framework of Science Learning Outcomes* (CMEC, 1997) the authors described the framework as being

> guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skill and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them (p. 4).

The goals for science education, meant to be "a key element in developing scientific literacy" (p. 5), were then outlined. Specifically, science education would:

- encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavors
- enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the

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[1] While the term scientific literacy was used in 1952 by James B. Conant in the foreword to *General Education in Science* (Cohen & Fletcher), Hurd's 1958 article, "Science literacy: Its meaning for American schools" has been cited (Bybee, 1997; Roberts, 1983) as the introduction of this slogan into common usage.

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lives of others
- prepare students to critically address science-related societal, economic, ethical and environmental issues
- provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities
- develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology and the environment (p. 5).

Science for All Americans (AAAS, 1994), the product of the first phase of the Association's long term curriculum project 2061, defined scientific literacy broadly:

> Scientific literacy - which encompasses mathematics and technology as well as the natural and social sciences - has many facets. These include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes (p. 20).

While the Canadian curriculum framework mentioned economic needs to be met by scientific literacy (careers and occupations), *Science for All Americans* (AAAS, 1994) placed more stress on scientific literacy for humanistic and democratic purposes (Eisenhart, Finkel & Marion, 1996). Thus, it is stated in *Science for All Americans,* that the need for science education is to "help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital" (p. 12).

The second recent major American science policy document, the *National Science Education Standards,* (NRC, 1996), gives more prominence to the idea of preparing students for "meaningful and productive jobs." In this document it is stated that in addition to needing scientific information for making everyday choices and "to engage intelligently in public discourse and debate about important issues that involve science and technology" (p. 1),

> Scientific literacy is also of increasing importance in the workplace. ... Other countries are investing heavily to create scientifically and technically literate

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> work forces. To keep pace in global markets, the United States needs to have an equally capable citizenry (p. 1-2).

Thus, scientific literacy was seen to be necessary for the economic health of the country.

A recent British report, *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998) stated that one reason for teaching science "is to enable young people to become 'scientifically literate' - able to engage with the ideas and views which form such a central part of our common culture" (p. 4), an opinion in keeping with that of the AAAS. This report emphasized science education aims similar to those advocated in the Canadian framework, with less stress on the economic advantages to be gained from science studies and additional stress on understanding scientific inquiry and why and how scientific decisions are made.

These recent reports and documents recommending directions to be taken in science education are a continuation of a longer discussion about why science should be taught to children. In the next section I present the writing of three groups of researchers who have attempted in the last decade to further this discussion of desirable science curriculum aims.

Contemporary Studies Defining Scientific Literacy

Jenkins (1990), reviewing studies attempting to describe scientific literacy, noted that a multiplicity of meanings exist, each defining some aspect of scientific literacy. However, "little is known about the needs of students or adults for scientific knowledge and about the ways in which such knowledge is acquired and used. It is also questionable whether a number of different aspects of scientific literacy can be accommodated satisfactorily within the same science curriculum" (p.49). "One alternative," he suggested, "would be the selection of a narrower, more positive and conventional range of meanings of scientific literacy" (p. 50) which would include "an introduction to the contemporary scientific understanding of the natural world" (p.50).

In 1992, Jenkins published further on the topic of reconstructing science education, proposing that "such a curriculum must present science as one of the supremely imaginative, creative and intellectual human achievements" (p. 243). As well,

> pupils should leave school knowing what science has to say about some matters of great interest and importance, e.g. about the nature and origin of life or the

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> cosmos. It seems equally important that attention be given to the scientific dimensions of the modern world, e.g. the manufacture of chemicals, the distribution of electricity, with proper consideration of who gains and who loses in each instance (p. 243).

Such science would be based less on laboratory work, but should include "some insight into the difficulty of generating understanding about the natural world ...if students are to be helped to understand that there is nothing inevitable about a now standard scientific explanation and that such explanation requires agreement about what constitutes reliable knowledge" (p. 243).

Atkin and Helms (1993) were persuaded that curriculum in a science for all "should be weighted toward the kind of outcomes that foster a desire to engage with the subject and to act discerningly with respect to issues for which science is relevant. Engendering, sustaining, and heightening interest in science are paramount goals for the general population" (p. 3). To this end, they suggested that subject matter (content) be chosen to support and advance three priorities.

First, science should be understood as human activity, emphasizing "how people generate, test and use ideas. Emphasis in the curriculum should be placed on justification for scientific ideas ("How do we know?"), and the influences and processes by which they are accepted or rejected" (p. 3).

Second, science should be seen as aiding in practical reasoning, reasoning used to solve the "problems faced by human beings." This would entail an understanding that many different approaches can be taken in solving a problem and there might not be one best answer.

Third, "'certain habits of mind' are among the most important outcomes of science education" (p.3). Among these habits of mind: a belief in one's efficacy to cope with a changing world; "a disposition to discuss science;" "knowing when one knows enough about a subject to take reasonable action" (p.16); a judicious and informed caution; as well as "the ability to identify a weak argument" (p.16).

Based on these priorities, content for learning could be chosen. "This content for learning (themes to explore, problems to solve, concepts for describing phenomena, and for explaining questions about them) should, in turn, define the appropriate pedagogies"

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(p.81). Here, then, neither content nor processes, but purpose would dominate in the making of curricular decisions.

Millar (1996) asked, "What would the science curriculum look like if it were designed with the needs of the majority in mind?" (p. 10), observing "that the present curriculum has evolved, in a fairly seamless line of descent, from curricula designed for training in science" making "the 5-16 science curriculum less suitable as a preparation for more advanced study, whilst largely failing to make it motivating or accessible to the majority" (p.10). He suggested that,

> [T]he science curriculum from 5-16 should have two aims as regards science content:
> - to help students become more capable in their interactions with the material world, by emphasizing a practically useful, technological way of knowing;
> - gradually to develop students' understandings of a small number of powerful 'mental models' (or 'stories') about the behaviour of the natural world" (p.12-13).

In addition, Millar's suggested science curriculum would include learning about the methods of scientific enquiry, "the collection of empirical data which can serve as evidence" and the use of 'systematic enquiry' (p. 15) as well as "the role of theory in science… [that] involves understanding that the purpose of science is to generate explanations of the physical world which account for observed phenomena, and may predict others, or suggest phenomena to look for or create" (p. 15-16).

The third aspect of an understanding of science he proposed was that of "understanding science as a social enterprise" which would include two key ideas. "That scientific knowledge is the product of sustained social work. It is developed through a struggle to understand, make sense and communicate and share ideas" and "[t]hat there are crucial differences between science in the laboratory and in the real world" (p.16).

I found strong similarities when comparing the statements made by Atkin and Helms (1993), Jenkins (1992), and Millar (1996). In arguing for the development of scientific literacy in school-aged students, all advocated the development of students' understanding of science as a human enterprise. Additionally, they advocated the development of students' understanding of how knowledge is generated in science; that is, through systematic enquiry, including the importance of "evidence in making or supporting a case" (Millar, 1996, p. 15).

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As well, these authors saw an understanding of science and technology as being an essential tool for living in and interpreting the natural and manmade world, providing "a means of thinking about what is going on, accounting for the things we have observed and imaging how things might turn out in new situations" (Millar, p. 13). Atkin and Helms (1993) believed, too, that "students with an appropriate and desirable orientation toward science believe that at some non-trivial level they can cope with a world that is being changed rapidly" (p. 15).

On the subject of the scientific concepts to be developed in school science, Jenkins (1992) argued for science content centered on "some matters of great interest and importance, e.g. about the nature and origin of life or the cosmos" (p. 243). Millar's (1996) suggestions for science content, quoted above, would include "powerful ...'stories' about the behavior of the natural world" (p.13). Atkin and Helms (1993) wrote that "the major concepts of science should be stressed" (p. 3), because "[students] need a perspective about science more than they need detailed information in these subjects" (p. 5).

All these aspects of science education would need to be considered in planning exemplary science instruction.

Challenges to Reconstructing Science Education

A recent study acts as a reminder of the challenges faced by science educators proposing innovations or a restructuring of science curricula. One of the case studies in *Bold Ventures* (Raizen & Britton, 1997) documented the implementation of The Voyage of the Mimi, a curriculum package combining a video series, computer software, and print materials designed to "present an integrated set of concepts in mathematics, science, social studies and language arts" (p. 409). Meant to supplement, not replace, curriculum in the upper elementary grades, the designers aimed to 'hook' students on the story and activities. They assumed the teachers would, in turn, be hooked by student enthusiasm. "The developers report, however, that they did not sufficiently take into account teachers' beliefs, styles, and constraints, that they failed to find ways to overcome some teachers' inability, unwillingness, and/or lack of support in allowing knowledge to be 'constructed,' rather than 'transmitted' and 'managed'" (p. 419). The case study

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concluded that "Mimi did not substantially change the way teachers taught science – science instruction continued to be short, mostly talk, and teacher-directed ... leaving little time for reflection, the airing of different perspectiveness [sic], or expansion of the topic. Additionally, hands-on activities – although more numerous than previously – followed scripted material" (p. 505).

Thus, reconstructing science to develop a 'scientifically literate citizenry,' the chief justification given for the teaching of science in pre-tertiary education for the last several decades, continues to be a challenge.

Why Teach Science in Elementary Schools?

Answers to the question, "Why teach science in elementary schools?", is less clear in the cited literature. Much of the periodical literature on the topic of scientific literacy emphasizes topics and thinking to be developed in the upper grades, rather than at the elementary level. It is in the major policy documents that science at the elementary level is given more recognition and justification.

The *Common Framework of Science Learning Outcomes* (CMEC, 1997) refers to "a steady and gradual accumulation of knowledge" (p. 9) and moving "from simple, concrete ideas to abstract ideas, ...from contexts that are local and personal to those that are societal and global, and [in decision making] from decisions based on limited knowledge, made with teacher guidance, to decisions based on extensive research, involving personal judgment and made independently, without guidance" (p. 11). Furthermore, "as students advance from grade to grade, the skills they have developed are applied in increasingly demanding contexts" (p. 13).

Benchmarks for Science Literacy (AAAS, 1993) outlined what students should know and be able to do in science, mathematics and technology by the end of grade 2, 5, 8 and 12. Beyond the benchmark statements of **what** should be learned (e.g., "By the end of 2nd grade, students should know that – when a science investigation is done the way it was done before, we expect to get a very similar result," p. 6), discussion of **why** science should be taught in elementary schools is limited. It was stated that "By gaining lots of experience *doing* science, becoming more sophisticated in conducting investigations, and

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explaining their findings, students will accumulate a set of concrete experiences on which they can draw to *reflect* on the process" (p. 4, emphasis in original).

The National Science Education Standards (NRC, 1996) also includes a set of fundamental concepts, principles, abilities and understandings to be reached by the end of different grade levels. Kindergarten to grade six teachers are "to lay the experiential, conceptual, and attitudinal foundation for future learning in science by guiding students through a range of inquiry activities" (p. 60). In pursuing these activities,

> children compare, describe, and sort as they begin to form explanations of the world. Developing a subject-matter knowledge base to explain and predict the world requires many experiences over a long period. Young children bring experiences, understanding, and ideas to school; teachers provide opportunities to continue children's explorations in focused setting with other children... (p. 123).

In the last document considered, *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998), primary science is described as providing a framework for developing children's curiosity about their natural environment and their skills of careful observation and "precise language for descriptive purposes" (p. 2008).

> More fundamentally, however, establishing any understanding of the world requires opportunities to interact with the wide variety of natural phenomena that exist, to investigate their behavior, and to learn how they are talked about. Such experiences are essential to constructing the basic representations and concepts on which a more sophisticated understanding of science and technology rests (p. 2008).

They described children's learning in primary school science using such terms as "begin to appreciate" and "become familiar with" (p. 2021).

Thus, science education in elementary schools has been viewed as building on the innate curiosity of young children about their world. Through participating in inquiry (explorations, investigations, or interactions), children can develop skills such as careful observation, comparison, and description as well as developing understanding (or familiarity) on which more abstract learning can be based. In several of the documents the importance of developing positive attitudes such as enjoyment of and interest in science was also mentioned.

These, then, are the views of what can be done in science in elementary schools to help develop scientific literacy. Relative emphases vary. The emphases contained in the Alberta elementary school science curriculum are detailed in Chapter Four.

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Having developed a broader understanding about **why** science should be taught and a sense of curriculum emphases suggested for achieving that broad goal, I turned to the literature focused more specifically on **how** this might be achieved in classrooms. That is the subject of the next review.

Teaching Science

Guiding this review of the literature pertaining to how to teach elementary science was the question, "What do teachers need to know to teach science that is consonant with the scientific literacy goals?" My initial review, however, was much less focused, much more practical. That is, I read widely, particularly in the elementary science education literature, to learn more about advocated possibilities, best practices in the Schwabian (1978) sense of best.

I have used Shulman's (1987) concept of knowledge bases, the "categories of knowledge that underlie the teacher understanding needed to promote comprehension among students" (p. 8), to categorize the teacher knowledge that appears to be important for the teaching of exemplary elementary school science. This knowledge base is the topic of the following discussion.

Knowledge of Inquiry

As Shulman (1987) postulated, teachers need to have a knowledge of educational ends and purposes. In the case of elementary science education, teachers will need to understand the scientific literacy goals previously discussed and the justifications for those goals. Such an understanding necessitates a knowledge of inquiry.

Inquiry (also referred to in terms such as investigations and explorations), widely considered to be an important component of science education (e.g., AAAS, 1994; Bentley & Watts, 1989; Gott & Duggan, 1995; Hodson, 1998; NRC, 1996), is central to the development of scientific literacy as described in current literature.

The assumption underlying an emphasis on inquiry is that by doing science inquiry, students gain an awareness of how science is pursued: how science demands evidence, is a blend of logic and imagination, both explains and predicts, and how "no scientist, however famous or highly placed, is empowered to decide for other scientists

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what is true" (AAAS, 1994, p. 7), because no one is believed "to have special access to truth" (p. 7).

Inquiry, however, is a word used to describe a very wide variety of science activities. Hands-on science activities that Tafoya, Sunal, and Knecht (1980) labeled as confirmation or structured-inquiry are frequently equated with inquiry science (Beisenherz, Dantonio, & Richardson, 2001; Brown & Hansen, 2000). In confirmation activities students verify a concept or principle through following a given procedure. In structured-inquiry students are presented with a problem for which they do not know the results, but are given enough structure to enable them "to discover relationships and to generalize from the data collected" (Tafoya et al., 1980, p. 46).

Neither of these limited "inquiries" conforms to the concept of inquiry being developed in the science literacy literature previously reviewed. *The Science Education Standards* (NRC, 1996) explains scientific inquiry as:

> the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.
>
> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries (p. 23).

Inquiry is obviously a complex activity, guided in the classroom by the teacher's awareness of the diversity found in scientific investigations.

The American Association for the Advancement of Science recommended that science inquiry involve elementary school students in active exploration of "phenomena that interest them," in investigations that are both "fun and exciting, opening the door to even more things to explore" (1993, p. 10). Communicating their findings, explaining the evidence they have for their explanations, and beginning to use scientific argument and debate are advanced as additional important investigative skills.

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Elementary school students, particularly ones in the primary grades, may not consistently engage in all these aspects of investigation, but inquiry science lessons require that the "real, relevant, and rigorous" (Reardon, 1996) spirit of this approach to science education be observed. Bettencourt (1992) also commented that "understanding starts with a question, not any question, but a real question ...[that] expresses a desire to know" (p. 83).

Hodson (1998) described learning by inquiry as an activity initiated by a teacher generating interest in and commitment to a topic of study. Through engaging in inquiry

> students acquire and develop their own skills of inquiry ...: by trying to use them; experiencing success, making mistakes and reflecting on them; gaining feedback, advice and support from the teacher, and perhaps from other students; reformulating their plans; trying again. Through these activities, student refine and develop their existing understanding, learn new skills and acquire new conceptual and procedural knowledge (p. 122).

Duckworth (1987) expressed it more poetically;

> the development of intelligence is a matter of having wonderful ideas. In other words, it is a creative affair. When children are afforded the occasions to be intellectually creative – by being offered matter to be concerned about intellectually and by having their ideas accepted – then not only do they learn about the world, but as a happy side effect their general intellectual ability is stimulated as well (p. 12-13).

It is this type of creative, reflective, interactive science – science as practiced by scientists – that teachers need to understand if they are to design instruction consonant with current, widely-accepted views of scientific literacy – to plan, that is, exemplary science lessons.

Knowledge of Constructivist Learning Theory

Constructivist learning theory provides a perspective helping explain how and why inquiry promotes growth in understanding. As Millar (1989) noted, constructivism is readily accepted by science educators because its central tenets are so unremarkable. Here Millar was referring to the theory that individuals construct their own understandings of events and phenomena based on their prior ideas and experiences and that these prior conceptions are often very difficult to change. Duit (1995), too, emphasized that "at the heart of constructivism" is "the idea that perception and the development of new theories is substantially influenced by the 'old' theories" (p. 274).

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Driver (1997) characterized constructivism as "a general framework theory to provide science educators with a perspective on how learning in science occurs" (p. 1008). Quoting an earlier paper, she explained that "learning involves an interaction between the schemes in pupils' heads and the experience provided.... This process of using and testing current ideas in new situations requires active involvement ... [and] entails the progressive development and restructuring of learners' knowledge schemes" (Driver, 1989, p. 84).

Translating this theory into features "characterizing the constructivist perspective on teaching," Constable and Long (1991) wrote that

> (a) The teacher starts a topic by eliciting learners' existing ideas.
> (b) The teacher provides practical experiences which relate to and extend the learner's knowledge.
> (c) In addition to practical experiences, the teacher provides separate opportunities for thinking.
> (d) The teacher emphasizes collaborative learning methods.
> (e) The teacher helps students learn how to learn.
> (f) The teacher provides a classroom environment which encourages the full exploration of ideas and their critical review, but where premature judgement is avoided.
> (g) The teacher accommodates learners' prior ideas in his or her teaching.
> (h) The teacher recognizes, and intervenes to overcome critical conceptual hurdles to help the learners restructure their knowledge (p. 408).

It would be helpful for teachers to have an understanding of the rationale for such constructivist teaching features and a willingness to try to incorporate them into teaching practice. This would include developing an understanding of students' ideas about science concepts, collaborative group learning, and situated cognition. How these understandings might contribute to the development of pedagogical strategies characterizing exemplary science lessons is explored in the following sections.

Students' Ideas about Science

With its emphasis on the influence students' prior ideas and experiences have on learning, constructivist learning theory suggested a fruitful research program to many science education researchers. Student ideas (referred to as alternative frameworks, misconceptions, preconceptions, and children's science) about a large number of science subjects have been a major science education research focus for the last two decades. So much preconception data have been gathered that listings and bibliographies of these

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studies have been published to help teachers and researchers access this wealth of information.

This research was done to help inform science teaching practice. Teachers may find it useful when planning instruction. However, if they are unaware of the preconception research findings, these data will obviously play no role in their teaching considerations; their choices are narrowed.

Collaborative Learning

A sociocultural perspective on learning, one emphasizing that "knowledge and thought are not just to do with how individuals think, but are intrinsically social and cultural" (Edwards & Mercer, 1987, p. 160), suggests a classroom emphasis on "discourse and joint action [where] two or more people build a body of common knowledge which becomes the contextual basis for further communication" (Edwards and Mercer, 1987, p. 160).

Studies (Bianchini, 1997; Kempa & Ayob,1995; Blumenfeld, Marx, Soloway, & Krazjcik, 1996) indicate that while students can enhance their learning of science and other subject matter by participating in group work and being a member of a community of learners, this does not just happen. "Learning from peers in cooperative or collaborative groups is difficult and complex to achieve" (Blumenfeld et al., 1996, p. 37). It is careful planning by the teacher – the organization of the groups, the tasks assigned, the sharing of ideas and insights, and the continuation of investigations based on student input – that makes a real difference in what students learn.

Because inquiry science is also dependent on a number of these features, teachers will need to take them into account in their science teaching. And, as Gallas (1995) documented, in exemplary teaching, it is the teacher who helps students develop the collaborative skills necessary for successful group discourse.

Situated Cognition

Studies of situated cognition have focused on "the critical importance of considering pupils' different experiences outside school and how these affect their perceptions of tasks and learning situations in schools" (Hennessey, 1993), as well as

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ways that instructional situations might establish "an intelligible context of interaction... since the learner's assimilation of new information depends on its compatibility with the learner's existing knowledge" (Rogoff & Gardner, 1984, p. 97). Brown, Collins, and Duguid (1989) warned that "by ignoring the situated nature of cognition, education defeats its own goal of providing useable, robust knowledge" (p. 32). Two ideas in particular have been suggested for teacher consideration by those investigating situated cognition: the provision of authentic activities and cognitive apprenticeship.

Authentic activities described as "coherent, meaningful and purposeful activities" (Brown et al., 1989, p. 33) are perceived to occupy an important role in the development of 'useable, robust knowledge.' "When people learn new information in the context of meaningful activities ... they are more likely to perceive the new information as a tool than as an arbitrary set of procedures or facts" (The Cognition and Technology Group at Vanderbilt, 1990, p. 3). For Van Oers and Wadekker (1999) it is important that the concept of authentic not imply a narrow, individualistic approach; rather, "authentic learning is a dynamic relation between a personality-under-construction and cultural practices-being-reconstructed which is aimed at developing an authentic and autonomous person able to participate in a competent yet critical way in cultural practice" (p. 231).

Two aspects of teacher action are discussed in the literature on cognitive apprenticeship, teacher-as-model, and teacher-as-coach. In the former, teachers model strategies for solving problems or making sense of an experience, initiating students into ways of thinking about these situations. In coaching, teachers provide a 'scaffold' for students. According to Bruner (Hall,1982), "learning is not a solitary activity, and development does not consist of a lone person building a model of the external world. Somebody provides a scaffold for the child to climb on – offers provisional hypotheses that the child can use in a tentative way until he can climb on his own" (p. 59).

Hennessey (1993) tied this concept of scaffolding more directly to Vygotskian theory, writing "*scaffolding* refers to the help which enables learners to engage more successfully in activity at the expanding limits of their competence, and which they would not have been quite able to manage alone, i.e. 'within the zone of proximal development'" (p. 12, italics in original).

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To offer exemplary science instruction, according to these criteria, teachers need, first, to be aware of what *their* students consider to be relevant and meaningful. They then choose activities, educative experiences, that involve students in meaningful learning experiences leading toward the development of common knowledge (Edwards & Mercer, 1987).

One message is clear in the literature on constructivist learning theory – involving children in these types of learning activities requires time, substantially more time than a traditional, transmission approach or confirmation and structured-inquiry instruction (Tafoya, Sunal, & Knecht,1980).

But this is not all that teachers need to know. Content knowledge is also considered essential for good science teaching.

Content Knowledge

Shulman described content knowledge as "going beyond the knowledge of the facts or concepts of a domain. ... [Teachers] must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions" (Shulman, 1986, p. 9).

Alexander, Rose, and Woodhead (1992) stated, "Opinion is divided about the relative importance of the teacher's subject knowledge, but few now dispute that it is important. Our view is that subject knowledge is a critical factor at every point in the teaching process: in planning, assessing and diagnosing, task setting, questioning, explaining and giving feedback" (p. 25). The number of papers written on "the importance of teachers' content knowledge" (Parker, Wallace, & Fraser, 1993, p. 169) indicates a strong acquiescence with this view by many in the field of science education. Many of these authors also agree with Feasey (1994) that "to make sense of the content of the science curriculum requires a more considerable science knowledge base than many teachers possess" (p. 76).

Studies have indicated that an understanding of science content plays an important function in the quality of questions asked by teachers (Goodrum, Cousins, & Kinncar, 1992), and in their feedback to students (Feasey, 1994). As well, Osborne and

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Simon (1996) reported that teachers with better subject knowledge make greater cognitive demands on children. Conversely,

> for teachers lacking adequate subject knowledge, the nature of the teaching and learning experience they offer to children is significantly inferior. Such teachers display a closed pedagogy, based on the presentation of unrelated facts and they fail to extend children since they lack the knowledge to see the significance of a child's questions, [and] why one topic is central and another peripheral (p. 133).

Lee (1995) contributed the observation that teachers with weak subject matter knowledge rely more heavily on textbooks and lecture, rather than inviting student questions and comments or engaging in discussion with students about science concepts and ways of knowing.

Working with teachers, several research groups have come to the conclusion that for teachers, just as for elementary school students, some science concepts are more easily understood than others. Harlen and Holroyd's (1997) research indicated that teachers' understanding of the "big ideas" in the elementary science curriculum could be divided into three groups "those already understood by a high proportion of teachers; those less commonly understood at the beginning but in which understanding was readily developed; and those less commonly understood and which were not readily developed (or resistant to change)" (p. 101). Summers and Kruger (1994) had earlier come to a similar conclusion, noting that "Some concepts were more easily acquired than others …. [and] teachers may retain misconceptions even when these are addressed intensively during in-service training" (p. 516). The topic of concept difficulty will be discussed in more detail later in this chapter.

The message from this literature is quite consistent: to teach science well, teachers need content knowledge that includes a flexible, thoughtful, and conceptual understanding (McDiarmid, Ball, & Anderson, 1989) of the basic science concepts taught at the elementary school level.

They need, as well, what Shulman (1986, 1987) referred to as pedagogical content knowledge.

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Pedagogical Content Knowledge

Shulman (1986, 1987) claimed that teachers need to develop pedagogical content knowledge,

> pedagogical knowledge which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching*. ... [which includes] the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others (Shulman, 1986, p. 9).

The necessity for developing pedagogical content knowledge has also been referred to by a number of other writers. Lloyd et al. (1998) advised that while the "Identification of the key ideas and the depth to which they need to be understood" is necessary in the design of courses for teachers, "this is not sufficient. ... Courses should also focus upon specific pedagogical content knowledge" (p. 531). Parker and Haywood (1998) found "making the teacher aware of the pedagogic content knowledge which transcends mere subject knowledge a challenge that is far and away more complex than the public rhetoric of developing teacher subject knowledge and understanding in science" (p. 519).

After producing teaching materials and providing in-service training "to help teachers develop their subject and teaching knowledge," Summers, Kruger, and Mant (1998) concluded that because the teachers they had worked with tended to transfer ideas and strategies directly from in-service activities planned for teachers as adult learners into their own classrooms, it was important in developing materials for primary science teacher education that the approaches used were ones that could be so transferred. This they referred to as subject-specific teaching knowledge, similar to Shulman's pedagogical content knowledge.

Furthermore, it is not just a knowledge of the major concepts taught in elementary schools that teachers need to know. It is also considered necessary for teachers of science to understand what is often referred to as the nature of science, the "complex intellectual and social processes by which science knowledge is obtained" (Jenkins, 1996, p. 143), those processes of inquiry and communication used to establish the guiding paradigms in the science domains.

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This repeats the message that science education is considered more than the teaching of science facts, but is tied to inquiry. Teachers can learn more about this aspect of science education by becoming conversant with some of the teaching approaches developed to help students construct scientific knowledge.

Teaching Approaches

A number of approaches and strategies have been advanced in the science education research literature in the past fifteen years to help make "available to young people the benefits of scientific knowledge and ways of thinking" (Driver, 1997, p. 1012). These vary in several ways, one being the degree to which they engage children in scientific inquiry.

Some approaches focus students' attention quite quickly on a predesignated science concept with lessons designed to lead students along a narrow pathway to an acceptance of this concept, an *induction 'into' science* approach (Fensham, 1988, emphasis in original). Other approaches attempt to broaden students' perceptions and thinking about a topic, what Driver, Asoko, Leach, Mortimer, and Scott (1994) referred to as conceptual development, changing students' understandings "*toward* (italics added) those of accepted science" (1995, p. 399).

A conceptual change model.

In one approach, labeled the Conceptual Change Model (CCM), a science concept or concepts that students should learn is commonly specified prior to the lessons being taught. For example, Neale, Smith, and Johnson (1990) described a unit plan that provided

> activities and discussions so that children could construct the following scientific content: Light travels in straight lines in all directions from the source. Shadows are places where light has been prevented from traveling (p. 112).

Introducing contradictory evidence, often referred to as discrepant events, is advocated by many researchers working to effect conceptual change. It is reasoned, using Piagetian theory, that such evidence will challenge students' existing conceptions, causing the disequilibrium necessary to start students thinking about a more fruitful and

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useful explanation, that being the scientific explanation designated for student acceptance.

Others believe "not all preconceptions are misconceptions" (Clement, Brown, & Zeitman, 1989) and have presented evidence of how 'anchoring conceptions,' "valid, potentially helpful beliefs of students" (p. 554) "in rough agreement with accepted physical theory" (p. 555) can be built on in science instruction to help students come to understand the targeted concept.

Whether using discrepant events or anchoring conceptions, the goal of instruction appears to be students adopting a "scientifically correct conception" (Tyson, Venville, Harrison, & Treagust, 1997), which may necessitate weak revision, referred to by Posner, Strike, Hewson, & Gertzog (1982) as assimilation, or strong revision, similar to Piaget's definition of accommodation. It is important to note that in the conceptual change model, the concept that students are to learn is targeted in advance of instruction.

A conceptual development model.

Driver and associates wrote more often about concept development than conceptual change. Rather than outlining definite pathways toward a conceptual goal, Driver, Guesne, and Tiberghien (1985) suggested strategies "which together could be helpful in promoting conceptual learning," because the choice of a teaching strategy is dependent "on the nature of the students' prior conceptions and the learning goals" (Driver, 1988).

However, based on classroom research revealing learners' ideas about particular topics and the intellectual demand (the "learning demand") of that topic for students of a particular age, they published a set of teachers' guides "providing opportunities for building on and modifying these [pupils' own ideas] towards the scientific theory" (Driver & Oldham, 1986, p. 116). At some point, "the teacher will present and explain it [the scientific view], providing opportunities for pupils to construct meanings for it by empirical tests and language activities" (p. 118). In the next phase, the application of ideas, "pupils are given the opportunity to use their developed ideas in a variety of situations, both familiar and novel. Thus the new conceptions are consolidated and reinforced by extending the contexts within which they are seen to be useful" (p. 118).

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The language of concept development rather than conceptual change and of helping students move 'toward the scientific theory' suggests a somewhat broader approach to science teaching than that of the conceptual change teaching model. However, there appears to be a very fine line between giving students the 'right answer,' the accepted scientific theory, after the students have engaged in a hands-on investigation, and suggesting the 'right answer,' the accepted scientific theory, to help students make sense of the results of their investigations.

As Driver et al. (1994) reiterated, "no easy rules for pedagogical practice emerge from a constructivist point of view of learning" (p. 11). Rather "the teacher is the often hard-pressed tour guide mediating between children's everyday world and the world of science" (p. 11).

Lessons in both these approaches work with students' ideas. Through explorations designed to direct student attention toward particular phenomena and in discussions about these activities, student ideas are (to varying degrees) elicited, examined, and/or challenged. Both approaches demand flexibility; as student ideas emerge, these are used to guide discussions and future activities useful in developing/expanding conceptual understandings. They differ in the extent to which students are directed toward an acceptance of a predesignated science concept.

The difference in the end goal of these and other approaches, between the goal to change or to expand student conceptual understanding, is important. Expansion reminds me of Cobb's (1988) statement that "the fundamental goal of mathematics is or should be to help students build structures that are more complex, powerful, and abstract than those that they possess when instruction commences" (p. 89). Conceptual change teaching literature appears to advocate for what Anderson, Holland, and Palincsar (1997) described as canonical science education where the primary focus is on the development of students' knowledge of "the key concepts, theories and habits of mind in the western scientific canon" (p. 362).

Conceptual Difficulty

As just mentioned, Driver and her associates (Scott, Asoko, & Driver, 1993) argued that the intellectual demand of a concept, or what Driver later referred to as

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"learning demand" (Driver, 1997), needs to be taken into account when planning science instruction.

Sadler (1998) commented, "Efforts to revise or create new curricula ... do not appear to take the extreme difficulty of scientific ideas into account. Many of the astronomical ideas found in textbooks and the new standards are far too difficult" (p. 289).

Studies have been done outlining the conceptual difficulty of a number of topics commonly included in elementary school science. This includes work on children's difficulties understanding evaporation (Bar & Galili, 1994; Russell, Harlen, & Watt, 1989); chemistry (Gabel, Keating, & Petty, 1999; Hesse & Anderson, 1992); light (Guesne, 1985; Osborne, Black, Meadows, & Smith, 1993); and astronomical phenomena (Baxter, 1989; Sadler,1998).

Gabel, Keating, and Petty (1999), after studying children's understandings of chemical and physical change concluded that "even at grades 4 and 5, the topic may be too abstract for some children" (p. 14). "More appropriate instruction" they wrote, "might help eliminate children's reliance on memorizing science and instead build appropriate foundations based on reason" (p. 15). Asked if it was, nevertheless, possible to teach this topic to this age group, Gabel answered that if the goal was student understanding, it depended on how long you wanted to spend on the topic (personal communication, March 30, 1999).

This research indicates that an awareness of conceptual difficulty could help teachers in their design of science lessons and in their interactions with students while teaching these concepts.

Teaching Strategies

Although an awareness of different science teaching approaches can enrich teachers' deliberations on classroom instruction, the literature on strategies for teaching science in elementary classrooms provides more direct examples of aspects of inquiry science and actions teachers need to consider in initiating inquiry in their classrooms.

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Teacher-student interactions.

One area of study has been that of teacher-student interactions during science lessons. Fleer (1992) wrote,

> The teacher's input into the child's construction of knowledge is crucial to the development of children's thinking.... [T]he teacher's ability to assist, model, and extend children at each stage of an interactive approach to teaching science was fundamental to the whole process. The factor that influenced the ultimate success and the depth of learning was the quality of the teacher's interactions with the children (p. 394).

Fleer (1995), describing the interactive approaches taken by two primary school teachers, observed that the teacher-student interactions in a class with a procedural focus resulted in children who were "unsure about what they had to do or how what they were doing related to the unit of work they were doing" (p. 330). Conceptually-focused interactions, with the "teacher continually intervening to focus the children's thinking" (p. 337) and "asking the children to consider what was happening and why it might be happening (p. 339), "led to the overall development of ideas, and hence induced conceptual change" (p. 339).

Segal and Cosgrove (1995) reported that in a year 3/4 classroom, students held "animated, intellectual and motivating discussions" (p. 19) about the nature of light and reflections, aided by the teacher's scheduling of adequate time for such discussions and the teacher's ability to ask questions critical for furthering her students' thinking and reasoning about the topic.

Roth (1996), describing a teacher's questioning techniques in a grade 4/5 classroom, similarly concluded that the teacher's questions played an important role in facilitating student learning. He concluded that "good question techniques require a great deal of competence in the discursive practices of the subject-matter domain" (p. 731). Scaffolding, too, was noted; the teacher "decreased her support as students' accounts of their work and plans became longer and more complete" (p. 730).

Flick (1995), analyzing an experienced fourth-grade teacher's blend of teaching skills in language arts and reading with hands-on science, concluded that this teacher's skill in initiating and sustaining student discussion about a science topic "helped students interact with science concepts through their own language" (p. 1080). As well, "good

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teachers in these [upper-elementary and middle school] grades have skills and knowledge that get students to think critically, sceptically, and cooperatively ... important for helping students to see science as an interesting and viable alternative for further study" (p. 1080). However, it appeared that had this teacher been more knowledgeable about the science content being studied, she could have guided student attention more successfully toward the concepts necessary to develop a robust understanding of the topic.

The teacher's role in introducing students to powerful, generative science concepts has been an area of interest for a number of science educators. Driver (1995) wrote,

> The teacher needs to provide the necessary experiences to enable students' science understanding to relate to events and phenomena. However, experience is by itself not enough. It is the *sense* that students make of it that matters. If students' understandings are to be changed toward those of accepted science, then intervention and negotiation with an authority, usually the teacher, is essential (p. 399).

Prawat (1993) also advocated "the teaching of the important ideas developed within the disciplines" (p. 5). He argued that it is these powerful ideas that "help educate attention," as perception alone does not efficiently lead to an individual's development of these ideas. In support of his argument, Prawat cited Vygosky's (1987) assertion that "the unique form of cooperation between the child and the adult is the central element of the educational process; it is explained by the fact that in this process knowledge is transferred to the child in a definite system" (p. 169). To implement idea-based social constructivism, teachers would work within a curriculum Prawat characterized as a "matrix or network of big ideas," rather than curriculum as "fixed agenda." Big ideas, he wrote, serve "as a kind of 'cross-country guide'" as teachers and their students "explore the territory mapped out by the network of big ideas" (p. 13).

Interactions, thus, enable teachers to introduce "big ideas" to their students. Teachers subsequently use their professional knowledge and skills to help students consider the explanatory power of these ideas.

Argumentation.

Research centring on "the place of argumentation in the pedagogy of school science" (Newton, Driver, and Osborne, 1999) has also contributed to an understanding

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of ways students may be helped to better understand both science concepts and how science is done. Zeidler (1997) explained that this is accomplished because

> Dialogic reasoning (argumentation) compels one individual to coordinate his or her reasoning structures with those of another individual. The result is ...each person is cognitively challenged during discourse to reflect on both his or her own beliefs, assertions, and premises, and those of the other individual. The resulting discourse leads to a joint construction of shared social knowledge (though not necessarily shared beliefs) (p. 485).

Kuhn (1993) proposed that a promising concept of science education has to do with its role in "promoting a way of thinking" (p. 319). Science, she continued, can be defined as argument, "a social activity ...in which ideas are articulated, questioned, clarified, defended, elaborated, and indeed often arise in the first place" (p. 321). In her view, such an approach might help students develop a more sophisticated epistemological understanding of science, an understanding that is critical to meaningful science education.

In a study by Meyer and Woodruff (1997), students engaged in a series of investigations were asked to develop a consensus explanation of the phenomena being studied. In building such a consensus, students "need to find and agree to a set of 'collectively valid statements' (Miller, 1987, p. 252)," a coordination that Miller defined as one of the first rules of argumentation. In Meyer and Woodruff's experience, "it takes time for students to become accustomed to generating and evaluating their own ideas" (p. 191). Similarly, Kuhn (1993) asserted that argumentation requires students to be able "to distance themselves from their own beliefs to a sufficient degree to be able to evaluate them as objects of cognition. In other words, they must have the capacity and the disposition to think about their own thought" (p. 331).

Newton, Driver, and Osborne (1999) also emphasized that "argument is a central dimension of both science and science education" (p. 553) and "if pupils are genuinely to understand scientific practice, and if they are to become equipped with the ability to think scientifically through everyday issues, then argumentative practices will need to be a prominent feature of their education in science" (p. 556).

As with other teaching strategies, educative discourse does not just happen, but is fostered by teacher instruction and the fashioning of lessons that encourage dialogic sense

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making. In all of these studies, the complexity of the task facing the elementary school science teacher is underscored.

Knowledge of Curriculum Materials

Complexity can be alleviated by knowledge of curriculum material, teachers' "tools of the trade" (Shulman, 1987). For many of the studies reported in the science research journals, (e.g., Anderson & Roth,1989; Muthukrishna et al.,1993; and Palincsar, Anderson, and David, 1993), the research team used curriculum materials developed for the study, but these materials were described in too little detail to be of much use to classroom teachers.

Roychoudhury and Kahle (1999) noted that the absence of commercially-available curriculum materials was a problem for teachers wishing to implement inquiry science. Faced with writing unit plans and lessons incorporating a questioning technique they were unfamiliar with, the teachers in their study resorted to a traditional science teaching approach. The National Research Council (2000) published a guide for inquiry science teaching offering justifications for and vignettes describing classroom science inquiry lessons, but few concrete recommendations of curriculum materials teachers can order to help them implement inquiry science in their classroom.

This appears, at present, to be an important knowledge base teachers will find lacking in substance.

Except for the realization that it is very complex, an understanding of how to teach science to most effectively develop student understanding of science concepts and the nature of science remains very much a work in progress. There is obviously no one right way to teach science in elementary schools. The literature does, however, advance a number of possible approaches and strategies worth exploring in the design and assessment of science lessons. From the literature, too, one can extract indications of components of exemplary science lessons, a topic of particular interest to educators in schools.

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An Exemplary Science Lesson

A major constant in the current literature on elementary school science education is an expectation that students will be involved predominantly in inquiry science. As previously outlined, inquiry is considered to be "a multifaceted activity" (NRC, 1996, p. 23) that involves seeking answers to meaningful questions about the natural world, science education Reardon (1996) referred to as "real, relevant, and rigorous." A number of teacher actions are proposed in the literature as important for encouraging inquiry through which "students refine and develop their existing understanding, learn new skills and acquire new conceptual and procedural knowledge" (Hodson, 1998, p. 122). Briefly, lessons featuring the following actions have been repeatedly advanced as representing best science education practice; that is, exemplary science instruction.

First, taking into account theory that claims knowledge construction is influenced substantially by a student's beliefs and past experiences, teachers will endeavour to find out what students know/believe about a target topic prior to planning "educative experiences" (Dewey, 1938/1963). Believing that engagement in meaningful activities is important in the development of "useable, robust knowledge" (Brown et al., 1989), teachers will also try to choose science topics and paths of inquiry their students will recognize, possibly with the help of the teacher, as interesting and worth pursuing.

Second, teachers will help their students plan ways of exploring a topic. This may include hands-on experimentation as well as reading, talking, and writing about the phenomena being studied. While students are working, teacher-student and student-student interactions are considered very important as it is through these interactions that students are encouraged to conceptualize, verbalize, and defend their explanations and to listen to and consider those of others (including the teacher's). Teachers, in addition, gain insight into students' views and interpretations, allowing them to design future lessons based on the ideas their students are forming.

A lesson (which is not necessarily just one class period in length) concludes, too, with words. The literature reviewed is unclear about how many of those words are the teacher's. He or she may choose to supply a scientifically "correct" answer, or the teacher and students may together review and "evaluate the status of the explanations and

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knowledge claims they have generated" (Bloom, 1998, p. 168). If inquiry as practiced by scientists is a curriculum goal, the latter would be chosen.

Summary

To sum up the literature on the teaching of science, in the words of Greene (1985), "In the sense that someone is teaching something to somebody, the teacher ought to have the kind of engagement with the subject matter that entails not merely a commitment to it but clarity about what needs to be made explicit at various moments in the teaching-learning process... [as well as] what might be appropriate for different pupils and for pupils at different stages of conceptual development" (p. 23) – a complex task, particularly for the elementary school teacher who is responsible for teaching a number of different subjects.

Two recent reports by long-time advocates of a conceptual change model of teaching demonstrate the complexity of the science teaching task.

Complexities

Anderson, Holland, and Palincsar (1997) wrote that while conceptual change strategies "often raised the proportion of students understanding canonical scientific concepts to 50% or more" far better than the "5%-20% success rates when teachers used typical approaches and standard commercial products," (p. 362), "conceptual change researchers have consistently fallen well short of the goal of science for *all* Americans" (p. 363). Wanting to teach science to *all* students, they developed a teaching approach combining "insights from canonical and sociocultural approaches" (p. 364). They concluded, at the end of the set of lessons they had designed and observed, "The story of Juan and his group is not a success story. It is the story of one small group of students engaged in a task that did not quite work in the way that we had intended, leading to only partial mastery of our key learning goals for most members of the group" (p. 377-378).

Thorley and Woods (1997) reported on a case study they did to monitor the effect of a conceptual change unit as students worked to develop an explanatory model of electrical phenomena. "Overall, the evidence suggests that on the score of changing conceptions we have achieved only a modest level of success" (p. 243). There was, they

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found, "no one best approach" as "any single model of curriculum will disadvantage some proportion of the student body" (p. 240). "The price to be paid for probing so deeply is the stark revelation of the limitations in students' understanding and of the instructional strategies in which much thought, effort and hope had been invested" (p. 242).

Anderson et al. (1997) concluded that "The story of Juan and his group, however, helps us to see how difficult it will be to help all students connect their curiosity about the world with our aspirations for their scientific literacy. ... [It] helps us to appreciate the depth and difficulty of the craft of these teachers" (p. 381).

As both sets of authors quoted above have stated, classroom studies provide insights into how elements considered integral to an exemplary elementary school science lesson work in actual classrooms with diverse groups of students. These insights, as well as the theories related to teaching and learning science, are topics that can be investigated in professional development – the topic of the next section of this review of the literature.

Professional Development

The focus of the literature review now shifts to the provision of teacher professional development. Not the type of professional development Miles' (1995) referred to as

> a joke.... It's everything that a learning environment shouldn't be: radically underresourced, brief, not sustained, designed for 'one size fits all,' imposed rather than owned, lacking any intellectual coherence, treated as a special add-on event rather than as part of a natural process .... In short, it's pedagogically naïve, a demeaning exercise that often leaves its participants more cynical and no more knowledgeable, skilled or committed than before (p. vii).

Instead, I was interested in professional development that is educative in a Deweyan (1938/1963) sense -- professional development experiences that introduce teachers to alternative ways of thinking about teaching and learning and create "conditions for further growth" (p. 36).

The professional development literature selected for review is broad-based. Very few studies document professional development introducing teachers to inquiry science

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instruction and fewer still focus on this topic for elementary school teachers. Where possible, examples from science education professional development have been chosen to illustrate the themes that emerged from reviewing professional development literature.

Additionally, the Alberta professional development to be analyzed for this study had been planned for the generalist classroom teacher, not for any particular group of teachers. Therefore, literature was chosen to indicate professional development practice advocated in books and journals for teachers in general, literature I judged would help me understand if a problem with professional development existed in Alberta and, if so, what the dimension of that problem might be.

I was also interested in current rationale given for professional development; that is, in the goals described as important for teacher professional development. It is this topic I address first.

Rationale for Professional Development

During the 1980s' call for educational reform (see Cuban [1990] on "Reforming again, again, and again"), two reports were published in the United States by groups formed to investigate the quality of education in that country. The Carnegie Forum on Education and the Economy, consisting of members drawn from business, government, and education asserted "that only by having the finest teachers obtainable can the country address the problem it faces" (p. 11). Teachers, they wrote, are crucial because

> a much higher order of [teaching] skills is required to prepare students for the unexpected, the non-routine world that they will face in the future. And a still higher order of skills is required to accomplish that task for the growing body of students whose environment outside the school does not support the kind of intellectual effort we have in mind (p. 25).

The second report, that of the Holmes Group (deans of education from fourteen leading American faculties of education), came to a similar conclusion. "American students' performance will not improve much if the quality of teaching is not improved .... And teaching will not improve much without dramatic improvement in teacher education" (Holmes Group, 1986, p. 3).

The clear message in both reports was that good teaching is fundamental to student learning; that is, teachers count. In their statements and those of others, the

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complexity of teaching in the current milieu was indicated. Darling-Hammond (1998) wrote that "schools are being asked to educate the most diverse student body in our history to higher academic standards than ever before" (p. 7). Borko & Putnam (1995) observed that reform necessitates that teachers teach "in new ways – ways that differ substantially from how they were taught and how they learned to teach" (p. 37).

Kennedy (1998) indicated that high academic standards did not mean students should simply learn more science facts, but that they should develop a conceptual understanding of science, as well as knowledge about and respect for how knowledge is generated in the disciplines. Thus, teachers count and their jobs are highly complex as they are expected to teach concepts, not facts, to an increasingly diverse group of students using new approaches to meet shifting societal demands and needs, one of those demands being that *all* students learn to their potential. In the opinion of William Kyle, Jr., writing as editor of the *Journal of Research in Science Teaching*, "The current emphasis on professional development comes from an emerging recognition of teaching as a dynamic, professional field" (1995, p. 680), a field obviously faced with a professional task requiring a complex knowledge of how to help students develop into thinking and informed citizens.

As Eisner (1995) wrote, the literature on education is presently "pervaded by the belief that central to the education of children is the competence of teachers."

These statements reveal a recognition of the complexity of the professional task faced by teachers. The previously outlined complex knowledge base needed for teaching inquiry science adds details to this picture. How teachers may be helped to further develop their professional practice given the complexity of their situations is the subject of a considerable body of literature. Studies addressing this issue of professional development are reviewed in the following section.

Developing "Better Teaching" Practice

The literature on how teachers may be helped in further developing their practice does not stand alone. It is framed by broader issues, some of which are suggested by titles of books on teacher development, titles such as *Teacher Development and Educational Change* (Fullan & Hargreaves, 1992) and *Teacher Development and the*

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Struggle for Authenticity (Grimmett & Neufeld, 1994). Chapter titles suggest additional issues: "Teachers' Work and the Labor Process of Teaching: Central Problematics in Professional Development (Smyth, 1995), "The Empowerment Movement: Genuine Collegiality or Yet Another Hierarchy?" (Ceroni & Garman, 1994), "Dynamics of Teacher Career Stages" (Fessler, 1995), "Development and Desire: A Postmodern Perspective" (Hargreaves, 1995), and "Challenges" (Bell & Gilbert, 1996). In addition, discussions of the nature of knowledge (Fenstermacher, 1994) introduce important theoretical considerations into the discussion.

Recognizing the existence of these issues and outstanding questions, I decided to concentrate here on literature focussed more specifically on <u>how</u> teachers can be helped to enhance their professional practice. Baird's (1992) goal of " better teaching," where "the teacher *knows* more about what teaching is and how it best works for him or her, is more *aware* of what is happening in the classroom as he or she teachers, and is more purposeful in the pedagogical *decisions* that he or she makes" (p. 33) helped me select studies to be reviewed and reported. First, however, I will describe the type of knowledge considered helpful for making reasoned decisions -- and for pursuing "better teaching."

Principled and Procedural Knowledge

In examinations of learning, numerous terms have been used to describe knowledge and knowledge development. Domain-specific principled knowledge, a knowledge of the principles of a domain, is a term that appears in literature written from the perspective of cognitive psychology. Davis (1996) and English (1993) shortened this phrase to principled knowledge in their explorations of children's learning in science and mathematics. The term principled knowledge was used in a similar sense by Lampert (1990) in her consideration of knowing and teaching elementary school mathematics and was adopted from this mathematics literature by Spillane and Zeuli (1999) as a conceptual frame for investigating mathematics teaching practice. Principled knowledge, they wrote, "involves key ideas and concepts that can be used to construct procedures" (p. 4). This they compared to procedural knowledge, knowledge of structured ways to proceed.

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Such a differentiation is not unusual and, again, a number of different terms have been used to label the differences. Hiebert and Lefevre (1986) contrasted conceptual and procedural knowledge of mathematics. Conceptual knowledge, they wrote, "is characterized most clearly as knowledge rich in relationships.... Relationships pervade the individual facts and propositions so that all pieces of information are linked to some network" (pp. 3-4). Procedural knowledge, as they defined it, is composed of both the symbol representation system used in mathematics and the rules for completing mathematical tasks and implies only "awareness of surface features, not a knowledge of meaning" (p. 6). This Carpenter (1986) characterized as "step-by-step procedures executed in a specific sequence" (p. 113).

Edwards and Mercer (1987), in their study of children's learning, made a distinction between ritual knowledge and principled knowledge. Ritual knowledge, their term for procedural knowledge, was defined as "knowing how to do something" (p. 97). This they contrasted with principled knowledge, knowledge that is "essentially explanatory, oriented towards an understanding of how procedures and processes work, why certain conclusions are necessary or valid" (p. 97).

These studies were all focused on examining and analyzing children's learning. Differentiating between principled and procedural knowledge appears to be an equally useful tool for analyzing what teachers learn through their professional development activities; that is, their knowledge development as they strive for "better teaching."

In reading through the literature on teacher professional development, it soon became apparent that a number of aspects of this topic have been particularly well-studied. Two of the more frequently addressed topics – teacher beliefs and teachers as learners – will be reviewed here, the first briefly and the second in more depth.

Teacher Beliefs/ Existing Ideas

Just as children's ideas about science phenomena are considered important because these ideas are believed to have an influence on subsequent knowledge construction, so, too, are teachers' beliefs seen to influence teachers' classroom actions and their understandings of any new ideas advanced in professional development activities (Haney, Czerniak, & Lumpe,1996). Yerrick, Parke, and Nugent (1997)

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described "the 'filtering effect' of teachers' beliefs on understanding transformational views of teaching science" (p. 137), again alerting "reform agents to the need for careful evaluation of teacher beliefs" (p. 138). Briscoe (1996) came to the same conclusion:

> Teachers construct their own interpretations of the [new] techniques and implement them based on their prior knowledge and beliefs about teaching and learning. Often these constructions are quite different than the 'experts' have intended and the new methodology is doomed to failure (p. 189).

Cronin-Jones (1991), giving examples of the types of beliefs that influence teaching, listed "beliefs about how students learn, about the teacher's role in the classroom, about the ability levels of students in the class, and about the relative importance of content topics. ...[as well as] attitudes toward the curriculum package itself and the implementation process" (p. 240). Barnes (1992) suggested a rather similar list: "perceptions, often implicit, about the nature of what they are teaching...; about learning and how it takes places...; about students (and about the particular group being taught) ...; beliefs about priorities and constraints inherent in the professional and institutional context..." (p. 19). As beliefs of this nature are fundamental to teaching and "beliefs are seen as critical determinants for teacher action" (Yaxley, 1991), it is not surprising that the subject of teachers' beliefs has become an area of research interest.

Louden and Wallace (1994) also reiterated that

> new ways of knowing can only emerge from reconstruction of old ways of knowing and teaching. Learning constructivist science is as difficult for competent, traditional teachers as learning to think like a scientist is for students. Clever books and well-organized workshops are not enough to convert chalk-and-talk teachers. The process of becoming a constructivist must involve teachers in reconstructing their own knowledge of science, and of science teaching (p. 655).

This process, they stressed, was not helped by impatient principals, school board officials, or researchers who would like teachers "to make the transition from traditional school science to constructivist teaching in a single step" (p. 655).

If one accepts the importance of teachers' beliefs on both their present teaching practice and on their understanding of new approaches to teaching, there is a need to incorporate this knowledge into professional development activities. Other aspects of professional development are equally important for developing "better teaching" practice. One of these aspects, engaging teacher/learners in professional development is the topic

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of this continuing discussion. Four broad and often interconnected categories – catalysts for action, teacher development programs/projects, the role of 'the other,' and "intentional learning communities" (Lieberman, 1996) – were selected to frame facets of this literature.

Teachers as Learners

Catalysts for action.

Catalysts reported as successful in initiating teacher inquiry into better teaching practice are varied. Van Wagenen and Hibbard (1998) and Wolf (1996) discussed how building a teaching portfolio can "significantly advance a teacher's professional growth" (Wolf, p. 34). Sahakian and Stockton (1996) described how teacher-guided observations, teachers observing each other, and their subsequent collaborative discussions led to "in-depth curriculum analyses" and increased teacher involvement in professional development programs. Teachers working to outline "ideal curricula" (Prawat, 1993) or working together to design curriculum (Parke & Coble, 1997) have also been advocated as methods for helping teachers think about the interconnections between the 'big ideas' in curricula (Prawat, 1993) and about the "connections between theory and practice and the value of continually testing, revisting, and reevaluating curriculum and instructional issues" (Parke & Coble, 1997, p. 773).

Others (Hand & Treagust, 1997; Ritchie, 1992) have involved teachers in exercises using metaphors as a tool for helping teachers consider their science teaching practice. MacGilchrist (1996), working with teachers in a school improvement project, asked teachers to identify a specific group of children whom they were concerned about and then to devise ways to improve the school achievement of these children. While a target, student achievement, was set externally, it was flexible enough to allow teachers in each of the four schools involved in the project to identify a goal that mattered to them. In working together to set targets for student achievement, identify criteria for success, and review and evaluate progress, "teachers made marked changes in their practice" (p. 74).

Research like this, done in classrooms by teachers, is often referred to as teacher research, defined by Lytle and Cochran-Smith (1992) as "systematic, intentional inquiry

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by teachers about their own school and classroom work" (p. 450). Britton (1987) stated that "every lesson should be for the teacher an inquiry, some further discovery, a quiet form of research" (p. 13). For this form of research there is, again, the need for a catalyst, a topic of adequate interest to make the time and effort expenditure necessary to conduct systematic inquiry worthwhile. Dilemmas as catalysts have been the focus of a number of papers.

Tomanek (1994) reported that through identifying dilemmas, "the instructional contexts in which a teacher experiences indecision or dissatisfaction with the choices she has make or is about to make" (p. 400), she was better able to examine, compare, and rethink her own assumptions about science teaching practice. Brickhouse (1993) discussed how David, a high school science teacher, faced dilemmas, "conflict-filled situations that require choices because competing, highly prized values cannot be fully satisfied" (Cuban, 1992, p. 6), as he attempted to provide "successful instruction" to his students.

Dilemmas were also a central factor in the Lange and Burroughs-Lange (1994) study of a set of experienced teachers. Asked to identify factors that had caused them to significantly change their professional practice, teachers commonly referred to dilemmas that had challenged their assumptions about good teaching practice. This had caused each to seek a resolution to his or her conflict through a process of "refining their professional knowledge and practice" (p. 627). Watts, Alsop, Gould, and Walsh (1997) referred to "critical incidents" rather then dilemmas – "a classroom episode or event which causes a teacher to stop short and think" (p. 1025). In their paper they described how student questions can "raise teachers' consciousness of both the nature of science and the processes of teaching and learning" (p. 1025-1026) and force teachers to revise their ideas about classroom science teaching practice.

McGonigal (1990), seeking to resolve a dilemma presented when she saw her twin daughters reading and writing at a higher level in their kindergarten class than were her own grade two students, sought help by enrolling in a graduate university course. The literature on professional development programs/projects, both university and in-service courses, programs that teachers like McGonigal have sought out, is presented next.

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Professional development programs/projects.

A number of studies document professional development projects designed to enhance teachers' conceptual understanding of science content and pedagogy. The varying degree of success reported in these carefully-designed programs further attests to the complexity of teaching science and teaching teachers to teach science. The following papers help illustrate this point.

Neale, Smith and Johnson (1990) reported on the extent to which eight elementary school teachers were able to implement a conceptual change teaching unit in their classrooms following a four week in-service program, monthly meetings during the school year, and coaching as they planned and taught the prepared science unit in their classroom. While teachers, to varying degrees, increased their use of conceptual change strategies in the science units they had worked on in the summer workshop and during the school year, none developed nor taught a conceptual change unit in any other topic. This research convinced the authors "how difficult it is for primary teachers to revolutionize their science teaching and to improve their subject-matter understanding significantly" (p. 126).

Having worked with a group of teachers to "develop a special instructional unit based on student ideas about a selected science topic" (p. 742), Shymansky et al. (1993) reported on how teachers' understandings of the selected science topics changed over the course of the project. Results suggested that while the teachers' understanding of the selected science topic was enhanced in this process, "not surprisingly, it was discovered that the teachers, like their students, harboured a variety of erroneous ideas about the science topics and were inclined to hold on to them" (p. 753).

Robert, an enthusiastic participant in a 20 day in-service program spread out over a 10 week period, agreed to share his classroom with Appleton and Asoko (1996) while he taught a set of science lessons to his students. Appleton and Asoko found that although he incorporated a number of features of constructivist learning theory (the focus of the course) into his teaching, those fitting most closely with his prior beliefs and practice, several other features were harder for him to implement. They concluded that teachers need long-term support if they are to continue to critically consider and make changes in their teaching practice after the end of an in-service course.

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In contrast, Jean, recognized as a highly competent science teacher, had, at the request of her principal, attended a seven day professional development program designed in response to state-driven changes in elementary school science from "a content-oriented, textbook-dependent way of teaching elementary science to a hands-on problem-solving approach" (Martens,1992, p. 150). Martens described how after attending the workshops Jean included some new materials and strategies into her lessons. However, nothing fundamental changed, especially the teacher's belief that students need "to get the right answer" in their science lessons. A seven day workshop was inadequate, she concluded, for teachers to reconceptualize their roles, especially if they are not supported by district and school administrators. Instead, teachers need a chance to "define the problems they want to pursue" (p. 155) if they are to come to understand the powerful learning that results from problem-solving exercises.

In another study, Watters & Ginns (1996) described the effect a series of eight televised professional development broadcasts had made on the teaching practice of an elementary school teacher. Anna, an experienced and enthusiastic science teacher, was found to have enjoyed watching the teachers and the classroom activities shown on the telecasts and had incorporated aspects of collaborative learning (children working in groups) into her own classroom practice following these shows. However, "missing from her practice was the extensive use of child-child interactions and reflective practice … there was little evidence of genuine sharing, discussion and consensus making" (p. 63), a key feature of the cooperative learning philosophy of the program. From this, Watters and Ginns concluded that to be successful, professional development programs "require collaboration and cooperation of whole school communities" (p. 65) and that "a critical function of professional development agents is to establish reflective practices within schools" (p. 66). Such involvement, they wrote, will only occur if both teachers and administrators are convinced that long term benefits will accrue from being involved in such a professional development program.

Conclusions to be drawn from these teacher studies are similar to those drawn from studies of children's learning in science: learning is hard work, ideas are resistant to change, and there is no one best way to effect conceptual change or development.

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Rosebery and Puttrick (1998) suggested, based on their Scientific Sense Making project, that to learn about and make changes to their practice, teachers need access to tools (audio and videotapes and transcripts of their classroom activities), and intellectual resources (articles, texts), and time, "time to discuss ideas, theories, and classroom data and stories with fellow educators" (p. 674). Jones, Rua and Carter (1998), too, spoke of tools, readings, and peers, but added students as additional mediating agents in teacher learning.

'The other.'

Support, tools, intellectual resources – these are examples of what I have come to call 'the other,' using the Fenstermacher and Richardson (1993) term. While they and Vasquez-Levy (1993) used this term to refer to a person helping a teacher form a practical argument as a means of "deliberating on and evaluating their thinking and action" (Fenstermacher & Richardson, 1993, p. 103), I will use it to categorize those human stimulants to thought and action indicated in the literature as promoting teacher development.

Both Erickson (1991) and Keiny (1994) referred to the dialectical discourse that can occur between participants in a cooperative research group where critical colleagues take the role of 'the other.' The role of dialectical conversations (although not commonly referred to as such) is the subject of many of the studies of teacher professional development. Keiny (1994), for example, designed a graduate seminar course to encourage a dialectical process of reflection, starting with dilemmas identified by the teachers involved. After working in pairs for a term, she reported that teachers gained a heightened awareness of their teaching assumptions.

Such discourse can also provide teachers with important opportunities "to interact and have conversations around standards, theory, and classroom activity" (Richardson, 1990, p. 16). Richardson also maintained that "a necessary element of the conversations are discussions of alternative conceptions and actions," thus adding the dialectical, and deliberative, component.

After working with a small group of practicing teachers, Hodson and Bencze (1998) identified the role of the researcher/facilitator to be crucial in helping teachers

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transform their theories about science teaching. They defined this role as one of "encouraging and supporting reflection on current practice and its underlying rationale, proceeds through critical consideration of alternatives, and culminates in deciding on, implementing and evaluating curriculum actions" (p.693). "Because teachers' views are built up over a long period and are burnished in the furnace of everyday practice, challenges must be vigorous and explicit if change is to occur" (p. 692). Hardy and Kirkwood (1994) defined the basic task of the science educator to be one of structuring situations that encourage teachers to explore their beliefs, assumptions, and practice "in a challenging but continuously supportive manner" (234). This same theme of 'the other' providing support and challenge is evident in a study by Geddis (1996). Based on a graduate course in science education, he suggested that coaching teachers in their own classrooms might help these teachers because reading, thinking, and discussing, he found, were not in themselves adequate for changing well established teacher actions.

Other studies document 'the other' as providing more support than challenge. Loudan (1991), engaged in a "carefully developed collaborative partnership" (p. 194), reported that his frequent questions to Johanna (questions he posed to allow him to better understand her work and the meanings she made of her classroom experiences) gave her a reason to reflect deeply on her practice. Roth (1998) and Ebbers and Cross (1996) reported on cases of co-teaching and the benefit teachers can derive from shared teaching experiences.

Boostrom, Jackson, and Hansen (1993) directed a three-year project intended to establish a collaborative conversation between "two different kinds of knowers – researchers and practitioners" (p. 37) where "no one person – researcher or teacher – dominated the conversation" (p. 42). This collaborative effort was achieved only after the teachers' wishes to centre the project on conversations about their own teaching concerns and classroom practice, not on classroom research projects, were respected. Through these conversations teachers generated new ways to think about teaching and to act in their classrooms.

The PEEL project (Project for Enhancing Effective Learning) in Australia is another example of a school-tertiary collaboration. Lessons learned from this on-going project include the necessity for teachers to voluntarily participate in such projects since

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"change is hard work and high risk" (Mitchell, 1994, p. 607) and that teachers need time -- time to meet, time to explore new teaching approaches, and an extended length of time (certainly more than a year) to engage in these activities – if change is to take place.

Intentional learning communities.

Projects such as these exemplify what Lieberman (1996) termed intentional learning communities and Shulman (1998) referred to as learning and monitoring communities, "helping practitioners overcome the limitations of individual practice and individual experience… [so that] individual experience becomes communal, distributed expertise can be shared, and standards of practice can evolve" (p. 520-521). Other examples of intentional learning communities described in the literature include: professional practice schools (Marshall & Hatcher, 1996; Nichols & Sullivan, 1992); teacher networks (Lieberman & Grolnick, 1996; O'Neill, 1996; Pennell & Firestone, 1996); collaborative inquiry – teachers coming together to study a dilemma of common interest (Halliwell, 1995); and teachers engaged in instructional conversations (Saunders & Goldenberg, 1996).

The effects of collaborative teacher interactions, described in one paper as the development of "cultures of collaboration" (Hargreaves, 1992), are discussed in three recent studies (Goddard, Hoy, & Hoy, 2000; Langer, 2000; Wolf, Borko, Elliott, & McIver, 2000). In each, research into teaching practices in schools that 'beat the odds' (where students performed better than students in other schools that were demographically similar) indicated a positive correlation between teachers engaged in professional teaching communities and student achievement in schools where this collaboration occurred.

Greene (1991) wrote, "I want to see teachers become challengers and take initiative upon themselves" (p. 13), which "cannot be divorced from a concern for cooperative action within some sort of community. It is when teachers are together as persons, according to norms and principles they have freely chosen, that interest becomes intensified and commitments are made" (p. 13).

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Summary

I will close this review of the literature on teacher professional development, a mere sampling of literature focused on that topic, with a statement I believe succinctly summarizes conclusions reached in the previously reviewed articles. Darling-Hammond and McLaughlin (1996) wrote that "teacher development focused on deepening teachers' understanding about the teaching/learning process and the students they teach," teacher development that involves "teachers both as learners and as teachers" must be:

> · Experiential, engaging teachers in concrete tasks of teaching, assessment, observation, and reflection that illuminate the processes of learning and development
> · Grounded in inquiry, reflection, and experimentation that are participant-driven (that is, learners take responsibility for posing questions and exploring answers)
> · Collaborative and interactional...
> · Connected to and derived from teachers' work with their students
> · Sustained, ongoing, and intensive, supported by modeling, coaching, and collective problem solving around specific problems of practice ... (p. 203).

It is very clear from this literature that no one engaged in working with teachers and writing about professional development aimed at promoting "better teaching" (Baird, 1992) views professional development as an easy task. Rather, professional development is a teacher activity requiring commitment, time, and support. There is also a strong emphasis in current professional development literature on teachers as collaborative inquirers into classroom teaching and learning. This, variously described as establishing "cultures of collaboration among teachers" (Hargreaves, 1995) and "a culture of continuous inquiry" (Lieberman, 1996), allows teachers to share and consider alternative means "to promote comprehension among students" (Shulman, 1987, p. 8).

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Summary

Examining the Situation

Through a Review of the Literature

In examining the situation through reading the literature related to elementary school science education and teacher professional development, I have gained a better sense of advocated desirable ends and proposed alternative means for reaching those ends; e.g., of current discussions concerning scientific literacy, science inquiry, and exemplary science teaching. I also have a better understanding of the complexity of the task and of practices that seem to offer promise in planning educative experiences for students and teachers.

Common to all the research reviewed in this chapter, research that was published in respected journals and by respected publishers, is the assumption that learners construct, not receive, knowledge. Moreover, learning, for the elementary school student and for the teacher, is hard work and requires time and commitment. There is no easy way. There is no one right way. However, there are a number of promising better ways. Some of those better ways informed the recommendations I suggest at the end of this dissertation.

In addition, a heightened awareness of possible means to desirable ends helped me start to identify problems in the Alberta elementary science education situation.

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Data Analysis

In the next three chapters I will continue my examination of the Alberta situation through an analysis of the data collected to address my three research questions:

- What do study participants believe constitutes an exemplary elementary school science lesson?
- What professional development was available to selected Alberta educators responsible for elementary science education in the two years following the issuance of the *Elementary Science Program of Studies* (Alberta Education, 1996b)?
- What messages about why science should be taught are contained in provincial documents relevant to the teaching of elementary science?

To contextualize this examination, I will first discuss the Alberta science curriculum documents, examining the message about why science should be taught contained in those documents.

Following this, the study participants will be introduced and their professional development activities discussed.

Last, the participants' descriptions of an exemplary science lesson are presented and analyzed.

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CHAPTER FOUR

ALBERTA CURRICULUM INTENTS

Guided by Millar's (1996) comment, "First we need to decide *why* we want to teach science to our young people" (p. 17, italics in original), I collected Alberta elementary science curriculum documents: the *Elementary Science Program of Studies* (Alberta Education, 1996b), the list of provincially authorized resource materials, and the provincially-prepared elementary science testing materials

In the following section I will describe the answers to the question "Why teach science?" detected in an analysis of these science curriculum documents. Data from those sources indicate a provincial stance on the understandings and skills viewed by provincial curriculum developers as important for students to learn while engaged in science studies in elementary school.

The Program of Studies

To discern curriculum intents in provincial documents impacting on elementary science education, I started with an analysis of the *Elementary Science Program of Studies* (Alberta Education, 1996b). This document is divided into two sections. In Section A, entitled Overview (reproduced in Appendix E), the program rationale, philosophy, and emphases are described. In the bulk of the document, entitled Learner Expectations, are outlined the specifics of what students are expected to learn. An indication of <u>why</u> is also discernible in these <u>what</u> statements.

As explained in Chapter Two, curriculum data were analyzed using a modification of Roberts' (1982, 1998) curriculum emphases. Accordingly, knowledge outcome statements were categorized as emphasizing Solid Foundations; Correct Explanations; Everyday Coping/Practical Applications; or Science, Technology, and Decisions.

I will start with a short description of the revision of the elementary science curriculum to give some indication of how this program was developed.

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Writing the Provincial Elementary Science Curriculum

The Alberta Department of Education typically revises or develops a new curriculum document for each elementary school core subject (language arts, mathematics, science, and social studies) every 10 to 15 years. Changes are meant to reflect enacted or proclaimed provincial education policy changes, recently developed knowledge and theories about subject area content and pedagogy, and an articulation with other provincial curriculum documents. Additionally, after 10 years many of the provincially authorized learning resources are out of date and out of print.

In 1989, in keeping with this timeline, an elementary science Needs Survey was prepared and sent to all school districts and schools, to science educators, the Alberta Teachers' Association (ATA), Alberta universities, and science institutions. From the 500 responses received, a set of recommendations was made and the Minister of Education was asked to approve an elementary science education program revision process (Alberta Education, 1991a).

When ministerial approval was received, a program manager was named to head the revision process and a Science Advisory Committee was set up composed of two elementary science teachers appointed by the ATA, one elementary science specialist from a provincial university, a representative sent by the College of Alberta School Superintendents, a representative from an Alberta Education regional office, and three additional representatives from Alberta schools who were currently teaching science. This committee met three or four times a year over the next three years to review draft curriculum documents with the program manager and to offer advice on topics and pedagogy.

Program managers are authorized to prepare a program of studies reflecting, to the best of their knowledge, current theories and knowledge about appropriate subject matter and pedagogy (B. Galbraith, personal communication, July 2000) constrained by provincial education policy. There were, as well, a limited number of curriculum branch guidelines to work within (A. McGillis, personal communication, February, 10, 2001). For example, the new science curriculum was to be skills-based (as recommended in the Needs Survey) and was to be organized by levels of understanding rather than by grade levels (echoing recent provincial curriculum development in elementary language arts

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and mathematics). The latter requirement was changed partway through the curriculum development process to a grade level-based program that included "clear learning expectations and standards" (Alberta Education, 1994b).

Working drafts of the revised science curriculum were circulated widely to school districts and schools with the request that the draft be reviewed and comments on the draft proposal be sent to the program manager. Numerous drafts were circulated and extensive revisions were made to reflect the comments received. As well, lobbying by at least one interest group led to the addition of a new topic of study, rocks and minerals.

The final draft of the revised elementary science program of studies was sent to schools in the spring of 1995. This program was slightly modified and authorized for mandatory implementation in the 1996-1997 school year.

Program Overview

In the Overview to the *Elementary Science Program of Studies* (Alberta Education, 1996b) are listed statements of

- program assumptions -- "Young children are natural inquirers and problem solvers" (p. A.1),
- educational theory -- "Children's initial concepts of the world influence what they observe and how they interpret the events they experience" (p. A.1), and
- curriculum directives -- "Learning about science provides a framework for students to understand and interpret the world around them" (p. A.1)

It is the last set of statements, the curriculum directives, that I analyzed for an indication of program intent, the scientific literacy (although this term is not used) teachers are expected to develop.

The stated purpose of the program "is to encourage and stimulate children's learning by nurturing their sense of wonderment, by developing skill and confidence in investigating their surroundings and by building a foundation of experience and understanding upon which later learning can be based" (Alberta Education, 1996b, p. A.1).

The first reason given for learning science is one of **attitude**. Science in the elementary years should:

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· "nurture their sense of wonderment" (p. A.1),

· develop student confidence in their ability to investigate,

· "nurture and extend [student] curiosity" (p. A.1), and

· encourage students to take initiative, be persistent, and become self-reliant.

Similar attitude goals are frequently listed in science curriculum documents; for example, Millar and Osborne (1998) propose a science education that "sustains and develops the curiosity of young people about the natural world around them...[and] seeks to foster a sense of wonder, enthusiasm and interest in science" (p. 12). According to the *Common Framework of Science Learning Outcomes* (CMEC, 1997), science education should "encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours" (p. 5). And the *National Science Education Standards* (NRC, 1996), states that science education should "offer personal fulfillment and excitement" (p. 11).

Second, in learning science, children should be "developing **skill** and confidence in investigating their surroundings." A reference to skill development was identified in over half of the statements in the program Overview related to curricular intent. Some of these statements explain which skills the curriculum developers considered important.

· "The skills of science inquiry include asking questions, proposing ideas, observing, experimenting, and interpreting the evidence that is gathered" (p. A.3)

· "Skills of problem-solving include identifying what is needed, proposing ways of solving the problem, trying out ideas and evaluating how things work" (p. A.3).

Other statements indicate why it was considered important for students to "extend and sharpen their investigative skills" (p. A.1). Here the emphasis is on

· students developing "the skills of learning how to learn,"

· students continuing "to question, explore and investigate with increasing levels of insight and skill," and

· students asking relevant questions, seeking answers, defining problems

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and finding solutions.

There is a definite sense that students should be actively engaged in "open-ended activities" to develop "the ability to make decisions, to plan and to evaluate their own progress – skills that apply throughout life" (p. A.2).

The last phrase in the statement of purpose indicates that elementary science is to build "a foundation of experience and understanding upon which later learning can be based." This adds the **knowledge** component, with an emphasis here on the provision of a Solid Foundation (Roberts, 1982, 1998) of knowledge for future science learning.

The Rationale statement continues:

> Elementary and secondary science programs help prepare students for life in a rapidly changing world – a world of expanding knowledge and technology in which new challenges and opportunities continually arise. Tomorrow's citizens will live in a changing environment in which increasingly complex questions and issues will need to be addressed. The decisions and actions of future citizens need to be based on an awareness and understanding of their world and on the ability to ask relevant questions, seek answers, define problems and find solutions (p. A.1).

Here we are given more indication why students should be developing scientific knowledge, the stress in this example being on Everyday Coping/Practical Applications. Additional Overview statements suggesting an Everyday Coping/Practical Applications emphasis include ones indicating that the science program is to help students

· understand and interpret the world around them,

· investigate their surroundings, and

· prepare for life in a rapidly changing world. (p. A.1)

As well, the reference to complex questions and issues suggests a Science, Technology and Decision rationale for teaching science knowledge and decision-making skills. This, again, is a goal for science education to be found in most current literature focussed on preparing science programs with meaning for the general populace.

However, the majority of the statements emphasizing knowledge are vague as to intent. These statements indicate that students will:

· "add to their knowledge"

· "modify their ideas and ways of viewing the world"

· "refine and consolidate their learning" (p. A.2)

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In summary, I judged over half of the statements in the Overview to indicate a curriculum intent of skill development. A quarter more focussed on knowledge development. The remaining statements referred to attitudinal development during the study of science. Taken together, the statements indicate an evident emphasis on a hands-on, investigative approach to science: students are to be involved in investigating and exploring the world around them. The context in which this is to be accomplished, the mandated learner expectations, is the subject of the following section.

Learner Expectations

Each of the thirty topics of study outlined in the Program of Studies (five at each grade level) is introduced by a paragraph giving an overview of what students are to learn and do, the knowledge to be developed and the actions students should engage in while studying a particular science or problem-solving through technology topic, followed by General Learner Expectations, one or two sentences describing, in general, what students will do. Specific Learner Expectations (SLEs) are then listed, a set of between four and fourteen statements specifying the content knowledge to be developed and the actions to be taken by students. In combination, these statements outline the standards students are meant to achieve. (A set of learner expectations for topics at grade four is found in Appendix F.)

For each grade level, too, descriptions of the Inquiry Skills or Problem solving through Technology Skills, and the Attitudes students are to develop while engaged in their science studies are listed. (The Skills and Attitudes expectations for grade four are also listed in Appendix F.) As explained in the Program of Studies, students are expected to develop these skills and attitudes while they are engaged in developing an understanding of the designated concepts (SLEs).

As teachers report (personal observation) that their teaching is guided, in particular, by the SLEs listed under Understandings it was these statements I analyzed for curriculum intent. I also referred back to the introductory paragraph and General Learner Expectations for confirmation, disconfirmation, or extension of the curriculum messages I was detecting. I randomly selected three topics from grade two, three from

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grade four, and three from grade six to analyze for indications of the scientific learning to be developed through the study of these topics.

My analysis indicates that in grade two, science is to be taught predominantly to help students better understand the world around them (an Everyday Coping/Practical Applications emphasis), followed by learning science concepts (a Correct Explanations emphasis), with learning science process skills a third goal. In grade four, the Waste and Our World topic emphasizes a Science, Technology, and Decisions issue with a concurrent emphasis on student understanding of their world, an Everyday Coping/Practical Applications focus. In the other two selected topics the stress is on content knowledge, with nearly three quarters of the SLEs having a Correct Explanations intent. In the selected grade six topics, 60% of what students are expected to learn has a Correct Explanations knowledge emphasis. The remaining 40% of the statements were fairly evenly divided between a focus on skill development, both simple (construct…) and more complex (problem-solving skills), and on knowledge for Everyday Coping/Practical Applications.

I was struck by the limited opportunities students are given for developing **skills** through engagement in scientific inquiry (NRC, 1996). Investigating "with guidance" appears to be the norm for science in these years. Statements in the Program of Studies indicate that students are to explore, compare, predict, and evaluate, but when the results of those activities are predetermined and stated as learner expectations (e.g., "by testing …, students will learn that…), students are afforded little room for inquiry. Yet it is the more open-ended investigations that enable students to "extend and sharpen their investigative skills" and to "continue to question, explore and investigate with increasing levels of insight and skill" (p. A.1), intents communicated in the program overview,

The extent to which students are engaged in relatively open-ended activities will also affect the **attitudes** they develop. That is, if students are given a considerable amount of guidance, there may be little chance or need for them to demonstrate such attitudes as curiosity, confidence in their ability to explore, inventiveness, and perseverance. As well, the amount of guidance students receive may have a considerable effect on the attitudes about science, doing science, and applying science that they develop.

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From this analysis of statements in the *Elementary Science Program of Studies* (Alberta Education, 1996b) providing indications of curriculum intent, I conclude that although the development of complex investigative skills appears to be the most important curriculum emphasis in the Program Overview, this is not the case in the Learner Expectations section of the document. In the nine randomly-selected topics I analyzed, a Correct Explanations emphasis dominated (although not in every topic), leaving the impression that the predominant intent of the Alberta elementary science curriculum policy is development of knowledge of a body of science information, of Correct Explanations.

The *Elementary Science Program of Studies* (Alberta Education, 1996b) is, however, but one of the documents guiding the teaching of science and the development of scientific literacy. Another set, to which I now turn, are the testing materials prepared under provincial guidance for assessing "what students know and can do in relation to provincial standards" (Alberta Education, 1998b) in elementary science.

Provincially-prepared Assessment Materials

Questions from the Classroom Assessment Materials Project (CAMP) and the Achievement Testing Program were analyzed to gather further data to answer the question, "Why teach science?"; that is, to try to discern the intents of the curriculum developers as regards the scientific learning to be developed in Alberta's elementary science classes – intents which may have influenced the teaching of science.

Writing Provincial Assessment Materials

"The Classroom Assessment Materials Project (CAMP) was launched in 1994 in response to Alberta Education's goal of establishing and effectively communicating clear learning outcomes and high standards for each area of learning" (Alberta Education, 1997, p. i). This was also the year the provincial government introduced a plan to restructure the Department of Education and to "establish a more accountable education system" (Alberta Education, 1994, p. 10), a plan to be effected partially through increased provincial testing.

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Tests were prepared for the core subjects for all grade levels not involved in the mandated provincial achievement tests (i.e., for all but grades 3, 6, 9, and 12). For elementary science, the CAMP materials contain two tests. The hour long end-of-year exam is comprised mainly of multiple-choice questions as well as several short answer questions. For each grade, there are also four performance tasks that require students to work with materials and write about their observations and conclusions. Each task is scored for problem solving and for communication

Provincial policy outlined in Alberta Education's three-year business plan at the time of the release of the elementary science curriculum stated that there should be "increased testing" to "ensure that students, teachers, parents and other Albertans know and understand what our young people have achieved and what they still need to learn" (Alberta Education, 1995, p. 3). For elementary school science this mandate for increased testing resulted in the development of science achievement tests that are written every year by all grade six students (with the exception of those students excused by the superintendent of his or her school district). "The purpose of the Achievement Testing Program is to determine if students are learning what they are expected to learn, report to Albertans how well students have achieved provincial standards at given points in their schooling, [and] assist schools, jurisdictions, and the province in monitoring and improving student learning" (Alberta Education, 1998a, p. 2).

A pamphlet on achievement tests further indicates, "Developers take into consideration those important learnings that can be assessed through a paper and pencil test, and within a given time frame" (Alberta Education, 1998b, non-paginated). Test developers are also provided a blueprint to guide the design of test questions. This blueprint indicates that 60% of the test items should emphasize the skills component of the program, "the application of knowledge," and 40% knowledge, "the fundamental understanding of concepts and processes of science" (Alberta Education, 1998b, p. 43).

In the following pages I will discuss the curriculum intents I discerned in an analysis of questions on these provincial tests, both CAMP exams and a provincial achievement test.

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Classroom Assessment Materials Project (CAMP)

Questions assessing "students' achievement of the learning outcomes specified in the *Program of Studies*" (Alberta Education, 1997a, p. i) for the grade two and grade four randomly-selected topics were analyzed to ascertain the message about curriculum intent suggested by the test questions. The categorization of each question on the end-of-grade exam was based on the answer to the question, "What learning outcome -- knowledge, skill or attitude -- would students need to have developed to successfully answer this question?" In addition, I asked "What category of knowledge (for Everyday Coping/Practical Applications, Correct Explanations, or Science, Technology and Decisions) is implied in the wording of the question?"

For grade two, I judged 90% of the questions to be knowledge-based with over half of these asking for responses exhibiting Everyday Coping/Practical Applications knowledge. Over three-quarters of the grade four CAMP questions focussed on knowledge, with over half of those testing for Correct Explanations.

For the performance tests, I judged the grade two problem solving tasks to emphasize, on the whole, complex skill development, albeit guided, in that students are allowed in two of the three tasks to work with materials, carrying out and drawing conclusions from predominantly self-designed investigations. For grade four, the performance tasks required students to observe and compare, design an experiment, and, in one of the tasks, carry out a test and come to a conclusion about the best product for a specified use. There was also a knowledge component at grade four. As in grade two, the communication score appeared to be based on precise writing – clear and detailed descriptions and explanations indicating an ability to communicate knowledge and actions.

When totalling the performance tasks and the end of year exam scores, it appears that slightly more than half of the total grade two CAMP score is based on skill assessment. The remaining score comes from knowledge assessment, both for Everyday Coping/Practical Applications and Correct Explanations. For grade four, the CAMP test slightly decreases the emphasis on investigative skills and increases emphasis on Correct Explanations.

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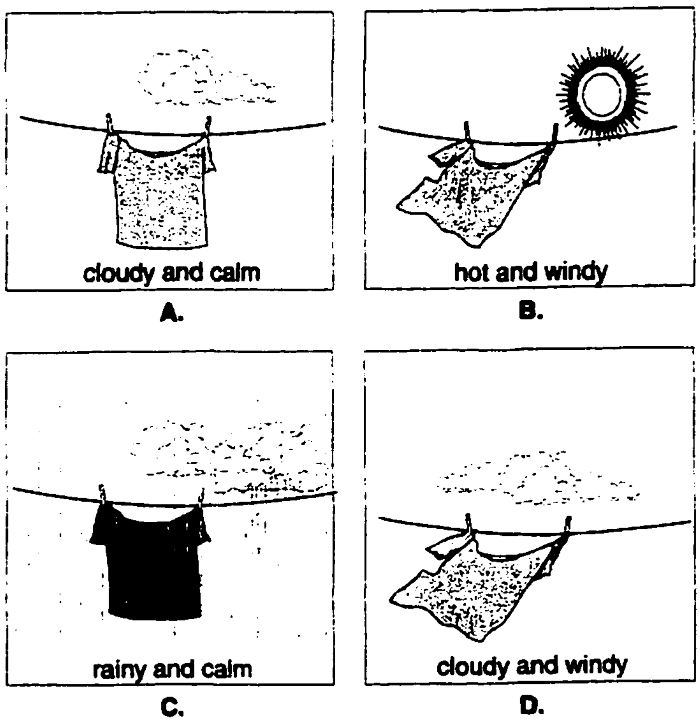
60% skill, 40% Knowledge Assessment

There is, however, a considerable discrepancy between my interpretation of curriculum intents and that presented in the CAMP document. The majority of the responses I had categorized as knowledge-based were categorized as skills by the provincial writers. For an example, see Figure 1 below.

4. David got his shirt wet.

A shirt will dry FASTEST in weather that is



5. **Why?**

____

____

____

Figure 1. Grade Two CAMP Questions (Alberta Education, 1997, p. 3).

Both these questions were classified as assessing skill development; question four requires students to "predict that wet surfaces dry more quickly when subjected to wind and warmth" and in question five, students "sequence events to support the prediction that wet surfaces dry more quickly when subjected to wind" (emphasis added, Alberta

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Education, 1997, p. 9). Although provincial writers may classify such questions as emphasizing skills, I believe that these and similar questions are actually testing student knowledge of specific content designated in the program of studies. Accordingly, I categorized both as assessing knowledge; as they were tied to events in students' lives, I judged them as having an Everyday Coping/Practical Applications emphasis.

The adjustments prescribed for calculating a final CAMP score were quite complicated, contributing to an impression that provincial test writers consider it very important to show that nearly 60% of the final score is based on skill assessment and the remaining 40% on knowledge.

CAMP Questions and Stated Curriculum Expectations

Several CAMP questions asked for more detailed knowledge about the topics than I would have anticipated from reading the SLEs. For example, in the Light and Shadows topic, the Program of Studies states that students are to "recognize that light can be reflected and that shiny surfaces, such as polished metals and mirrors, are good reflectors" (Alberta Education, 1996b, p. B.21). Two CAMP questions, however, ask for specifics about angles of reflection. Two study participants, Jane and James, expressed similar observations about CAMP questions for topics that they taught.

Jane remarked that, "Sometimes I think some of the units are trying to be so general and the children are expected to know so much that they're missing out on the specifics. I'll give you an example – animals in grade one. If they need to identify, which I understand from the CAMP materials -- some of the questions say, identify all these different animals -- then you have to be a lot more general in the way that you teach to expose them to all that. And I miss being able to be more specific. But sometimes the testing doesn't even follow the objectives very closely." (T8)

James explained, " In the CAMP materials there's a fair whack there on animals and looking at animal adaptations. I realized the first year I taught the curriculum, when that test actually came out, I realized from looking at that test that I had not taught what they expect in that area. To me, you have to get into a really fairly detailed classification thing in that. Because the questions that they give, to do the background, I found that deceptive." (T9)

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Taking into consideration specific activities students will need to do to successfully answer some of the questions in the CAMP exam, teachers have even fewer chances to engage students in scientific inquiry, in investigations allowing students to "extend and sharpen their investigative skills," than would appear to be the case from reading the Specific Learner Expectations.

Science Achievement Test

In grade six, all students, except those specifically excused by the superintendent of their school districts, take the provincial achievement test for science. As teachers at all grade levels have indicated that it is this test, the form of the test and the knowledge, skills, and attitudes being tested, that most strongly guides their science teaching practice, it appears to be very influential in indicating curriculum intent to educators. (A set of Achievement Test questions is found in Appendix G).

To help educators prepare grade six students to take the achievement tests (in addition to science, students also take a social studies test, two language arts tests – one for reading and one for writing – and two mathematics tests – one testing knowledge of basic math facts and the other testing problem solving skills), the Department of Education publishes an *Information Bulletin* each year. The science section of this document gives a general description of the test, a list of approximately 60 vocabulary words students should be familiar with, and examples of test items.

An analysis of the June 1997 Science Achievement test for curriculum intent suggests that the first answer to the question, "What learning outcome -- knowledge, skill or attitude -- would students need to have developed to correctly answer this question?" would be knowledge; I concluded that 60% of the responses required students to have developed specific knowledge to answer a question correctly. Nearly three quarters of those knowledge responses were judged to reflect a Correct Explanations intent.

Nearly half of the skill questions (40% of the total questions asked) asked students to interpret evidence (e.g., footprints, fingerprints, handwriting) related to the Evidence and Investigation topic. Only one question referred to investigative skills, asking students to select a set of variables that should be "kept the same" in a suggested experiment.

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In summary, my analysis of the grade six science achievement test and the grade two and grade four end-of-grade CAMP exams, exams similar in format to the high-stakes grade six test, indicates that the majority of the questions at all three grade levels test knowledge, with approximately 40% of all questions asking for Correct Explanations. Very few questions examined students' ability to "investigate their surrounding" or to "ask relevant questions, seek answers, define problems and find solutions" (Alberta Education, 1996b, p. A.1).

Provincially Authorized Resource Materials

The third source of information about curriculum intent are the resources authorized by Alberta Education for use in Alberta classrooms. To find an answer to my question concerning the messages about teaching and learning science these materials might suggest to teachers, I gathered the authorized teaching and student support print materials listed in the *Learning Resource Centre Buying Guide 1997* (Alberta Education, 1997b) for one of the topics I had analyzed at each grade level. I then analyzed each of those resources for the curriculum emphasis or emphases evident in the goal statements, activities, and assessment recommendations contained therein.

I will start with a background explanation of the authorization process.

Authorizing Materials

In Alberta, the Minister of Education may authorize "instructional materials for use in schools" (Province of Alberta, 1988, p. 19). Schools need not buy or use these resources, but there is a price advantage for doing so (as the government purchases authorized teaching and student learning resources in bulk, they are able to offer these materials to schools at a reduced rate). And, as the Department of Education considers the authorized teaching resources to be "the best possible teaching resources" (Alberta Education, 1991b, p. 1), purchasers are assured the teaching and student learning resources meet the criteria set by the Department.

Near the end of the science curriculum development process, a Call for Resources was issued, requesting " publishers listed in the publishers' mailing list maintained by the Curriculum Branch" (p. 10) to submit print and non-print resources appropriate for

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elementary school science. The resources received were reviewed using criteria such as: consistency with the philosophy and learner expectations stated in the draft science curriculum, applicability to the teaching and learning of science in the elementary years, emphasis on science inquiry and/or technology problem solving, inclusion of a variety of teaching and learning and assessment strategies, and promotion of tolerance and understanding of others (Alberta Education, 1994a).

The "Initial Proposal for Change" of the elementary science curriculum (Alberta Education, 1989) recommended that "a wide variety of resources should be reviewed and authorized" (p. 8). Consequently, a number of teacher and student resource materials were authorized for each topic, some meeting the published criteria better than others.

Two series of science teaching and learning resources, *Explorations in Science* (Campbell et al. 1992) and *Innovations in Science* (Peturson, Clarke, & Cooke,1991), were authorized. Both are composed of a teacher's manual, student books containing supplementary information about each topic, and assessment materials for each grade level.

Authorized teaching and learning materials for a randomly selected grade two, four, and six topic are now analyzed for their messages about curriculum intent.

Authorized Materials

In eight authorized resources containing activities related to the grade two Exploring Liquids topics, all the lessons were predominantly hands-on. In five of these resources, the question, 'Why teach science?' was answered with a skills emphasis statement. "The explosion of information, especially in the field of science, makes it clear that our main task as educators is to help children learn how to learn" (Campbell et al, 1992a, p. 10) expresses a common outlook in the resources authorized for this grade level. Assessment was also focussed on evaluating the students' skills in investigating liquids.

Although many of the activities in the Liquid Explorations lessons are related to events and materials in the children's lives (for example, water repellent clothing and drying clothes), none of the resources consistently stressed this relevancy aspect either by initially setting the activities in a child's-world context or stressing this context when

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students discussed what they had observed and concluded. For this reason, I did not consider any of the authorized resources to place an obvious emphasis on knowledge for Everyday Coping/Practical Applications.

Teachers reviewing these grade two provincially authorized teaching materials for Liquid Explorations might, I believe, conclude that skill development, referred to as science process skills in some resources and thinking processes in others, is the dominant emphasis. Students are expected to gain a broader understanding of properties of liquids through their investigations, but it is the exploring and describing, not a knowledge of specific science concepts, that is most often stressed and evaluated. While Exploring Liquids, students are also commonly being encouraged to develop certain attitudes listed in the *Elementary Science Program of Studies*: "an appreciation of the value of experience and careful observation" and "a willingness to work with others and to consider their ideas" (Alberta Education, 1996b, p. B.7).

The grade four authorized resources for the topic Light and Shadows were much easier to analyze as there were so few of them. Possibly because "the concepts involved in the study of light are not easy for children to understand" (*Explorations in Science,* "Light Moments," Campbell et al., 1992b, p. 3), lessons are more directed than those in grade two toward specific knowledge outcomes. For example, typical wording in the teacher's manual for grade two, "encourage the groups to share their discoveries and observations" ("Mirror Images" p. 18) is replaced by "encourage students to understand..." ("Light Moments," p. 11), "draw students toward the conclusion" (p. 12), and "they learn that..." (p. 17). Teachers are encouraged to let students try out their own ideas to test different light phenomena, but "if they [students] seem stuck, you may wish to share the following method..." (p. 11, similar wording on page 17), guiding students toward a designated Correct Explanation. This emphasis is also reflected in the test questions provided in the "Alberta Implementation Guide;" paper and pencil test questions assess students' acquisition of specific knowledge, Correct Explanations.

As described for grade two, while lessons in both major science series occasionally refer to Practical Applications of the concepts being studied, this connection is not consistently pursued, even for activities easily set in an everyday context.

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In summary, I believe that teachers would likely form the impression from these resources that Correct Explanation is the emphasis of the study of Light and Shadows at the grade four level.

Flight, the grade six topic chosen for analysis of curriculum intent in the provincially authorized teaching resources, is the 'problem solving through technology' topic for that grade level. While students are to "apply their knowledge of aerodynamics to design, build and test a variety of flying objects," they are also to "apply appropriate vocabulary in referring to control surfaces and major components of an aircraft. This vocabulary should include: wing, fuselage, vertical and horizontal stabilizers, elevators, ailerons, rudder" (Alberta Education, 1996b, p. B.31). There is, then, both a skills and a Correct Explanations emphasis in the program of studies.

The curriculum intent for Flight in the *Exploration in Science* (Campbell et al., 1992) series was judged to be primarily problem solving skills, followed by Correct Explanations, and attitudes, those habits of mind essential for problem solving. In contrast, the stated goals and a majority of the activities on Flight in the *Innovations in Science* (Peturson et al, 1991) series appeared to emphasize Correct Explanations.

Five other resources authorized for use with this topic were analyzed. Lessons in one of these (Hetzel & Wyma, 1995) generally contained a set of instructions for students to follow and worksheets to fill in with questions intended to lead students toward a Correct Explanation. *Flying Machines* (Nahum, 1990), following the Eyewitness series format of text accompanied by photographs, is clearly focused on providing infonnation, Correct Explanations, while the photographs help tie each section to Everyday Coping/Practical Applications.

Three books (Darling, 1991; Dixon, 1990; Williams, 1991) had similar formats – text and fairly detailed instructions for making objects or doing activities to demonstrate the concepts, Correct Explanations, being presented. In all three, text and photos placed the concepts in real-life contexts, providing an Everyday Coping/Practical Applications aspect to the Flight topic. These books were judged capable of extending the curiosity of students who came to them already interested in the subject of Flight. The books, however, are not designed to promote the attitudinal growth outlined in the Program of Studies.

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In all, these authorized resource materials for the "problem solving through technology" grade six Flight topic do provide more opportunities for the development of the skills and attitudes designated in the Program of Studies and a better understanding of how the concepts developed in this topic relate to their everyday lives than did those for the grade four Light and Shadows topic. Teacher provision of opportunities to design, make, and test more than once will help determine the science emphasis enacted in the classroom.

Edmonton Public Schools Unit Plans

Although these unit plans are not authorized by the Alberta Department of Education, they were mentioned more often than any other teaching resource by study participants. As these teaching guides are likely to have an impact on the way science is taught and learned, I am including an analysis of them in this section.

The guides, written by teams of district teachers, were edited into a standard form by central office personnel. The standard format for each activity consists of a list of Materials, a Procedure for students to follow, and a 'Teacher's Notes and Debriefing' section. Masters of worksheets for students to fill in are provided for most lessons. In the preface to the unit plan, teachers are provided with background content knowledge.

For the grade two Liquid Explorations topic, over two thirds of the 34 lessons analyzed were judged to have a Correct Explanations focus; students are given a procedure to follow and a worksheet to fill in that directs their attention towards a predetermined science concept. Three of the lessons have an obvious Everyday Coping/Practical Applications focus; that is, lessons were set in a real life context. In at least one third of the lessons, "real life applications that may be brought up" (p. 33) were indicated to the teacher in the end notes. Twenty percent of the lessons were judged to be skills oriented, including activities asking students to explore the properties of water and other liquids and to share their observations.

In the grade four Light and Shadows unit plan, all of the activities were judged to have a Correct Explanations focus. In only two of the activities did the teacher's debriefing notes contain information linking the concept being studied to the everyday world outside the school, but in neither case was this incorporated into the body of the

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lesson. Other than learning to carefully follow directions, I was unable to detect any appreciable emphasis on student skill development.

Reflecting the 'problem solving through technology' designation of the grade six Flight topic, in this Edmonton Public Schools unit plan, nearly 40% of the 18 reviewed activities are skills oriented. Students are frequently given instructions for making an initial model of such aircraft as gliders, parachutes, and rockets, but are then challenged to modify these themselves to meet a particular challenge.

Despite the problem solving focus, over half of the lessons emphasise Correct Explanations. No Science, Technology, and Decisions links are made.

In all of the Edmonton Public School unit plans there is a dominant emphasis on the development of students' knowledge of Correct Explanations. In some lessons scientific skill development is emphasized as students engage in planning and carrying out investigations of phenomena or objects to meet teacher designated ends. The attitude most consistently emphasised at each grade level is "confidence in personal ability to explore materials and learn by direct study" (Alberta Education, 1996, pp. B.7 and B.18).

Summary

Messages about Curriculum Intents

From my analysis it was clear that the dominant emphasis across the grades, according to the specific learner expectations (SLEs), provincially prepared science test questions, and provincially authorized curriculum resources, is on student learning of specific science content, on Correct Explanations. This contrasts with the sense of curriculum intent gained from analysing the Overview section of the *Elementary Science Program of Studies* (Alberta Education, 1996b) where science is most frequently described in terms of its role in building investigative skills, as being a subject where students are actively engaged in "open-ended activities" to develop "the ability to make decisions, to plan and to evaluate their own progress – skills that apply throughout life" (p. A. 2).

What also became apparent through this analysis was the conflict between the number of knowledge specific learner expectations, some of them quite difficult for

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students according to the science education literature, and the mandate to concurrently develop students' inquiry skills and a positive attitude toward science and science learning. That is, the number of mandated knowledge outcomes will limit the amount of time available to pursue the knowledge SLEs through an inquiry process, and the difficulty of concepts may encourage memorization rather than active sense-making (Gabel, Keating, & Petty, 1999; Sadler, 1998).

The number of topics and science concepts in the Alberta elementary science curriculum also suggests a more traditional survey approach to science education, rather than reflecting the current emphasis in the literature on choosing a limited number of science topics "of great interest and importance" (Jenkins, 1992), also referred to as powerful stories about the natural world (Millar, 1996). An additional emphasis in the literature on why science should be taught is on the importance of seeking answers in science classes to the epistemological question, "How do we know?" Although the stated inquiry emphasis in the Program of Studies indicates that students are to be involved in collecting and interpreting evidence, time pressures allow students little chance to do "real, relevant, and rigourous" science (Reardon, 1996) where children learn both how to do science and how science is done by undertaking scientific investigations.

Thus, given that inquiry science requires a considerable amount of time because students are engaged in planning, doing, considering, replanning, redoing, and reconsidering, educators faced with the task of teaching many science concepts, some of them judged quite difficult for elementary school children to understand, may decide that an inquiry approach is clearly impossible. Although this may best meet the conflicting requirements of the mandated curriculum, it does not reflect science education goals outlined in current literature on this subject.

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CHAPTER FIVE

PROFESSIONAL DEVELOPMENT

As reported earlier, in Alberta, the Department of Education is responsible for developing "programs of study that provide a clear framework of learner expectations" (Alberta Education, 1995). On completion, these curriculum programs are released to school districts that are then held responsible for the implementation of the mandated curriculum.

As I wrote in the introduction, to understand the Alberta elementary science education situation, I wanted to know more about the professional support available to teachers as they implemented the newly revised *Elementary Science Program of Studies* (Alberta Education, 1996b). Because the new science program of studies required a substantial shift in what and how many teachers taught and because a major stated goal of the Alberta Department of Education at that time was to improve teaching, I wondered what was being done to achieve that goal in elementary science education.

The situation in the six Alberta school districts selected for this study will be described in the following pages.

The science education professional development offered to educators was differentiated using the concepts of procedural and principled knowledge development. Briefly (a more complete exploration of these terms is found in Chapter 3), procedural knowledge is knowledge of "structured ways to proceed" (Spillane & Zeuli, 1999, p. 4). For teachers, this includes becoming acquainted with the curriculum and curriculum requirements, with available teacher and student resource materials and recommended activities, and learning the basic science facts or concepts outlined in the science curriculum. Procedural knowledge helps answer the questions: "What am I supposed to teach?" and "How can I teach the topics to my students?"

Professional development focused on principled knowledge, knowledge of "the key ideas and concepts that can be used to construct procedures" (Spillane & Zeuli, 1999, p. 4), offers educators a more theoretical perspective on science education. This might include aspects of:

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· pedagogical content knowledge (Shulman, 1986),
· content knowledge, "going beyond the knowledge of the facts or concepts of a domain" (Shulman, 1986, p. 9), and
· theories about children's learning in science.

The difference is an important one. The development of principled knowledge is educative in that it involves a consideration of alternative possibilities. Deliberation on possibilities helps educators make "informed and intelligent decisions about what to do, when to do it, and why it should be done" (Richert, 1990, p. 509) and deepen their "understanding about the teaching/learning process and the students they teach" (Darling-Hammond & McLaughlin, 1996, p. 203). These actions also help teachers develop better teaching where "the teacher *knows* more about what teaching is and how it best works for him or her, is more *aware* of what is happening in the classroom as he or she teachers, and is more purposeful in the pedagogical *decisions* that he or she makes" (Baird, 1992, p. 33).

Professional Development in Six Alberta School Districts

In my examination of the professional development situation, I start with a description of the professional development offered by school districts or other organizations. Participants' views on science education and the knowledge base needed to teach science are also reported. The names of all school districts and participants are pseudonyms.

This is followed by a discussion of "conversations," a set of more informal learning interactions undertaken by study participants in response to the revised science curriculum.

Spruce School District

Spruce is one of the two large urban school districts selected for this study. Unlike many school districts in Alberta that responded to the Alberta Education key strategy of implementing school-based management (Alberta Education, 1994b) by handing over nearly all decisions for professional development to individual schools,

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Spruce had maintained professional development as a free service offered by the central office.

A school district administrator suggested the names of two principals and two teachers in four different school to be interviewed. After talking to them, it was obvious they were all science enthusiasts. Peter (P7), a principal for over 15 years, had become acquainted with inquiry science units as a young teacher and had subsequently helped develop science kits for the district to help other teachers teach activity-based science. Marlene (P10) was just finishing her first year as a principal. In the past she had taught science and social studies at the junior high level and had served as an assistant and then as a vice principal, again in junior highs. Both teachers, Alice (T4) and Sharon (T11) had acted as facilitator teachers for the district science consultant. Neither had taken more than the required science courses at university, but had come to enjoy science teaching based on their students' enthusiasm for the subject.

At the time of the interview, Mary had been the Supervisor of Science for Spruce School District for seven years. She had a Bachelor of Science degree in microbiology, a Bachelor of Education degree, a graduate diploma, and was working on her Master of Education Degree. She had taught science at all four school division levels, although to a limited extent at the elementary level, and had been active "with all kinds of committee work, both district and provincial" in the area of science education. She described her major responsibility as the translation of the prescribed science curricula to help teachers and, secondarily, administrators implement those programs. In addition to administrative work concerned with science education, she provided in-service professional development for teachers at the district level and visited schools where she modelled science instruction in classrooms and met with teachers and administrators. She was enthusiastic and well informed about science education and appeared to be a friendly and approachable person. The teachers and principals whom I interviewed in her district all volunteered praise for her work in the area of science education.

When the new *Elementary Science Program of Studies* (Alberta Education, 1996b) was introduced, her concern was to have "teachers actively involved in a process of taking a look at the science curriculum and determining what they were going to do with it." To accomplish this, Mary first recruited a group of lead teachers, teachers

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known to enjoy teaching science. They met to review the philosophy of the science program and then "took a look at what we know about how children learn science – the learning theory and that kind of thing." Next, a pair of lead teachers at each grade level developed a unit plan for a topic at their grade that was based on the ideas about and from the science program of studies and about teaching and learning in science that they had been discussing.

Following this, a similar series of sessions was held for all the elementary school teachers in the district. Meeting by grade levels, the approximately 120 teachers at each grade were divided into three or four smaller groups. These groups met six to eight times with the goal of "collaborating with peers on interpreting the program of studies, planning for instruction, and planning assessment." For some of these sessions substitute teachers were hired, allowing teachers to attend half-day sessions during regular school hours. Other sessions were held after school.

In a session on learning in science, aspects of constructivist learning theory were introduced. Based on ideas taken from Harlen (1985), this session focused on engaging children in investigations and helping them to generate, communicate and critically reflect on their scientific ideas and the evidence for them. Included in this were discussions of children's ideas and how these ideas can influence science learning. In other sessions, teachers worked on brief science activities, activities they could do with their own students. As well, teachers were introduced to teacher and student resources, print and computer, and provided time and help in the computer lab. Later, the pairs of lead teachers presented the teaching unit they had developed, explained how the unit was developed, how the curricular objectives were met, and why certain instructional and assessment strategies had been chosen.

After this, grade groups of teachers were divided into yet smaller groups each of which was to choose and write a unit plan for a topic at their grade level. (They were encouraged to pick a topic they did not yet feel comfortable with.) Teachers started by looking "at all the SLEs (specific learner expectations) and then tried to find things they could do that would support those SLEs." Mary remarked that a number of teachers wrote in their evaluations of the sessions that they found working in groups very helpful as questions about and interpretations of content and pedagogy were raised that had not

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occurred to them. For example, some teachers had discussed the depth of knowledge teachers need to effectively teach specific science concepts, as well as what might be reasonable learning expectations for students learning particular concepts.

In the end, each group presented the unit plan it had developed to the full assembly of teachers at that grade level. Each plan was photocopied at the central office and sent to every elementary school to be placed in the school library. These plans were to be considered "working documents"— not perfect, but ideas and sequences of activities gathered by teachers for teachers. And, as Mary said, while these unit plans represented a material end product, that "wasn't our real goal. Our real goal was to work them [teachers] through understanding the program, understanding what science should look like, understanding how you would know whether students are really learning science."

Mary thought many teachers needed further help in developing the content and pedagogical knowledge necessary to teach some of the topics well. However, she recognized that elementary school teachers "are bombarded with so many different subject areas that they have to attend to" that there was only a small window of opportunity during the implementation of a new curriculum to focus intensive attention on teaching and learning in science. Working with her colleagues, the other area specialists, she saw a chance for helping teachers develop more robust understandings about how children learn and about best teaching practices as teachers were further involved in professional development in teaching the other curricular subjects.

The district also provided a short in-service series each year for teachers new to teaching science or who were teaching science at a new grade level. Again, these teachers analyzed the Program of Studies and its underlying philosophy and good teaching and planning practice. Having a core of lead teachers, Mary would also introduce the possibility of networking, working collaboratively with these experienced teachers.

Reflecting on the professional development that she had organized, Mary commented:

> We modeled constructivist learning in our sessions in the way that we handled them. We didn't just present. The easy way would have been just to present in two or three sessions. Actually, we were asked the question, 'Why didn't you

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> just have your lead teachers put all the units together? We'd come to the different sessions; they'd just walk us through the unit. We'd get the unit and we'd be done.'
>
> And the answer was, 'That's not what we'd want you to do in your classroom. We don't want you to just give the information to your kids and say, 'There you go.'' Again, it wasn't easy because they had to come and work and that's not something that we've been used to as teachers in our professional development. We've been used to going to a session, getting the stuff, and leaving. Maybe even doing an activity, but still leaving with the stuff and not really having to put yourself into it. And when we set up this in-service, we said, 'No, that's not what we want. We want people to be really involved in putting this stuff together, really thinking it out.' Asking, 'How am I going to achieve this SLE? With the stuff I have in my classroom and the kids I have in my classroom, with whatever current realities that happen to be, how do I make this work? With the support of all these other teachers who can give me some ideas and suggestions?' But we all know there are those file folders that say whatever that you never look at again. But if you've had an active part in putting it together and talking about it and wrestling with it, chances are pretty good you're going to use it. Or, at least, modify it to make it work....
>
> We were also asked, 'Why not just purchase the stuff? It seems good enough for everybody else. It would save us a whole lot of money in the district and then we have our unit.'
>
> Again we said, 'That's not what we're looking for here. What we're looking for is that we work through it, that we put stuff together individually ... [because] there isn't that one canned, perfect lesson.' (CF2)

Alice, asked to describe professional development experiences that had been particularly useful, replied, "The workshops I did with Mary." Not the sessions that she had facilitated, but the experience of working with Nicole (another lead teacher) to develop a sample unit plan had

> challenged us in a way we hadn't thought possible...We'd meet at the school at 6:30 in the morning to work on this unit because that's how excited we got about it. We'd work a little after school, but not as much because we were pretty tired after school. The most exciting thing was gathering all the materials, seeing what was out there and what wasn't, and looking at the SLEs, and trying to decide how to narrow down all the information... We liked the thrills and the highs and the lows that came with it. And presenting it to the kids and seeing what works and what doesn't work is just so much fun. And then having the added opportunity to present it to other teachers and share your expertise and knowledge. (T4)

Sharon, the second teacher interviewed, remarked that she appreciated that some of the in-service time had been during regular school hours because, "You are very tired by the end of the day... You're hungry. Your family's at home. Many people have families; they need to get home to their families... I have only one child [who is 15] and I

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have a husband who cooks. So I'm very lucky. But I don't how many people do it, because it is very stressful."

In addition to this set of in-service sessions, the participants interviewed in this district mentioned other types of available professional development. Frequent reference was made to the chance to go to other district-wide in-services. As one principal said, "All they have to do is fill out a form and hand it to the secretary and it's electronically sent down and they are booked for a particular in-service." In this district, two days were allotted for school based professional development and if science education were seen to be a school priority, time could be devoted to that topic. The Science Supervisor could also be booked to come to the school to work with a teacher, teachers, or the staff. In addition, personnel from both city school districts coordinated a Science Forum held once or twice a year, an evening of workshops presented mainly by teachers on science education topics. There was also a Science Helpline teachers could call to find answers to questions about science or to request a guest speaker for their classrooms.

Marlene mentioned that teachers could attend the Alberta Teachers' Association Science Council Conferences, but added, "I don't think anybody on this staff would go to a science conference except for possibly one." University courses were also mentioned once as a possibility.

By far the most frequently mentioned means for further developing teacher knowledge was through teachers collaborating with other teachers: talking together, working together, sharing ideas. It was suggested that this could be facilitated by a principal asking a more experienced teacher on staff to 'buddy' a new teacher or by scheduling time for teachers to plan together. Telephone mentoring was suggested by a principal, but Alice remarked that while mentoring by phone might be a possibility, "It seems to work best when you can get together with that individual... Because you can explain it to them, but when they see it all, it works much more effectively."

Thus, the chance of mentoring being effective was believed to improve if teachers could sometimes meet together, if "it's easy to pop in and talk," and this was more likely if teachers were teaching in at least the same quadrant of the city. On the same theme of convenience and professional development, a principal felt, given the crowded schedule of teachers, that "Sometimes addressing it [professional development] at a school-based

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level is a better situation than having people drive miles and miles to attend an in-service that is like a two hour fix."

Marlene also expressed the opinion that teachers, especially beginning teachers, are interested in very practical matters and want practical suggestions to support their classroom teaching. More experienced teachers, she felt, might develop their own theoretical knowledge of teaching by helping the newer teachers because "in supporting the teachers that need more, ...[as] you teach, you also learn."

Mary agreed, too, that, "Talking, the collaborative time with other teachers is very important... We have very little time in a school, in the course of a school week or a year, that teachers get together and talk about instruction. And talk about curriculum. And that's too bad." Exemplary professional development would be "bringing people together, that's the most important thing, so that they can dialogue and they can find out from each other. And embedded within that is reading and discussing professional literature."

Knowledge Development

In summary, this school district took responsibility for introducing teachers to both procedural and principled knowledge.

Examples of procedural knowledge development include discussions held about specific learner expectations in the new science program of studies and about basic strategies for teaching and assessing learning in science. Through their discussions and unit-writing, teachers also became acquainted with a variety of teacher and student resource materials that supported the science program.

A number of additional activities introduced possibilities for principled knowledge development. Teachers enhanced their knowledge of science concepts and the interconnections among these concepts in the topics for which they prepared a unit plan. They read about and discussed constructivist learning theory and the role students' preconceptions play in science learning. Using these ideas to fashion a unit plan, teachers had a chance to further develop their pedagogical content knowledge. In addition, through their discussions of the rationale for the program and a consideration of different

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teaching and assessment strategies, teachers were introduced to ideas on which to base future teacher inquiry into teaching and learning in science.

Teachers also worked with other teachers teaching at the same grade level from other schools in the district, teachers with varying degrees of expertise in and comfort with teaching science. Such acquaintanceships allow teachers to reach out and develop collaborative professional partnerships and networks.

Elm School District

Elm School District, too, is located in a large Alberta city. A leader in developing school-based management, Elm School District handled professional development very differently from Spruce School District.

I interviewed a principal and a teacher at two district schools. Bertha (P4) was the principal of Chester, a kindergarten to grade nine school located in an inner-city neighbourhood with a large immigrant population. In university she had specialized in elementary art and special needs education, but most of her teaching experience had been in English at the high school level. In school she had found science confusing; "it made no sense to me." Jackson (P8), however, with a Bachelor of Science degree, had started teaching in elementary school "mainly as a holding pattern" while waiting for a secondary position to open up. He enjoyed elementary school so much he remained at this level, moving from teaching into administration after eight years; he had been a principal for 17 years at the time of this study.

Maryanne (T3), a grade three teacher at Chester, after studying English, sociology, and psychology, had received a Bachelor of Education degree and then a diploma in early childhood education. She described science as "learning about the world and how it works," an emphasis she tried to maintain in her science lessons. James (T9), also a grade three teacher, had done a specialist science education program in England. While maintaining an interest in science, since coming to Canada he had taken enough courses to qualify as a secondary history teacher and had received a diploma in special education.

Elm employed both an Elementary Science Consultant and a Secondary Science Consultant. I interviewed Susan, a classroom teacher for 17 years, who had been in the

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Elementary Science Consultant position for only four months. Her teaching experience was in grades one and two and she had taught grade five science as well. She had received a Master of Education degree on the topic of kindergarten children and their attitudes toward writing. Prior to coming to this consultant position, she had been part of a district writing team which created a grade two science unit plan and had reviewed the grade two provincially authorized science resource materials for her school. She explained that she had for years had an active interest in reading articles about science in news publications such as *Time* and *Newsweek* and used this information to "show the children how that [science] would affect their daily lives." "Because the way science is being taught has changed so drastically in the last two years with going to a hands-on curriculum and a grade specific curriculum," she confessed she had read "very few books on the teaching of science." She appeared to be a science enthusiast teacher, a lively and approachable person who was interested in helping others teach science with similar enthusiasm.

Susan described her responsibilities as, first, in-servicing teachers on the new science curriculum. In addition to meeting with colleagues to coordinate projects, she edited assessment materials district personnel were writing, met with publishers to preview their materials, and reviewed elementary science materials that came to the district office. She was focussing on reviewing CD-ROMs so she could make recommendations to teachers to save them time in making choices about computer software.

It was this aspect of consulting that Susan stressed, saving teachers' time. "Alberta Education comes out with this mandate that this is what we're going to teach. And classroom teachers, normally, we don't have the time to find out all this information for ourselves. We look for someone else, for that middleman between Alberta Education and the classroom teacher. And that's the role of the consultant, is to interpret, to a certain degree, what this documents means and how it could be taught and present that to the teachers on a more general basis." As a teacher, "[O]ne of the things I've thought of as a consultant's role is that they are the ones that are going to do the reading for me. As a classroom teacher, I don't have that time."

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After the *Elementary Science Program of Studies* (Alberta Education, 1996b) was mandated, Elm School District decided to produce a set of teaching plans, one for each topic of study. Jackson, a principal, explained, "We [certain teachers and principals] were strong about some support for the science. And we yelled loud and we yelled long and we got our consultants to move and start developing some units.... I, as an administrator, do not like to see my staff spending that kind of time on developing curriculum. First, sometimes a good teacher does not write good curriculum and, second, they're dying in the classroom. There's only so much energy one has and this is only one subject."

James, a teacher, was of the opinion that, "When the emphasis is just completely on test results, because that is the complete emphasis now in this system, ... it is the job now of consultants to get out materials that teachers can basically just kind of 'Boom' use. This is a lifesaver for them [teachers who don't have a particular background in science] and they might not even question that something was not good." (When completed, the unit plans were offered for sale for $30 apiece.)

The in-service sessions offered by Elm School District consisted primarily of a review of the school board produced teaching resources. Thirty such sessions were offered each year, one for each of the teaching units. These sessions were held after school from 4:15 to 6:00 pm and cost district personnel $30 to attend. (Teachers from other school districts could attend, as well, but at a somewhat higher charge.) In addition to going through the teaching manuals and discussing how the activities addressed each specific learner expectation in the program of studies, teachers were often presented with ideas about additional resources related to the topic. These ideas ranged from suggested ties to literature and other trade books to suggestions about where one might find a ready and cheap supply of student materials. When possible, teachers worked through some of the activities found in the unit plans.

Some in-service sessions were held at sites offering special facilities and displays for teaching specific topics. Other sessions were focused on integrating science topics across the curriculum, preparing students to take the grade six provincial achievement test in science, and teaching science in combined grades. Because Consulting Services operated on a cost recovery basis, "[W]e supply what's demanded... What we're looking

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at now is how we're going to be able to broaden our scope, to broaden our market, basically. ... A new topic of discussion that's come up this year is curriculum alignment. It's brand new. ... We'll be looking at 'Yes, this is something that principals will hire us to do, to come out to do on a [pause] sort of like a four time a year thing' and bill accordingly."

Asked about this cost recovery system, Susan explained it meant that "[T]hey've taken the money that used to be left in central office for consultants and put it out into the schools. So the schools have to hire us back. We have an hourly rate that we charge and if a school would like me to come out to their school, that's going to cost them however many hours of preparation and can include travel." When teachers call in for advice or help, "[W]e now have what we call a non-billable. We have to keep track of our non-billable hours. A five-minute phone call is a non-billable item, a 10-minute, even up to a 15-minute phone call is a non-billable item if it's a one-off sort of thing. But I've been told, 'If you find that there's someone who's calling on a fairly regular basis, after about the third call, you say, 'You know, I'd really love to help you, but it sounds like you need more help than I can give you over the phone. Would you like to check with your principal because we're going to have to start charging.'"

Other available professional development opportunities Susan mentioned were similar to those advanced in Spruce School District: university courses, a Science Helpline, the Alberta Teachers' Association Science Council Conference. Bertha mentioned the Teachers' Convention where publishers mount big displays, teachers can view resources and curriculum material and even collect "freebie stuff." In her school "we try to make sure we have a little bit of money to reinforce that search for the new and different resources."

James described two different professional development experiences he had had on the topic of Rocks and Minerals. Because he did not think "you can teach anything unless you know something really well," and because geology was the area of science he felt weakest in, he went on a field trip sponsored by a geologist association, a three day trip conducted by three geologists for about 20 teachers. "I was just like a kid; 'Tell me what this rock is.' And I found out sometimes it's very difficult to say just what a rock is.... You don't need that kind of knowledge specifically, but that's the way I approached

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it." He had been very disappointed at a district in-service he had attended on the same topic prior to that trip. He had taken along a rock he could not identify and "I was not impressed with the fact that she [the science consultant] couldn't tell me what this rock was. I determined afterwards that it was really, really simple to tell." For James, exemplary professional development was being in a situation where he could get accurate answers to questions he had and, "you might hear somebody talking about what they've done and being really enthusiastic about it and they tell you something that is new for you."

In-services, Maryanne suggested, are useful when "you are lucky enough to have someone teach it to you in such a way that it turns you on and sets you on fire." Ideas about good activities, how they work, and ways to introduce the topic really efficiently can be suggested. But, in the end, "you learn best by doing it."

In this district, there were also two days assigned for school-based professional development. James reported that in the previous year the staff in his school had decided to use one of those days doing a first aid course so all staff members could receive certification in first aid. (The province requires that a certain percentage of staff members in each school have current first aid certification.) Maryanne explained that "We had always had a music specialist up until last year and then budget, no more music specialist and all of us suddenly got to be music teachers. It was terribly difficult for us because we don't have a background in music. ... And we also discovered that all the resources in the music room belonged to the music teacher. And when she left, so did they." The result: a large portion of professional development time during that school year was spent becoming proficient in teaching music.

Other professional development initiatives had also been organized at the school level. The principals of ten elementary schools in one geographical location were in the process of organizing a 'mini conference,' a series of sessions on different topics that teachers could attend, where they could also "liaise." Then, Jackson said, "They can talk on their computers from school to school." Believing that teachers "need time to network," a group of principals in this same area had set up a meeting for teachers at each grade level the previous year. Jackson's goal was "to get them together and then they'd start talking." He had hosted the after-school meeting for grade four teachers and

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reported about a 30% teacher turnout. "And some of those groups died after the first meeting because there was no teacher willing to take that kind of energy to run, to keep them together, and some of the groups took off because they had the type of classroom teachers that saw this as 'This is going to help me.' ... And I think we as educators need to develop more of that where we allow our teachers time to talk and then see where their greatest need are."

A number of schools in Elm School District have reorganized instructional time to allow students to be dismissed early one day a week. The remaining hours of the afternoon (non-contract hours for teachers) are devoted to professional development. Maryanne explained, "Some of our time is spent in staff meeting, some of our time is spent in division meetings, and some of our time is spent strictly for [personal] professional development. So if we have ideas to share, you can ask for some of that time." At such times, teachers may share ideas and resources from in-service sessions or conferences that they have attended, thus stretching the scarce funds available for professional development.

Money was a topic both principals commented on at some length -- the difficulty teachers and schools are going to have if the province sets up accountability standards for teachers, but "doesn't put up money to enable teachers to do it." They felt that teachers need time to engage in professional development when "they're not brain dead," referring to the most common type of professional development offered by the school district, the after school, single shot in-service session. Bertha expressed appreciation for the professional development funds her school had accessed from the Regional Consortium, the only person in this district to mention the provincial attempt to provide professional development.

Knowledge Development

Through the development of a set of teaching manuals providing little guidance for teaching science through inquiry and the provision of in-service sessions predominantly focused on the use of those manuals, Elm School District's efforts helped educators, in the main, develop procedural knowledge.

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The teacher manuals produced by Elm School district provide teachers with specific, factual knowledge about the science topics. Through attending in-services sessions and using the manuals, teachers became better acquainted, too, with the specific learner expectations in the curriculum document.

I find little evidence that teachers were introduced to principled knowledge in the school district-arranged professional development. It appears that the development of principled knowledge about science education rested with the teacher, perhaps aided by colleagues. It would seem to be left to chance whether or not professional dialogue in Elm School District is embedded in reading and discussing professional literature, a central tenet of the professional development offered in Spruce School District.

Currant School District

Currant School District is a suburban school district adjoining one of the urban centres in Alberta.

In this district I interviewed a principal and a teacher at a 500-student school in the largest town in the district. Deanna (P2) had been "a very good classroom teacher" when she was asked by her principal to take a short-term vice principal position. She hesitantly accepted, but found she really enjoyed the different view of school life, teaching, and the community she got from the administrative position and felt she "might have some influence on the direction that my school went outside of my classroom." Since that time she had been a principal for 17 years at five different schools, had done a Master of Education degree in Administration, and filled in yearly as a teacher "in whatever blank is left after you timetable everyone else." Jennie (T12), in her seventh year of teaching grade three, described herself as "a come-back-again-later" teacher; she had attended university with her own children. She said that teachers in her school were very pleased with the revised science curriculum, but were having problems translating anecdotal notes on performance into the percentage marks required on district report cards. Both Deanna and Jennie mentioned that the conservative views on education held by parents in the area required the school to maintain traditional teaching practices (e.g., using textbooks, teaching phonics, stressing math facts) while they also introduced newer practices (collaborative learning, student explorations and problem solving activities).

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The second school, located in a rural area of the district, had 150 students, most of them living on acreages. Lena (P3) had been an elementary teacher for nearly 25 years, broken by a sabbatical to do a Master of Education degree in computer applications in elementary schools. She had been an assistant principal for three years and at the time of the interview was in her first year as a principal. William (T1), the grade 6 and 3-4 science teacher, had taught for over 20 years, five of those as a junior high science teacher. He felt very comfortable teaching science and thought that anyone who had passed grade 9 science should have developed the vocabulary and background knowledge necessary to teach elementary science well.

Constance (CF1) was responsible for computer education, science, mathematics, Career and Technology Studies, environmental education, and, usually, physical education for grades kindergarten to 12. She had a staff of 11 working under her in Technology Services and she supervised two other employees who developed and refurbished science kits used in all the elementary schools, public and separate, in this area. Constance had received a Bachelor of Education degree from the University of Alberta with a major in mathematics and a minor in general science, had done a graduate degree in computers in education, and earned a Master of Education degree in administration.

Currant School District was unique in having centrally developed science kits to loan to teachers in its elementary schools. Located in a major industrial area, Currant School District was the recipient of funding from Cheber, a chemical corporation. An engineer from Cheber reported that her company, recognizing "the benefits of kids learning [science] by doing, rather than learning by reading" (SP3), had funded the establishment of kits containing science materials. While Cheber had funded the initial kit development, the school district committed itself to refurbishing the kits through a per student charge to elementary schools. (This charge was $6 per pupil in 1998.) In addition to student materials, the kits also included one or more teaching guides for teaching the topic or aspects of the topic.

When asked about the knowledge teachers need to teach elementary school science well, Constance replied, "I think, understanding science inquiry. I don't think every elementary teacher needs to be a science specialist. But I think you do need to

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understand there are some processes in science." In addition, knowing the terms specific to science and how the science being taught is applied in society were listed as important.

"We don't have a lot of money for staff development and the school district has been decentralized to the schools." Constance went on to explain how the implementation of new curriculum programs was handled in her district.

> The information that's coming out from Alberta Education is usually sent to the principals of each school and with site-based management, schools now are responsible... Central Services are there to support and help, but not in the role of years gone by where we had funding specifically for the implementation of new programs. That is all gone. That's all been decentralized; it's up to the schools. So when it comes to implementing a new program now, our job is in the communication of the new program, ... trying to deal with the vendors of the different software or the different books so that they're not at every school, because the principals don't have time.... We did sessions with the principals letting them know about the new program. And we asked for lead teachers when we did meet. Now these meetings were after school; there was no money for sub release. But, then, of course, teachers on their own are responsible for their own personal staff development and the implementation of new programs. (CF1)

Deanna (P2) opined that teachers need to have a fundamental knowledge of the mandated science concepts in order to answer student questions and provide guidance. In addition, based on teachers' personal professional development plans, she knew that teachers wanted to know "how to organize 30 children to do these kinds of things so that learning occurs. ... Some of it is just opening up their minds to different ways of structuring their learning environment and their learning day... They need some options in terms of how to go about doing some things." Since new ways of doing things sometimes clashed with parents' views of what should be happening in schools, teachers also needed to be aware that these different approaches were 'okay and acceptable.' (Some parents had been critical of classrooms they perceived to be noisy and where kids were seen "to be all over the place." As well, "Parents want to have a text book home to study for the test from. ... So, from time to time, if we find a resource that teachers really like, we buy one for everybody and it's mostly to satisfy our community rather than to satisfy the learning needs of kids.")

To help develop this knowledge base, Deanna encouraged teachers to attend the ATA Science Council Conference. "I really encourage them to go in small groups because I find, if you go [alone], you've had a unique experience. But you come home

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and no one else has had it and you don't share it and it doesn't have the same carry over. Whereas if I can get two or three or five of them to go, there's some bonding, they come back, and they start working together on something. Those who didn't go are soon dragged in. There's more carry over."

Since kits were available to help teachers in the program implementation, Deanna considered that "a lot of the professional development for myself and my staff, was actually getting in, using it, seeing what worked, seeing what didn't and then working in grade group teams, saying, 'What do we like? What don't we? What do we need to do to change what's in this kit?'"

Jennie really liked geology, had a collection of 'rocks and stuff,' and offered to write a Rocks and Mineral unit plan. She and a colleague did a summer Ed-geo in-service that gave them additional ideas for this unit. After the Rocks and Minerals kit was developed centrally, they also incorporated ideas from that into their own unit plan. As additional kits became available, these teachers had used them to start teaching the remaining topics and to adapt the teaching plans included in the kits to meet the needs of the students in their classrooms.

Lena (P3) believed that as science at the elementary school level is 'fairly simple,' "a teacher teaching it for the first time, would need to work ahead and see what the next unit is, to see if there are areas that are unfamiliar to them. ... If there are areas you feel you're not [familiar with], then do some reading, get some films, go and talk to somebody who has more background, share with your colleagues, ask questions." "But the kits are fairly comprehensive and then it would be a matter of, in the areas you're not sure of, doing the experiments ahead of time so you know what you can expect."

When the draft science program was sent out for comment, the staff in Lena's former school had spent a "fair amount of time, several lunch hour meetings" reviewing it and suggesting changes to the provincial curriculum writers. As soon as the program was finalized, the staff had collected and reviewed available teaching resources, looking for applicability to the provincial science program document. But "the most helpful thing" was the district partnership that supplied kits to the teachers. "I don't know how the teachers would have survived without that help, if they had had to gather all the materials themselves," commented Lena.

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William felt comfortable with the science content. However, recognizing in the draft versions of the science program that this was to be a much more activity-based science curriculum than the previous one, he had started to gather materials early in the change process. He was one of the teachers the district invited to help choose materials and teaching resources for the kits. These kits, he said, meant that teachers only need "an hour or two of planning and you're ready to go with them. Sure, you're going to be fine-tuning and changing and doing all those things we all do, but one to two hours and that's it. You're ready to go, whether you've ever seen a caterpillar before in your life or not."

In-service sessions were offered to Currant teachers, generally after school, to introduce them to the individual kits. While some teachers did come to these, Constance thought, in actuality, "[E]ach kit is almost having an in-service in itself."

Ruth, the Cheber engineer, described an experience she had had one year at the annual school district planned professional development day. A number of sessions on the use of the kits in elementary classrooms were scheduled, but only 10 to 20% of the teachers chose to attend these. "There were more teachers who were interested to go into line dancing than there were ones that wanted to come in and learn about how to teach this kit in their science class. I was just aghast." She added, "We also had some great in-services. We had a lot of the same teachers coming out to get very knowledgeable in the kits they were teaching in their classrooms."

As alluded to earlier, this district provided more in-service opportunities than just a series of after-school sessions. Five days were set aside during the school year for professional development: two days for the annual Teachers' Convention, one day of sessions planned by the local ATA professional development committee, one organized by the district, and one for school-organized professional development activities. Deanna found that the district-wide after school sessions were poorly attended, but those organized to meet needs identified by the staff and held in the school have "virtually the whole professional staff" in attendance. William, too, commented that although "nothing had met staff needs in some of the other larger in-services," professional development organized to meet "specific needs within the school here have worked pretty well."

In addition to the professional development activities already mentioned, the study participants named a number of other means for developing the knowledge

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necessary to teach science well. Constance remarked that the Regional Consortium offered professional development, and that the district "promoted and encouraged teachers to take advantage of the Science Alberta Foundation summer workshops." However, none of the other participants mentioned these possibilities. They did refer to professional development sessions they could attend offered by the largest school district in the area.

William felt that "just by living in our world, it's pretty hard not to have picked up on most of the basics." William, although he was confident of his basic science knowledge, reported that he had attended "three or four different sessions on the forest unit and came out with way, way more than I'd ever need. But the result is now it's there for me when I'm planning my forest unit."

Jennie thought, "Life experience is good. ...But there's lots of extra work always on each unit. ... You're limited to hoping the stuff that is in the kits is good. You hope this is good background information, that it's factual." In science," she maintained, "you're more or less on your own."

Describing her idea of exemplary professional development, Constance said:

> I find staff development to be successful when we get teachers together and we talk about a unit. We'll go back and teach that unit and then come back. How did it work? Where do we need to change? And just sharing with each other, what worked, what didn't work.... So I would really like to have the opportunity where they can come together. It would be nice if the school day ended earlier and teachers could come together after school. But as soon as you start bringing teachers in [from a geographically large district], you're into subs and as soon as you're into subs, teachers say, 'Oh, it takes me more time to prepare for a sub.' So it's just really hard. (CF1)

She hoped that web pages and chat rooms would be ways teachers could share ideas once they all had access to e-mail. As well, if lead teachers could be given release time, they could work with the teachers in their schools rather then just fulfill the role of disseminators of information at staff meetings.

Knowledge Development

The professional development offered and that sought out by these teachers would appear to have been focused mainly on the development of procedural knowledge; that is, on developing knowledge of the mandated science program, of related teacher and

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student resource materials, and on science content knowledge. In Currant some of that information was available in the kits, but teachers did pursue further teaching knowledge as evidenced by Jennie's decision to do the Ed-geo summer in-service course and William's attendance at several different in-services on Trees and Forests, a new topic in the elementary school curriculum.

In working with other teachers to change and adapt the activities suggested in the kits to meet the needs of their specific students, teachers may have collaboratively developed principled knowledge.

Gooseberry School District

Gooseberry School District, the second suburban school district chosen for this study, abuts one of the two major urban centers in Alberta.

I again interviewed a principal and a teacher in two different schools. Muriel (P1) was the principal of McDade Elementary, a school located in a low-income neighborhood at the edge of the largest town in the district. She had taught for over 20 years and had been a principal for the last eight years; in her present position she also taught more than half-time. Jane (T8) was in her sixth year of teaching, most of it at the grades 1 and 2 level, but she was teaching a grade 3-4 class in 1998. As she pointed out, in six years she had taught the science curriculum "in four different grade levels."

Ralph (P9) was the principal of Hilltop School, a 650-student kindergarten to grade nine school located among acreages in a rural area. After teaching at the elementary and junior high levels for a number of years, he had taken a sabbatical to do a Master's degree in environmental science, described as a curriculum-type program. He returned to teaching, was an assistant principal for several years, and had been principal of Hilltop School for 11 years. The assistant principal in his school handled curriculum matters. Kathy (T6) had been teaching for 10 years, predominantly at the grades 3 and 6 levels. She reported feeling pressured by the grade 6 achievement tests; she did not feel she had the freedom to explore some aspects of science in adequate depth as she had to cover all the material to give students a chance to do well on those tests.

Gooseberry employed a Curriculum Facilitator who was responsible for all kindergarten to grade 12 curriculum subjects except computer technology and second

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languages. Ken (CF3), who had been in this position for four years, described his job as working with teachers in areas of emerging curriculum changes, on topics they designated as being of interest, and on district concerns such as classroom student assessment. In addition, he was the district liaison person to the Alberta Education Curriculum Standards and Student Evaluation branches and with organizations such as the Alberta Assessment Consortium and the University of Alberta.

In university he had trained as a secondary school social studies teacher and had started his career teaching English in high school. After teaching for a few years he went back to university and earned a Master of Education degree in administration. Returning to the classroom, he taught six years at the grades four to six level, followed by several more years of junior high teaching, English and some mathematics, and had set up and run his school's computer laboratory.

When the new elementary science program was introduced in the mid-1990s, Ken reported:

> As with every emerging curriculum, I try to figure out what the best way is to make people aware of it, to give them opportunities to look at the curriculum, to talk about what impact it's going to have on them. Because of my range of responsibilities, I can't be the expert in every field. And so I try to set up opportunities for people to talk with each other, because I think that's valuable and they can use the internal expertise that they have within the group. (CF3)

Looking for a "model that might work," he followed the process his predecessor had found successful when the current elementary social studies curriculum was implemented.

> What I did was invite people at grade levels to get together and we took a look at what was really happening, the change that was happening. They took a look at possible resources because none were authorized at that point. And we decided that we were going to work on unit development. So over the last 2 ½ years or so, they've worked in committees to look at the topics in detail and to develop the unit plans from that.

Part of the process of unit development involved seeking out good teaching resources and "taking a look at how we might incorporate them ... to expose them [the teachers] to the ideas in the resources." Ken described this as "sort of a multi-tasking type of development" as it included getting a really good understanding of the topic of study, of the resources, and of different approaches for teaching that topic.

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Teachers need content knowledge, he acknowledged, but, "I think it's more an openness to try a variety of different kinds of approaches and an openness to try to individualize for students that's a key element to this." Building such knowledge and openness was an incremental process in his view; "Certainly the thing that stands out for me is that it takes a period of time for change." "I believe one of the key things is providing teachers with opportunities to talk to each other. ... I think they do have expertise to share with each other. But then it has to go beyond that a little as well. [They need] opportunities to have exposure to things like conferences, to speakers at Teachers' Convention and other venues, so other ideas can come into the system."

While the units were being written, schools, too, started to work on implementing the science program. Ralph reported, [W]e've tried to leave the ownership as much as we can with the teachers and then be the facilitators for them for what they need." To teach science well, Ralph believed that teachers need to thoroughly understand the science concepts they are to teach. Building this knowledge base can be supported, in his view, by textual materials, videos, the Internet, and the 'canned units' put together by his school district. "They [the unit plans] work well, people can understand them. ... They can adapt them if they want, but it's there for them to go through." "I guess the big part is, people have to go out and they have to look for it [implementation ideas] outside." To support such initiatives, the school budgeted $400, plus substitute expenses, to allow teachers to pursue professional development.

Ralph also encouraged his teachers to form groups and submit proposals for collaborative professional projects focused on an area of mutual interest. Kathy described being a member of one of these, a collaborative action research project, as

> probably the most worthwhile professional development activity that I've ever been involved in. It's timely. It's current. It's relevant. It's inspired me to do things in the classroom. It's inspired the others. Our conversations together have led us to get to know each other better as people, has led to a very strong spirit of collegiality. It's ensured a commitment... I've made a commitment to the group, I've made a commitment to myself as part of that group and, also, then I'm making a commitment to my kids. (T6)

She also remarked that she and her colleagues had learned more about research methodology and "it's interesting how often we kept coming back to the topic of curriculum. And looking at commonalities across curriculum and concepts."

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Some of the meetings of the four teachers involved in this project were held after school, but teachers were also able to use school funds provided for their project to purchase release time during school hours. This time they had spent discussing, planning, and reflecting on the use of computer technology leading to student success in their classrooms.

Muriel also reported being pleased with the district-produced teaching units. The school had purchased additional binders of teaching materials because the staff had felt that if such materials were available, "Why are we going to redo everything?" Planning time was being spent, instead, particularly in the primary grades, trying to link the new science topics with other curricular objectives to fit with the school's thematic approach to teaching.

Muriel thought, to teach science well, teachers "still have to have that background information, some of the basic scientific knowledge and skills." They also needed to have materials available, and, "I think we've all had to change our focus over the years from being givers of knowledge to facilitators of learning. That's the big change. And that doesn't just apply to science. That applies to everything we're doing now." Teachers develop this knowledge base, she thought, by "reading and going through all the materials that we have. ... Basically, we have the units developed by our district, we have the units developed by Elm School District, and then we have that other set of binders. So they have all this that they can pull materials from." Teachers from McDade School had attended in-services presented by Elm School District centred on the unit plans developed by the district, but Muriel could not think of any science conferences teaching staff had gone to.

Both teachers interviewed reported having been involved in gathering materials needed to teach the science topics. Kathy and a colleague had visited another school where "we looked at some of the things they were doing and some of the materials they were using and talked to some teachers." They had also borrowed materials from the District Resource Centre, examined them, and tried to match them to the student expectations listed in the Science Program of Studies.

To teach science well, Jane thought teachers "need to be comfortable with the fact that things will not always go your way....You have to be willing to fail and not take that

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too seriously. It's just that's what's happening and you explain to them [students] what should have happened." Also, "I'm finding you have to be willing to let the children explore. You have to let go, ... but always come back and reinforce as well." To develop these skills, she reported that teachers need to stay one step ahead by "reading through materials" and "using enough resources to make me feel confident in what I'm saying or what I'm teaching." Kathy felt a teacher would need "a knowledge in how to structure the environment so these things can take place. Confidence, some confidence in the subject area and the materials to be covered. (pause) Opportunities to try things out. (pause) Reflection, too."

Besides preparing unit plans, Gooseberry School District maintained a Resource Centre, a facility where as many resources as possible were stored for teacher use, including at least one copy of each of the provincially authorized teacher and student resources. The Resource Centre librarian also compiled a list of all the available resources by grade level and topic and sent these lists out to the schools.

As in all the other school districts, teachers received two days to attend the annual Teachers' Convention. They also attended a school district planned in-service day each fall, a day planned around a theme such as computer technology or student assessment. Teachers had another three or four days of school-planned professional development time, some of which could be used for teacher-parent conferences.

The school district offered a limited number of after-school sessions on subjects identified by schools and/or teachers as being of particular concern to them. Ken was praised by all the participants for visiting each school "to identify the sorts of things that we are interested in. ... And then he takes that information back from all the schools and they see how they can best serve the majority of the teachers. But a lot of it still depends on how much a school or an administrator values professional development" (P1).

Other sources of professional development for teaching science mentioned by participants included a school district-university project, in-services held by publishers' representatives to present their print resources, and talking with other teachers, especially as both teachers had maintained close ties with colleagues in their previous schools. While Ken referred to the ATA Science Council Conferences, no other district participant mentioned these annual conferences.

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Jane reported on her attempts as the Alberta Teachers' Association's school district professional development chair to coordinate professional development activities offered by the individual schools in the district.

> Because if schools were doing their professional development individually, we found they were overlapping. They would bring in this speaker from Elm School District, pay for them, and then another school would do it six months later. And so we tried to coordinate it. But what we found is that with school-based management, most schools wanted to do their own thing, that they weren't going to release teachers to go attend sessions at other schools on those days. So we found it didn't work, ... Schools basically had their school drives.... So the professional development days at the school-based level were more for what the school needed and not for what the individual teacher needed. And that's the difficult part – there seems to still be money for what the school needs, but not so much money for what the individual teacher needs. Depending on the school. (T8)

As reported above, Ken was convinced that exemplary professional development "has to be an on-going kind of thing." Outlining what he believed to be important elements, he explained that teachers need

> first of all, knowledge of curriculum, what's in it. Because I think teachers often don't have the time to spend <u>really</u> taking a close look at what's in the curriculum – to delve into it very deeply. Some of the changes in teaching strategies I think need to be dealt with, and that is going to take some time. How do you deal with an activity-based classroom? How do you run it? Just the practical problems. Then how do you ensure that the concepts are taught? How do you ensure assessment is happening? ... I'm not talking about evaluation. I'm talking about diagnostic, formative assessment. (CF3)

He believed that it was not enough to merely introduce these aspects; it was also necessary to come back and revisit them. Teachers who had attended sessions on teaching the problem-solving through technology topics told him a couple of years later, "Those were great. That was a good starting point. Now I sort of see what he [the presenter] was getting at after I've had a chance to work with it in my own classroom.' So it takes a period of time." Other teachers "who had received information at the beginning [of program implementation]," later reported that "they had sort of hit the point where they had run out of their own ideas and needed an infusion of other ideas."

Ideally, professional development would be organized as "half day sessions, spread out over a period of time, because I believe that's a far more effective use of time. When we get people together to talk about ideas, a half day seems about the maximum

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they can absorb and if they can go away and try some of those and come back and talk some more and go away and come back, then that's much more effective."

Ralph concurred that a half day was optimal for keeping attention focused on a single topic. He saw exemplary professional development coming out of the professional development plans staff had been involved in writing for the past three years. These plans included a teacher evaluation of his or her current practice, goal-setting, and reflection on the effectiveness of professional development undertaken in the past. "So the perfect professional development to me comes from the person themselves. They are demonstrating that they're doing a great job and they're developing and changing each year."

Muriel spoke of both school and individual education plans. In both plans, she thought that the identification of goals, strategies to achieve those goals, and analysis of results were necessary components.

Jane's comments on exemplary professional development expanded on the value of collaborative professional experiences. "I don't think there are enough opportunities where teachers in professional development actually get to share ideas. And I hear so many teachers say what would be most useful for them is actually sharing sessions or planning sessions together in groups. People may think that a planning session on science is not actually professional development, they're not really seeing how much it is, because when you're sharing ideas and planning for something, you're learning. And that's what professional development is about – it's about learning and moving on."

Knowledge Development

In Gooseberry School District the Curriculum Facilitator stressed that curriculum knowledge should involve more than a superficial reading of program expectations, more than the development of procedural knowledge. As elsewhere, the need for teaching resources was recognized, as was the need for teachers to have content knowledge of the science topics they were teaching.

As in Spruce School District, but on a much smaller scale, committees of teachers writing teaching units considered not just specific activities matched to the program of studies, but different approaches to teaching the topics, as well. Working with the

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curriculum facilitator, they also looked at different ways to individualize and assess learning. Such activities help teachers develop principled knowledge.

In this district, too, a principal had encouraged teachers to research aspects of classroom education of mutual interest. This exercise, described by teachers as very worthwhile, engaged teachers in classroom inquiry where they considered different aspects of teaching and learning, deliberation capable of building principled knowledge.

Clover School District

Clover School District is one of the larger school districts in the province in geographical area, as well as being one of the most sparsely populated. Many of the schools in this district provided education to students in kindergarten through grade eight, with students being bussed longer distances to the four-year high schools.

I again visited two schools in this district. The first school, Valleyview, employed two teachers to serve 25 students who lived on the surrounding farms. Esther (T7), whom I interviewed, was the principal of the school as well as the grade 1 to 4 teacher. (She taught kindergarten to grade 4 when a kindergarten-aged student attended the school.) Esther had been a teacher since 1960, but had taken time off to raise a family. Returning to teaching, she had worked part time as a grade 1 to grade 9 teacher, "wherever they needed me," for a number of years. For the last six years she had taught and been principal at Valleyview. Being so isolated, "we don't really have a whole lot of opportunity to go out and see what other classes are doing," but when they do get out, they attempt to "discuss with other teachers as much as we possibly can, what they're doing, what they have, and try to work with materials that have been successful for them."

The second school, Bennett, located in a regional town, had 340 students. Jeff (P5) was in his first year as principal of this school. He commented that he had been in administration for most of his career. After teaching for 2 ½ years, he had become principal of a small rural school, moved on to a larger elementary school as a vice principal where he had become principal before transferring to Bennett School. Much of his educational background had also been in administration. The Edmonton Public

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School science units he felt were "very well put together" and their short 30 to 45 minute lessons were not only easy to use, but "very much student hands-on."

Tanya (T2) had taught at Bennett for about 15 years, most of those at the grade 4 level. She described how she and the other grade 4 teacher had prepared to teach the Wheels and Levers unit. "We'd be every night preparing our science and we'd say to the janitor, 'What are we supposed to do? We don't get this.' And he'd say, "Eh, don't do it that way. This is an easy way.' But we just didn't know; we didn't have a clue.... Boy, if you don't understand this stuff, it's hard to teach it."

Russell (CF4), the Supervisor of Curriculum and Instruction, had been employed by this school district for over 25 years, first as a high school science teacher and then as a teacher and vice principal of a rural school. When he moved to a larger town in the district, he continued to teach high school science until he accepted the position of vice principal at the town's elementary school. After a year as vice principal, he became principal and remained in that position for the next 12 years. After being named Supervisor of Instruction, he took on additional duties, including teacher evaluation. School district amalgamation in the mid-1990s resulted in a change of title to Supervisor of Curriculum and Instruction. In that position he was also in charge of evaluating and reporting on student performance on the Alberta achievement tests and diploma exams to the district and to each of the 19 schools in the district.

Asked about professional development in his district, he indicated that his role is to get information to school principals, "informing the schools of the changes, giving them some idea of how significant or insignificant the changes are, and making them aware of workshops and materials. Whether they attend those depends on their school's plans, professional development goals, and budgets." He continued:

> To me, this is a major problem with site-based management. Being a jurisdiction such as ours, and there are plenty like us, we have non-specialists teaching. For instance, you visited Valleyview School where you have a teacher teaching 3 or 4 grades, all subjects, and the funding is largely based on the number of children. They who are in the greatest need for professional development, because they're delivering so many subjects, have the fewest resources to access and in many cases, the longest distance to travel to access it. So, to give an example, the first Science Conference after the new curriculum came in, I think it was in Red Deer, naturally people were encouraged to go. I'm pretty sure no one from Valleyview went, but something like five or seven teachers from Bennett [the town school] went. Now that's not a very efficient way of doing things.

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> You can argue that Bennett can share their information with Valleyview. Which they can, but to do that costs them money and in the present site-based environment, why should they pay for their teachers to travel anywhere to spread this information? And Valleyview doesn't have a lot of money to come to town to get it because they'd have to come down to get the science, to get the language arts, they'd have to come down for it all. I haven't solved this one.
>
> By putting all professional development money out in the school, it's really made provision of in-service locally, other than in-school in-service, next to impossible. (CF4)

The funding for professional development he does have he saves to send a district representative, often a lead teacher, to in-services or information meetings offered by the provincial Department of Education on new curricular initiatives.

In this school district, the Regional Consortium was mentioned by all the study participants as offering a valuable service. Russell said, "For the first time, really, we've had numerous courses delivered by experts that normally, the only way of accessing them in the past, no matter how the funding was, was going at least to Edmonton." Both teachers said much the same thing, that it was good to have workshops offered in the area, "and you can go on a Saturday and you don't have that expense of a sub, because that's costly when you're sending people out." The principals reported, too, that the director of the consortium was very good about coordinating professional development activities when requested to. No participants, however, mentioned any regional consortium organized professional development on elementary science education that they or their staff had attended.

When the teachers and principals were asked about the professional development they and/or their colleagues had been involved in following the introduction of the new *Elementary Science Program of Studies* (Alberta Education, 1996b), they replied that they had first sought out possible resources for teaching the new topics. The annual two-day Teachers' Convention was one source, the second major one being the ATA Science Council Conference. Tanya reported that her school had "sent quite a few people to the Science Conference for a few years." "It sort of gave us a sense of direction of where to go to [get resources] and which of the larger school districts were developing things and where we could get stuff from. ...We just brought back as much as we could and then we started working from those."

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She also said, "The first time we went to the Conference, it sort of opened our eyes more to what was there [in the Program of Studies] and the kinds of things that were involved. We hadn't worked through it and we didn't really understand it. Then I know this year when we went to Teachers' Convention there were a couple of sessions that I went to and I learned a lot more from them because now I had a bit of a background already and I could make the connections. Whereas in the beginning in a topic like Wheels and Levers, they might have been telling me lots of stuff, but it wasn't connected, so I couldn't bring it back and use it in the room because I didn't understand it myself."

Esther, the teacher-principal at Valleyview, remarked that she was pleased to find a number of unit plans for teaching the provincial topics "that were well developed by teachers and [included] lots of good material." This was particularly important for Esther as her position required her to teach 20 of the topics in the Science Program of Studies. Jeff, the principal of Bennett School, indicated that his school had found the recommendations of books and resources in Alberta Science Foundation (ASF) newsletters useful in making choices about resources to buy. Esther also mentioned that she found suggestions for experiments in the ASF newsletter useful and that she was taking information off the Internet and bringing it to class for her students to read.

Two days were allotted for professional development in this district (in addition to the two days for Teachers' Convention.) The district ATA professional development committee organizes activities for one of these days. Jeff remarked, "Whether that hits everyone's needs is debatable." He preferred school-based, staff-planned professional development. After setting school priorities, his school had sometimes paid for an expert to come in from an urban or larger regional centre to work with teachers on a targeted goal. Initiating a new writing program was one example he gave of such a goal. In Valleyview, too, it was the staff working together as a team that was stressed as being of paramount importance, because, "If it's a team decision, then you're going to do it and everyone's going to be quite enthusiastic about it. ... When we do go out to workshops and conferences, our staff, whether they're support staff or teachers, they come back and share that information with everybody."

In addition to participating in the collaborative planning of the school-based professional development initiatives, Jeff reported that he saw his role in curriculum

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implementation as one of budgeting to buy the teacher resources and student materials needed to teach the science topics and of encouraging his staff to attend conferences.

To teach science well, Jeff thought that teachers "need to start developing the skills to lead students into problem-solving and other techniques to lead to higher thinking skills." As well, "They need to be able to manipulate and handle groups ... a lot of cooperative learning-type activities." Esther stated, "I think anybody, just a generalist, could teach elementary science very, very successfully," but it was necessary to be well-prepared and "have your information and materials on hand."

Asked how teachers build the knowledge and skills necessary to teach science, Esther replied, "When you have curriculum changes, there's an awful lot of work, a lot of planning. I guess a lot of that is done in the summer and also in holiday time and, basically, that's when you try and put it together and be ready for the following year. I always say, 'If you've got a new curriculum, make sure you have your planning done.'... If you're not well prepared and you don't have your materials on hand, everything just falls apart."

Tanya thought "it would be good when you implement a new program to give people some time and to take them out of their rooms and put them with a bunch of people at the same [grade] level and let them work through the main concepts with somebody who knows what they're doing. ... Not everybody can go to a conference every year." Jeff felt that "the successful ones [teachers] are the ones that take the time and make the effort, for the most part, to get out and find out a few ideas here and there and see how other people are doing it, picking up a little bit here and there." In contrast, Esther remarked, "We don't really have a whole lot of opportunity to go out and see what other classes are doing.... It's not like you can just go over to another school."

Russell, reflecting on the knowledge and skills teachers need to teach the science curriculum, commented that teachers need, first and foremost, curiosity, but, "In a lot of conversations that I have with teachers now ... one of the comments is that they don't have the fun that they used to have teaching. And part of the fun is the childlike aspect of curiosity. And they can't afford the time anymore to be childlike. The emphasis is much more on being efficient and accountable."

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Exemplary professional development for Tanya would include, "times when we [teachers] got together....And sometimes it would be nice not to do everything in the evening or on the weekends, because we often have our secretaries and our administration people going out to workshops during the day, but not very often with the teachers."

Russell stated that the person organizing exemplary professional development should, "ideally, understand where the subject is coming from philosophically." Professional development should

> involve a lot more philosophical basis than content basis. And right now professional development revolves around content. ... Unless the teachers understand or have a philosophical position on why a subject exists and why it is being taught, it's not going to get done very well. It's going to get delivered. But it's not going to get delivered with excitement, conviction, or a sense of purpose other than passing an achievement test with suitable colours. ... And when we're studying China, what do you really want students to learn about China? Most of our professional development will be focused around, we have to teach China and here are the things that we have to teach about China and here are the resources that you can use to teach about China. So I think that in our professional development we're missing the initial step. Not that that other stuff isn't important, you have to know where the resources are that you're going to be using, et cetera, but it's a case of us constantly seeing the trees, but not seeing the forest. (CF4)

Knowledge Development

Because of geographical isolation and lack of school district-based professional development, it appears that the teachers in Clover School District frequently have to be quite proactive in seeking out professional development activities to enhance their teaching knowledge. The teachers' responses indicate that they saw their primary goal to be finding resources with lesson plans to teach the science content. Having purchased teaching resources, teachers believed they were in a better position to teach themselves the content they felt they needed to know to teach the topics. These are both examples of procedural knowledge development.

The teacher who had attended two ATA Science Council Conferences remarked that as she teaches the topics, she is figuring out "the sequence that makes sense," an indication of seeing interrelationships between propositions. She also reported gaining a

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better understanding of possible approaches for teaching the topics. Both these indicate a growth in principled knowledge.

Flax School District

Flax was the second rural school district visited for this study. While geographically smaller than Clover, there are more students and schools in this district.

In Flax, I visited schools in a small town and in a larger, regional centre. Lyndon (P11), principal of a small town school of 170 students, described himself as "a math and science type of person," having specialized in math for his education degree. He had taught for a number of years in kindergarten to grade 9 schools, mostly at the junior high level, and had been a principal at two schools before coming to McNeil School eight years previously. He was teaching grade 6 science at the time of the interview. Liz (T10), the grade 3 teacher and grade 1 science teacher in this school, stated that she had a very limited science background. However, being married to a person who was very science-oriented had helped her science teaching. "I find science a real challenge.... I'm getting better at it, but I don't do it easily." Despite being "terrified of all creepy, crawly things," she "was amazed" with herself and "those crazy meal worms." "I come to school and feed those darn things on the weekend."

Isabelle (P6), principal of River Crossing, a school of 425 students, had taught for six years before taking a vice principal position in her present school. At the time of the interview she had been an administrator in that school for 13 years. She thought science was one subject where students might "become responsible for what they're going to learn," thus learning to be more independent learners. Rosemary (T5), a grade 5 teacher and part time teacher-librarian, wondered if "we are getting to the point where a teacher has to have a good strong background?" Although she did not have a university background, she had gotten "to the point where I'm really enjoying science; it's like my favourite thing that I do during the day." But, she worried, "if we stipulate that the person who is teaching science has to have a certifiable background, I'd never have got here."

Davis (CF6), the Chief Deputy Superintendent for the district, had a number of responsibilities, including advising the district and schools on curriculum changes. Other

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major responsibilities included organizing meetings -- School Board meetings, principals' meetings, committee meetings -- and writing reports. In addition, he is principal of the district virtual school, an outreach kindergarten to grade 12 school, mainly "for kids that don't fit into the normal classroom today." He has a Master of Education degree in curriculum studies as well as a postgraduate diploma in education administration. He had been a teacher, mainly in the upper grades, a principal, and had "evaluated classes [in Alberta and Saskatchewan] K to 12, teachers as well as curriculum." All of his experience was in rural schools.

Asked about how the district dealt with curriculum change, Davis explained, "I just look at the new programs coming in. I'll attend, or more likely send a representative from the Division [to provincial curriculum information meetings] and gather materials and what's happening in curriculum. And then we'll distribute it to a committee [of school representatives] who then go back to their individual schools." When the *Elementary Science Program of Studies* (Alberta Education, 1996b) was introduced, the committee "looked at what changes there would be and how it influences how it is taught, the resources materials, i.e., not just the textbook. And the hands-on, practical experiences, that sort of thing."

Isabelle, the principal of the elementary school in the town where the district office was located, said that her school representatives attended a number of the meetings Davis had called to look at the new curriculum. Lyndon, principal of a school about an hour's drive from the district office, did not mention these meetings. He indicated, "There was not district level decision making on this. ... We did have one [professional development session] for all teachers where they had somebody come in and do a science thing – it wasn't a very good session, actually. It really wasn't geared to selecting certain kinds of resources or setting up a system; it was just something, a presentation on the new science."

Lyndon described a number of initiatives undertaken by his school staff to prepare to implement the new science Program of Studies. A representative of a publishing house had come to the school to give an in-service. "She brought all of the materials and we had a look at the materials." On another school professional development day, the staff sat down and asked, "How are we going to attack this new science program?" They

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decided to clean out a storage room and buy large plastic containers to store all the required science equipment and supplies. They then decided who would be teaching science and those teachers received some release time for planning and ordering equipment. Staff spent another half day deciding which teaching resources they would purchase. In addition, a rather large grade six class was split in half because, "We felt that science, being an activity type of a course, it's tough to do it with a big band of kids." After two years of teaching science to smaller groups of students, the school was planning to return to a whole grade six class the following year, because "the teacher is now feeling comfortable with it."

To teach science well, Lyndon thought that teachers needed to have an interest in the topic, and "I guess to have a better understanding, maybe a teacher would have to do a little background reading in there." Most of all, "you just have to be learning along with the kids. And once you teach it, you know it."

Isabelle described her staff's initial reaction to the new science program as one of panic; "It was something new and as teachers you don't like new stuff.... Having studied the program and discussed it, the next step was, 'Okay, we've got the curriculum, where are the materials [for the hands-on activities]?'" At that point they started to gather materials and develop topic-based kits. The teachers were displeased with the available teaching resources until the Edmonton Public School Board unit plans became available.

She reported that she felt it was her responsibility to provide funds for the purchase of necessary student supplies and to allow teachers to access professional development focused on teaching elementary science. She indicated that to teach science well, teachers needed to know the curriculum, to do a lot of planning, and to be knowledgeable about resources and materials available in the school and in the community. Cooperative teacher planning was a good way for teachers to build this knowledge in her opinion.

In addition to the two professional development days designated for Teachers' Convention and a professional development day organized by the local ATA teacher committee, this school district designated five Fridays during the school year for school-based professional development. School staffs set school goals annually, planned their professional development days, and forwarded these plans to the district office. "Then,"

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Davis said, "we make up a booklet [listing the professional development being pursued in each school on the designated professional development days] and it's given to all our schools. Anyone can attend these certain days… they can go from school to school."

Despite this booklet, Lyndon reported, "We really haven't done any real idea sharing. To be honest with you, I don't know what the other schools are doing in elementary science." Isabelle agreed; "In the past few years there hasn't been a lot of sharing."

The school district also funded two substitute days for each teacher to encourage the district teachers to pursue professional development. The staff at Lyndon's school had decided to allocate a further $500 per year per teacher for professional development activities. At River Crossing, teachers received up to $300 a year to cover professional development expenses.

Davis emphasized the role of experience in developing teacher knowledge, indicating that school districts must try to "make sure they [teachers] have materials that are accessible to them as well as people [colleagues] to work with." As well, both Lyndon and Liz from the smaller Twin Pines School mentioned the importance of experience. Liz explained, "I've learned a lot this year trying to stick to the whole new curriculum all year long. I've learned lots about time management. I think for a lot of it you just have to live it and really work through it and just see how it's going to fly." Teaching the science topics "is still an on-going process of, 'What do I need today?' I don't really have a whole unit plan in mind even yet. I kind of still go day by day." She also felt that the new science program had "certainly made me more inventive and creative" and "I've come quite far in my learning."

She reported the same initial response when the science program was introduced as Isabelle had mentioned – panic. She started ordering books from publishers such as Troll and Scholastic and gathering "handouts, reproducible things I thought might be useful for the kids. And then, after going to the Science Conference, I found – that's not what it is at all. We really need to throw away the paper and do this stuff. And that's been a real adjustment." Another valuable source of information for her were the contacts she made each year as she marked provincial grade three achievement tests with other grade three teachers. "Seven people sit around a table and mark them, so we get to

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be quite friendly over the week's time. I beg and people have been extremely generous sharing their unit plans with me.... We really scrounge. And I end up being quite envious of people in a bigger system, their readily available stuff."

Both of these teachers also believed that teacher interest and enthusiasm were very important in the teaching of science. Liz added, "And a willingness to try something new and different ... and a willingness to put up with the mess and the chaos and the noise level."

Exemplary professional development was described by Liz as "times when I do things ... And it has to be stuff that I think I could do in my classroom." Rosemary, too, talked of excellent professional development being, "Hands-on. Going and actually getting to work with materials and come home with ideas, really practical ideas on how to get something to work." Isabelle thought, "The best kind is somebody who will give you the meat of the subject, the basics, and then you go out and try it. Or you meet with people and you talk about it. ... Teachers need the time to sit down and chat and see how they can build up their units and their materials with what they have amongst themselves."

Knowledge Development

In Flax School District, the principals and teaching staff in both participating schools responded to the introduction of the *Elementary Science Program of Studies* (Alberta Education, 1996b) by reading this curriculum document and initiating a search for resources to support it. The teachers, through reading and talking with others, sought to increase their own content knowledge. As in many other school districts, teaching resources and content knowledge were the focus of the professional development for these teachers.

One teacher, Liz, however, talked about attending an ATA Science Council Conference where she was introduced to the idea that it was students doing science, not handouts and worksheets, that was central to this curriculum, an awareness on which to build principled knowledge.

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Conversations about Curriculum: Developing Professional Knowledge

An analysis of planned professional development experiences revealed considerable variation both across the province and within school districts. Furthermore, the planned professional development had focused predominantly on procedural knowledge development. Given this evidence, I wondered how new ideas about curriculum, and teaching and learning in science in particular, might be entering the Alberta education community.

Returning to the interview data, I looked for further indications of learning interactions that might have affected knowledge and beliefs about science teaching and learning at the time of the science curriculum change. As explained earlier, these interactions can be thought of as conversations, "in its largest sense … [involving] readers and writers as well as speakers and listeners" (Applebee, 1996, p. 40); that is, as conversations with 'others.' To learn more about the range of ideas about science teaching and learning being exchanged, I analyzed participants' reports of conversations according to whether their conversations appeared to be directed toward developing procedural knowledge, structured ways to proceed in the teaching of the mandated topics, or principled knowledge, the "key ideas and concepts that can be used to construct procedures" (Spillane & Zeuli, 1999, p. 4).

To make the changes required by the new science program of studies, teachers needed to develop new procedural knowledge. Were there indications, however, of educators also starting to inquire more deeply into why they were doing what they were doing (or being told to do)?

The reported conversations were certainly not the only ones held by the study participants about science education. They were, however, the ones readily recalled when participants were asked how they had prepared for the implementation of the revised elementary science curriculum.

In the remainder of this chapter I will describe the science education conversations each group of participants (teachers, principals, curriculum supervisors, university instructors, and science education service providers) reported on and the general topics of their conversations. This will help provide evidence of the information

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exchange within the Alberta elementary science education community and the knowledge being constructed through those conversations.

Teachers

Most of the science education conversations/interactions teachers reported fell into three categories: conversations with other educators, with resources, and 'with self.'

Eleven of the twelve teachers described conversations held with other teachers while preparing to teach the new science curriculum. The majority of these conversations were focused on the selection of teaching resources and student materials necessary for teaching science – a procedural focus. Four teachers from larger schools also described joint planning sessions with other teachers at the same grade level. Some of these planning sessions were procedurally focused -- dividing up the work preparatory to teaching the topics, planning when certain units would be taught, and writing common exams. Two teachers described working collaboratively with colleagues to write and pilot a teaching unit for a topic of study. As this involved reviewing various resources, choosing and adapting activities appropriate for students at their grade level, piloting and assessing lessons, and redesigning activities, these teachers were involved in activities developing principled knowledge.

Staff room conversations were mentioned, times when teachers brought questions they had about aspects of their science lessons for their colleagues' input. "We kind of discuss things in the staff room as to why this would work and this wouldn't work. Someone was questioning something written in one of those unit and we came to the conclusion that this particular piece of information was completely wrong" (T9). Here a specific example of content knowledge, procedural knowledge, was the topic of conversation.

Other reported conversations with school staff, including the principal, focused on choosing resources to meet the requirements of the Program of Studies and purchasing and storing student materials. Three teachers mentioned curriculum facilitators who were very helpful and always available to answer a variety of questions. As well, one teacher talked about her husband being an important source for her of information about and enthusiasm toward science.

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In teachers' conversations/interactions with resources, the predominant focus was again procedural. Five of the teachers talked about choosing books to teach themselves the content knowledge they felt they needed to teach the new topics of study. Catalogues and newsletters provided ideas about materials and experiments to try, again a procedural focus. Two teachers described critically reading the Program of Studies and teaching resources in order to choose activities that met the mandates of the Program of Studies and the needs of their students, a more principled questioning of curriculum materials.

Rosemary (T5) reported that the primary activity undertaken for her personal growth plan that year had been science related. She took the electricity unit, "made a list of the materials that we would need and got a hold of various supply houses and had them send us sort of one of everything. This let us actually get our hands on them and find out how things worked and then from there, order what we need for the class. And that worked really well. But that's on the practical side. I can't think of anything else in terms of going out and learning about different things."

The conversations 'with self' showed a wider diversity of topics. Several teachers mentioned evaluating their own background knowledge and thinking about how their own interests and experiences might be used in teaching the topics. James said, "Because my background in science was so strong… I looked at these grade three units and I *thought about them a bit* (italics added), … at what the intent of the curriculum was."(T9) Two other teachers expressed similar strategies, examples of moving beyond basic procedures.

Alice explained, "You have to get the information on your own …[and] if you plan your own unit it's a lot more beneficial. By doing your own preparation and your own background reading, and looking through the resources, and knowing what your SLEs are, and focussing on that, that's where you get all your information if you don't have it [already]. It's very much 'teacher teach thyself' before you can move on to the students" (T4).

In summary, teachers engaged in many conversations about science education with a number of different 'others.' An analysis of the interview data indicates that most of the conversations held by most of the teachers were focused on developing their procedural knowledge, answering their practical questions about how to teach the new

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science topics. There were only a few indications that new ideas about science pedagogy had entered these conversation, ideas capable of helping teachers become more aware of what was happening in their classrooms and more purposeful in their decision making (Baird, 1992).

Principals

Principals reported on considerably fewer conversations about curriculum than did the teachers. As well, two of the principals explained that in their schools the assistant principal, not the principal, was responsible for curricular issues.

Two principals and the teacher/principal described working closely as a staff on the implementation of the science curriculum. In one school that included reading the Program of Studies and developing checklists of the expected outcomes. In another, staff looked at available teaching resources and then decided on how to order and store student materials. Jackson (P8) cautioned his staff "to calm down, take it one step at a time" and lobbied his school district to produce instructional unit plans for teachers. Isabelle reported that her staff, after reading the Program of Studies and asking, "OK, we've got the curriculum, where's the material?" started building kits of student materials and searching for teaching resources. In all of these examples, the response was procedural, a search for the resources and supplies considered necessary for teaching science.

Five principals talked about their responsibility to help teachers by bringing professional development opportunities to a teacher's attention. They described encouraging teachers, "assisting, helping and providing them opportunities for growth" in those areas that the teachers themselves, or the principal and teacher together, had designated as priorities in the teacher's professional development plan. Marlene explained that, initially, teachers were interested in working "on very practical kinds of matters," developing basic teaching strategies and the resources to support those. "As a teacher develops, there may be a need to go beyond that, to go into a more theoretical area" (P10). Thus, principals may encourage teachers to engage in professional development activities that have a procedural or more of a principled focus depending on their analysis, and the teacher's, of productive professional development.

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Principals generally did not talk to other principals about curriculum. Principals' meetings were described as being focused on 'policy things.' Principals suggested that opportunities existed for setting up subcommittees to examine curriculum issues more closely; however, none of the principals reported sitting on any such curriculum subcommittee. One principal said she simply calls colleagues when she has curriculum questions. It was not clear whether the very limited number of principal-to-principal curriculum discussions referred to ever moved beyond a procedural level.

The two major conversations/interactions reported on between principals and school district personnel were both procedural in focus. In Currant School District, "the Principal Association worked with our central office, seeing if we could find industry partnerships" (P2) to help fund the preparation of kits containing the student materials necessary to teach the new science curriculum. And, as reported above, Jackson strongly advocated the preparation of written teacher resources. It appears that principal-to-district conversations, as with principal-to-principal conversations, about curriculum were quite limited in number.

Principals also mentioned that part of their job included "being on the lookout for resources" for teachers, print resources related to teaching the curriculum topics. The print resources in the principals' own offices were predominantly contained in binders with administrative titles on their spines, suggesting that limited school time was spent reading professional literature of a pedagogical nature.

The most common response by principals to the issuance of the revised science curriculum is summed up by one principal's statement that "We've tried to leave the ownership [of the curriculum] as much as we can with the teachers and then be the facilitators for them for what they need" (P9). Principals did not appear to spend any appreciable amount of time on curricular conversations, and the interactions with curriculum they did have appeared to be predominantly procedural in focus.

Curriculum Facilitators

Reflected in their job title is the curriculum facilitator's responsibility for curriculum matters and for 'facilitating' that curriculum. To accomplish this, the six curriculum facilitators interviewed for this study referred predominantly to

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conversations/interactions with curriculum documents, with Central Office staff and colleagues, with teachers, and with resources.

All of the curriculum facilitators received provincial curriculum documents as part of their school district administrative role. All read those documents. However, just as their curricular responsibilities varied widely, so did the focus of their curriculum reading. Mary and a committee of lead teachers "took a look at the philosophy of the program. We took a look at what we know about how children learn science – the learning theory and that kind of thing" (CF2). A similar exercise was conducted with all the teachers in the district. Ken took a similar approach, although on a far smaller scale.

At the other end of the spectrum, Davis, with limited funds for professional development and a wide range of administrative responsibilities, generally sent a representative of the district to curriculum briefing sessions to "gather materials and what's happening in the curriculum. And then we distribute it to a committee who then go back to their individual schools" (CF6). From their statements, only Mary and Ken appear to have focused on more than procedural aspects of the elementary science curriculum documents, while the other four curriculum facilitators focused on more procedural aspects, ways to inform or help teachers implement a science program obviously intended to be hands-on rather than textbook-based.

In their conversations with Central Office staff and colleagues, the curriculum focus was equally diverse. Mary reported attending "regular department meetings where we share what we're doing, what's current in our areas and so on. We also have a Supervisor of Elementary Education and a Supervisor of Secondary Education and part of their responsibilities is to coordinate and to look for some of the commonalities, instructional strategies and those kinds of things" (CF2). As well, the subject area supervisors regularly shared research articles they thought would be of interest to colleagues. In these ways, they shared both procedural and principled knowledge. Being supervisor of a staff of 13 school district employees, many of Constance's collegial conversations were administrative in nature, as were those of Russell and Davis whose administrative duties are outlined in the chapter on school districts. Another deterrent to collegial conversations was being the only, or perhaps one of two, curriculum facilitators in the district. As there were no formal channels in the province for sharing curricular

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information, concerns, and questions with others having similar curricular responsibilities, some curriculum facilitators were very isolated from collegial curriculum conversations. The opportunity to collectively develop principled understandings about curriculum was, thus, negligible.

In their interactions with teachers, with the exception of Mary and Ken, conversations appeared to have been mainly limited to giving advice or providing in-service sessions with a procedural focus.

Four curriculum facilitators reported that part of their job entailed the review of resource materials and making judgments about whether to recommend these for use in district classrooms. "You preview resources and see if there is a curriculum fit, it teaches good science, it's interactive, and it's at a level that children can manage. ... It narrows down the selection process for the teachers, so they're not using up their time" (CF5). As well, Constance reported that part of her job was "trying to deal with the vendors of the different software or the different books so that they're not at every school, because the principals don't have time" (CF1). From their brief descriptions, I was unable to determine the focus of their interactions with resource materials.

These were not the only curriculum conversations referred to by curriculum facilitators. Three facilitators mentioned occasionally attending a science education conference. The few conversations held with principals about science curriculum matters appeared to be procedurally focused. In discussing reading that had influenced their thinking about curriculum, only Mary referred to professional journals and articles related to science education.

In summary, the interview data indicate that four of the six curriculum facilitators participated predominantly in science curriculum conversations with a procedural focus following the release of the current *Elementary Science Program of Studies* (Alberta Education, 1996b). For two of the curriculum facilitators this was due to curriculum being a minor aspect of their administrative responsibilities. For the other two, the provision of teaching resources or student materials was the focus of district efforts to help teachers implement the new elementary science program.

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University Professors

Two university instructors teaching elementary science education courses were interviewed. Their conversations about elementary science curriculum matters can be categorized predominantly as those with colleagues, with other educators, with printed material, and with university students.

Curriculum conversations were held mainly with colleagues teaching at the same university in the same faculty and with colleagues while attending conferences. "There's a little bit of gossip, of course, who's going where. But we also raise issues and talk about concerns and there seem to be very similar concerns across Canada" (U2). Neither instructor reported on curricular conversations with science education instructors at the other provincial universities. "Within Alberta, not really," was the response of one of these professors. Thus, few science curriculum conversations were held with colleagues other than "the people down the hall" (U2).

Few conversations with science educators in elementary schools and at the school district level were referred to. One participant, located in the same city as the provincial Department of Education, reported that being friends with several program managers in the curriculum branch made it easy to call them with questions about the curriculum. This person, as well, had attended a few Alberta Education Elementary Science Advisory Committee meetings when the curriculum was being drafted and had spoken to the need for a conceptual framework to provide a sense of continuity to the program. As this contribution was made at the end of the curriculum revision process, "it was far too late" (U2).

Far more conversations were held with printed resources, with books and journal articles advancing theories and principles of teaching and learning in science. Participants talked, in particular, about the need for "being very familiar with constructivist literature in science" and the implications that had for science education. As well, both mentioned a knowledge of the nature of science and the history and philosophy of science as being fundamental to a principled understanding of science.

Both expressed a professional responsibility to introduce theories of science education to their university students, the "philosophical points behind the process of

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knowing and what knowledge is" (U1). "Unfortunately, recent hiring trends show that those students haven't been able to work themselves into the classroom. So our message has stalled because of hiring within the province" (U2).

Thus, interview data indicate that in their offices and in their classrooms, university instructors engage in conversations with a principled knowledge focus. Similar conversations are held with colleagues at conferences. However, few conversations of this type are held with other science educators across the province.

Service Providers

The final group of study participants were those who, working outside the school districts, offered a science education related service -- professional development, speakers, and/or teacher resources and student materials. Three of the five service providers were knowledgeable about the details of the *Elementary Science Program of Studies* (Alberta Education, 1996b) and their curricular conversations will be reported first. Art (SP1), a science teacher for 18 years, had been seconded by an Alberta organization to provide teacher professional development and work with schools on various science-related projects. Florence (SP2) was the Student Outreach Coordinator for a professional organization interested in science and technology education. Ruth (SP3), an engineer with Cheber, a chemical corporation, was the liaison person between her corporation and Current School District, responsible for helping that school district develop hands-on science instruction.

The approach to service provision taken by this group of three can be summed up in the words of one of the participants: "Bottom line – they [the teachers] have got to teach. How can we help them do that better?" (SP1). The answers all three gave were heavily focused on helping teachers procedurally.

All three mentioned meeting with or speaking to representatives from Alberta Education, a higher proportion than found in the other groups of study participants. The focus of these conversations, according to a provincial curriculum writer, was generally procedural in nature, an exchange of information about specifics in the program of studies.

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Conversations helped service providers better understand the science education needs expressed by teachers. Their perceptions were that teachers' needs were procedural in nature, but each of the three stressed a different aspect of these perceived needs. In his conversations with teachers, Art had found that teachers wanted to learn more about approaches to teaching the new inquiry and problem-solving though technology units. To this end, workshops were organized that guided teachers through a unit, "showing them activities they can do in their classrooms and a process they can use," as well as providing them with "hints of making it easier, to downgrade the amount of work they have to do in this particular subject area" (SP1).

Florence talked more about teachers needing to develop their content knowledge; for her, "A very telling question that I think speaks volumes came from an elementary teacher who called me up a number of years ago saying she did this experiment and she explained to me, 'You know, it didn't work and I don't know why it didn't work and I can't tell the children why it didn't work. Can you let me talk with someone who can explain this to me?' That to me indicated, because they are teaching very basic science, that there wasn't an adequate level of understanding of the science concepts" (SP2).

In her capacity as the industry representative in a school district-industry partnership, Ruth's focus was on the provision of student materials. "The cornerstone of the program is a resource center that furnishes kits and circulates them out to the teachers. ... The primary vision for the team is resources that match the curriculum" (SP3). Thus, helping teachers develop an understanding of content knowledge, lesson procedures and activities, and providing student science materials were viewed as being of primary importance to the implementation of the new hands-on science curriculum -- all procedural knowledge.

Conversations with colleagues had either initiated or subsequently reinforced the ideas these service providers had about teacher needs and ways that teachers might be helped to teach science. Thus, Art spoke of discussions at his institution about how to help teachers "imagine how this [the new science program] could happen in their class" (SP1). Florence said that one of her volunteers who had done professional development workshops for teachers had reported that it was "kind of a frightening experience to learn that the teachers are so ill-prepared to teach science" (SP2); this is, teachers were lacking

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the necessary conceptual knowledge to adequately teach a science topic. And when Ruth met with colleagues working on similar projects for Cheber in other North American sites, they would talk about their successes in helping teachers through the provision of teaching resources and student materials.

While Art and Ruth mentioned some contact with local school districts, none of these three mentioned meeting with other private sector science education service providers outside their own organizations. Florence reported: "One of the things I'd hoped would come out of the Science Alberta Foundation would be a connection of the groups, so there would be more collaboration in programs. But that has never come and I've come to think everyone wants their own little turf" (SP 2).

For all three, conversations with resources centered on evaluating these resources for how well the activities outlined in each fit with the specific learner expectations in the science program. There was no report of critically looking at the pedagogical or philosophical stance of the resource.

The other two individuals in this group of participants I have called service providers held positions with a broader mandate than science education. One of them, the Executive Director of one of the six provincial regional professional development consortia, explained that "Our mandate is to provide quality professional development in four primary areas – technology being one of the main areas, special needs being a second area, curriculum and new curriculum development the third area, and school-based decision making and school council development the fourth area." "We've done some work in the science area, but not a lot. We'd like to do more in that area ... with respect to what resources will be available and so forth and how teachers can access those resources" (SP4). However, as "the number one area identified for professional development in the province right now is the use of technology [computers] in the classroom," the regional consortium was focusing its efforts and funds on developing a professional development program on this topic.

The directors of the regional consortia "meet approximately four times a year for planning, to make sure we're on the same wave length. ... If there's a criticism, a constructive criticism, one might have, it's that the six consortia have not been coordinated in such a way that they would take a specific focus in a certain area" (SP4).

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Thus, there was no mechanism to assure that any one of the six consortia would develop any sort of professional development program for enhancing teachers' procedural and principled knowledge following the release of a new program of studies.

The remaining participant in this group was an Alberta Teachers' Association (ATA) employee in the professional development program area of that organization. Asked about the professional development offered by the ATA following the release of the *Elementary Science Program of Studies* (Alberta Education, 1996b), Lucy explained, "The Association doesn't do any specific curriculum workshops, because we don't have the staff to do that. ... Also, there's a political feeling that it is the government's responsibility to provide in-servicing for their curriculum, especially when they change them so rapidly and there are so many at once" (SP5).

Lucy, surrounded by books on professional development, explained :

> Most of the research says if you're going to do professional development, you should do it in an over time, sustained way rather than smorgasbord, a little bit of this, a little bit of that. And the very best way to implement change is then to have teachers practice change in their classrooms. (SP 5).

She added, "There are many different ways to do professional development rather then just going to a conference or having a workshop. There's reading, doing a study group, watching another person's classroom, doing some team teaching, looking at videos and talking about them, ...many inexpensive ways" Ways, too, that help teachers extend their thinking about teaching and learning beyond the immediate practical, procedural knowledge necessary to implement a program of studies.

Thus, one of the most knowledgeable study participants about the development of principled teaching practice was not involved in curriculum matters. The other service providers focused on the teachers' immediate procedural needs – resources, supplies, and a process to follow in the teaching of hands-on science.

Summarizing Curriculum Conversations

At the cross-provincial level, interview data indicate the occurrence of only a limited number of elementary science curriculum conversations. A number of participants (none of them teachers or principals) mentioned contacting and speaking to Alberta Education curriculum developers as the elementary science program of studies

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was being written and following its dissemination to the school districts. Provincial curriculum developers also spoke at Science Council Conferences and, when invited, to groups of educators. The nature of these conversations was reported to have focused on information about and orientation to the program of studies, a procedural focus.

The Alberta Teachers' Association, a province-wide body representing teachers and principals, did not have the funding for, nor did it define its role as, developing subject-specific curriculum knowledge. Subject specialist councils with the ATA have assumed a role, however, in such knowledge development. The Science Council holds an annual conference where attendees are offered a variety of workshops and presentations that introduce procedural and/or principled knowledge about science education. Two teachers, both from rural school districts, reported attending Science Council Conferences. Three of the six curriculum facilitators also said that they had occasionally attended a Science Council Conference, as did two of the science education service providers. Conference programs indicate that the majority of the sessions related to elementary science were procedurally focused on presenting ideas for activities related to specific learner expectations.

Regional ATA Teachers' Conventions also provide a context for curriculum discussions. Two teachers mentioned attending sessions on science curriculum topics, but none mentioned talking to colleagues about science education while attending one of these annual events. Several participants did talk about these conventions as useful sites for viewing vendors' displays of print resources and student materials.

I interviewed school personnel located in four of the six provincially-financed professional development consortium areas. The head of one of these consortia reported that there was no real coordination of efforts between consortia to provide professional development related to elementary science. In only one school district did anyone mention attending a session devoted to science education offered by the local consortium.

Other than through personal contacts, curriculum facilitators across the province were not in contact with each other. This was true, too, for university science education professors.

From this, I conclude that there was no provincial plan for developing knowledge about teaching and learning in elementary school science beyond the procedural level.

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The ideas that were introduced at the provincial level on elementary science education were generally procedural in nature and conversations reported in the interviews having the potential to enhance that procedural knowledge with a theoretical underpinning were limited in number.

Conversations held across school districts were reported in some detail earlier in this chapter. Briefly, principals held very few conversations with other principals about curricular matters and only a limited number with district curriculum facilitators. In the two rural school districts, the curriculum facilitator was responsible only for the dissemination of curriculum documents to schools; distances and funding precluded the provision of most professional development. Elm School District produced teaching unit plans for each of the mandated topics and Currant School District provided teachers with kits including teacher resources and student materials for doing hands-on science activities. In-service sessions offered by these two school districts focused on how to use the teachers' manuals or science kit, procedural information.

In Gooseberry School District, teachers were invited to join small groups of teaching colleagues to write unit plans for other teachers in the school district to use. In Spruce School District, all teachers were required to attend a series of professional development sessions. In both of these school districts, topics introduced by the curriculum facilitator and some of the teachers enhanced both procedural and theoretical knowledge. Teachers also spoke with teachers from other schools, increasing the possibility of an exchange of ideas and thoughts on teaching and learning in science.

It was within schools, between teachers and sometimes teachers working together with the principal, that science curriculum conversations most frequently occurred. These discussions were predominantly procedural; there appeared to be only a limited number with a theoretical, inquiry focus.

Stability

A review of the education and employment backgrounds of the participants revealed substantial stability, possibly furthering limiting an infusion of new ideas into science curriculum conversations. Ten of the twelve teachers had received their teaching degrees from an Alberta university and nine of the twelve had always taught in the same

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school district. Only one teacher reported having taken university courses since completing a Bachelor of Education degree.

Eight of the eleven principals had received a teaching degree from an Alberta university and six had also completed a Master of Education degree, four of them from an Alberta university. Three of these advanced degrees were in Educational Administration. Ten of the eleven had always worked in the same school district. A similar pattern was seen for curriculum facilitators: four of the six received teaching degrees from an Alberta university and five of the six had always worked in the same school district. All six had completed or taken courses toward a Master of Education degree, three in Educational Administration, and four from an Alberta university. Both university professors had taken all of their degrees in Alberta and had taught only in this province. The majority of the science education service providers were also educated exclusively in Alberta and had also always worked in Alberta.

Stability, of course, need not limit conversations to procedural matters. However, this stability was paired with few references to either reading about or being introduced to new ways of thinking about science education.

Summary

Currently, teacher professional development literature emphasizes the importance of establishing "cultures of collaboration" (Hargreaves, 1992) and "a culture of continuous inquiry" (Lieberman, 1996), collapsible into "cultures of collaborative inquiry." Such a 'reculturing' (Hargreaves, 1996) did not appear to be happening for most of the study participants.

Instead, faced with an immediate need to locate resource and student materials for teaching the revised, mandated science Program of Studies, a majority of the educators in this study focused their attention on learning more about basic curriculum requirements and related resources – procedural knowledge. Conversations about elementary science education introduced at the district level having the potential to enhance procedural knowledge with a principled underpinning were limited in number. Within schools, science curriculum conversations appear to have been equally procedural in nature.

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There appeared, thus, to be only a limited number of conversations introducing alternative conceptions of teaching and learning science into the dialogue.

Educators reported enthusiastically welcoming the arrival of teaching resources and student materials closely matched to the learner expectations stated in the science curriculum. The most popular teachers' guides (produced by one of the urban school districts in the province) are composed of discrete lesson plans for doing hands-on activities. Both teachers and students follow "predetermined steps to compute correct answers" (Spillane & Zeuli, 1999), an end at odds with the inquiry emphasis stated in the *Elementary Science Program of Studies* (Alberta, 1996b) and currently espoused in many science curriculum documents (AAAS, 1994; CMEC,1997; NRC, 1996).

Principled knowledge, insights and theories that suggest different approaches to teaching and to thinking about teaching and learning in elementary science, is continually being advanced in the field of science education. This knowledge can inform and be informed by practice to the extent that it enters educational conversations. There is little to suggest from the interview data that this commonly occurs in many of the school districts and schools in Alberta.

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CHAPTER SIX

AN EXEMPLARY SCIENCE LESSON

The Program of Studies

As reported earlier, in Alberta **what** science should be taught in elementary schools is presented in the document *Elementary Science Program of Studies* (Alberta Education, 1996b). Although this document outlines the attitudes, skills, and knowledge to be developed by students and suggests an inquiry approach, just **how** this is to be accomplished is left to the discretion of the school districts. In the following section I will discuss how participants in this study described exemplary science lessons in elementary classrooms, a concept developed in Chapter Three.

Teaching a Science Lesson – Patterns of Instruction

Study participants were asked to describe what they believed to be the most important elements of an exemplary science lesson. They were asked, in addition, to describe the teacher's role in such lessons; that is, what they thought a teacher would do before, during, and at the conclusion of an exemplary science lesson. From their responses, participant views of the course of an exemplary science lesson were interpreted as falling into one of three patterns.

Although there were distinct differences of opinion about specific elements of instruction to be found in exemplary science lessons, there were also broad areas of agreement about what such a science lesson would look like. The participants were unanimous in describing science lessons where students worked with materials, hands-on, to explore and investigate science phenomena. Students were also described as commonly working together in small groups and being encouraged to discuss their observations and ideas with each other. The teacher acts as a facilitator, generally guiding students as they work, "moving from group to group, offering suggestions, asking questions about how things are working." (P3)

Acknowledging these similarities, in the following pages I will describe and illustrate each of the three different patterns of instruction that emerged from the data

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with statements made by the study participants. These patterns I have named Pattern A, Pattern B, and Pattern C.

Pattern A

Observing a Pattern A lesson, it would be apparent that the teacher is firmly in control of the direction of that lesson. William's (T1) description exemplifies such a teacher. William was teaching grade six and science to a grade three-four class at the time he was interviewed. He had received a Bachelor of Education degree with special education and language arts as his specialty areas. In his more than 20 years of teaching, he had taught special education classes at the upper elementary and then at the junior high level. While teaching in a junior high school, he was asked to teach a grade eight science class and continued teaching science for the next five years because "I guess I just accepted more science as I was having fun with it and I enjoyed it." After five years at the junior high level, he returned to elementary school teaching, and had been at his present school for six years at the time of this study.

Prior to teaching a lesson, William stressed the importance of "the planning, the organization, the having it all together. It's really essential to have this activity lab be able to go click, click, click." William explained that in introducing an activity:

> I believe in a brief overview so the students know what the whole thing is, where we're going, a focus and that's the term I use. ... I go in and say, 'Here's our focus. Get this down. This is what we're aiming at. This is what you will come out of it with. This is what I want you looking for.'... Then continue with the overview, what the expectations are in how they'll be spending their time, in what they'll be doing....What is going to happen here while we're doing this. This is what's going to happen. I really find that not just useful for me, but very useful for the kids. It's been my experience that children are just like people, they like to know what's going on, and why they're doing it. (T1)

One curriculum facilitator expressed a similar view, "I think the teacher starts by leading her students. 'Today this is what we're going to learn. This is what we're going to discover. This is what is going to happen.'" (CF1) A second curriculum facilitator stated it this way; "She [sic] has to be very clear, this is the concept that I want the children to come out with ... And go through the lesson with the kids, 'You know, you can expect to see this, be prepared.'" (CF5)

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Thus, in focusing a Pattern A lesson, a teacher poses a question and then outlines a procedure for students to follow to answer that question. The objective of the lesson is for students to discover through their investigation a designated scientific concept; for example, "light travels outward from a source and continues unless blocked by an opaque material" (Alberta Education, 1996b, p.B.21).

During the lesson, the teacher is involved in 'monitoring and reminding' students. William described his procedure, "We get into it fairly quickly even if it's going to be necessary to stop periodically for more explanation or instruction or question period ... Usually there's a stop in the middle of it where we're catching up, getting more stuff down on paper." Lyndon, a principal, explained it as, "You're basically a facilitator, going around making sure everybody's got the instructions correct, they're interpreting everything correctly. Making sure they're doing their recording. Kids get excited and forget about the paperwork you have to do with it. Make sure they're doing that." (P11) Similarly, "While they're going through the activities, supporting, checking, making sure they're staying [on task], they're recording their finds and that they're handling the materials as intended." (T5)

At the conclusion of the lesson, in the section of the lesson referred to as Reflect and Interpret in the science Program of Studies, teachers focus on what the students had done and how well that had "worked." It appears from the data that an investigation is seen to have "worked" if it, in the teacher's estimation, clearly demonstrated the designated science concept. Ascertaining whether the students understood the scientific concept being illustrated by the investigation could be accomplished in a variety of ways. William's grade six students nearly always handed in a written report on their investigation. "Their total mark comes from what they put down on paper. ... The communication process is a big part of it."

Another teacher explained, " We write in a journal or we write up a formal science experiment or sometimes just notes – we record something and come to some sort of a conclusion. We discuss our results so that – in any normal classroom there are always some kids who are doing the experiments and not quite getting out of it what they should be and they aren't really drawing the conclusions." (T7) As well, "At the end, you culminate it with taking your information, asking what did we learn, what worked,

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what didn't work. Is this the true answer or did it just not work because something wasn't put together right?" (P3) A second principal described it as, "After the lesson is over? Wrapping it up and making sure that the students understand the concepts that they've been covering, the conclusions that they needed to draw. Again, facilitating it and instructing if they [teachers] see that it's needed, that students haven't picked up all the things that they need to know." (P5)

In summary, a Pattern A lesson is distinctly teacher directed. In this approach to science instruction, prior to teaching a science lesson, teachers select an activity and a set of procedures deemed highly likely to lead students to the discovery of a designated science concept. In introducing the lesson, teachers pose a question for students to explore and carefully explain the exploration procedure. During the lesson, teachers monitor and remind students about how to proceed, and at the end they make sure students draw the correct conclusion. These structured activities are viewed as appropriate for helping students learn the proper process skills for carrying out scientific investigations and develop a specific body of scientific knowledge.

Pattern B

As previously explained, teachers in Alberta have a science program in which the specific science concepts they are expected to teach are listed. Given this reality, few educators advocated opening science classes up to any topic students identified as personally interesting or relevant. They did, however, describe an approach different from that for Pattern A.

In this approach, the teacher may still introduce the question to be explored, but students are given greater latitude in seeking ways to answer that question. This was generally referred to as setting the scene or creating a situation for an investigation. "I see myself as creating situations for events to occur, ... setting the scene and then letting them go off and do things." (T6) "The kids have to understand what you want them to do.... And they have to kind of feel free to get this stuff [student materials] and use it. And that they aren't just rigidly bound by your thought -- that their thought processes are allowed." (T9) Somewhat less open, a professional development provider remarked that

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students should be given opportunities to come up with questions and "design, to a certain degree, the experiments that they'll carry out." (SP1)

Others described lessons where the teacher introduces a broad topic of study (e.g., liquids) and encourages students to ask personally relevant questions related to that topic. In introducing the topic, the teacher has not decided in advance the particular aspects of a topic to be investigated in a lesson or set of lessons. "An important element in a science lesson is finding ways to help kids answer *their* questions." (P10, emphasis added) As above, students are expected to plan, or help plan, ways to explore and find answers to at least some of the questions they have posed.

During the lesson, the teacher's role was described as that of "a facilitator, going around checking on progress, checking on learning, on procedure." (SP1)

In the end, teachers "ensure that the outcomes or the important parts of the lesson or activities are documented by the student in preparation for provincial exams or whatever assessment vehicle you might be using." (SF1) Thus, while students are to be given some freedom in planning and carrying out an exploration, it appears they, at the end, are expected to reach a predetermined conclusion, to come up with the specific scientific knowledge outlined in the program of studies and tested for in provincial exams.

Pattern C

Pattern C lessons open in a very similar way to those described in Pattern B. That is, the teacher introduces a topic or a question to guide student exploration, but students are given some choice in how they will proceed to answer the question or investigate the designated topic. "The teacher's job is to translate an inherent interest of the children into an issue of some sort… The teacher's role is in determining the interests of the children and encouraging the interest of children…. The teacher's job is to present them with an interesting problem, preferably based on something that they're very familiar with and they've never really thought about as a problem." (CF4)

During the lesson, the teachers' interactions with students were seen to be of a guiding nature, supportive of student initiative. Teachers were not primarily focused on ensuring that students were following a set of instructions. As described by one teacher,

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> You're paying really careful attention to what the kids are doing and you're listening to their talk. And you are asking questions, because that's very often the way to keep them on task, is by asking the kind of questions that will lead them to the thinking that they need to be thinking to find an answer to their question. But one wonderful thing about working with children is that when you start out with a lesson you have a clear idea of how your lesson is going to go, the questions that you're asking, the procedure that you're going through to find the answer, and how it should turn out. And because children are children and they don't know how you've written this lesson down, they make all these incredible discoveries that you've overlooked. (T3)

Another teacher said,

> You may be going around just looking at what children are doing and you may want to suggest something to them or you may just want to leave it. And if something isn't working out, then you would be asking the child if they can think of why it isn't working out. And then making some suggestions of what they can do. But I personally try not to interfere that much when they're doing it. I want them to see what's happening. (T9)

A principal added that guidance and support needs to be active:

> I think the teachers have to be there, to be watching for when it is becoming a frustrating experience to the point that it is not productive anymore. When is it productive? When do you need to provide a little guidance? When do you perhaps have to stop and provide a little demonstration? When do you have to do some pushing? In a class of 30 you have to be able to be reading and watching every student and knowing what kind of support to provide. (P2)

As well, the importance of watching for and being receptive to teachable moments was commented on by several of the participants, including Constance, the curriculum facilitator for Currant School District. " If we're being respectful of the dynamic of the classroom and things that really happen, we have to be prepared to take a little side step and explore those areas...being prepared to go on, you know, to the next step if it looks promising or to stay and dwell on something." (CF1)

The Reflect and Interpret stage of a lesson was explained as a time to help students make sense of the data they had gathered during their investigations. The educators espousing a Pattern C approach did not appear to presume that students would have, or, in the view of some, even should have come to a single conclusion during their investigations. As expressed by one of the university science educators:

> The fact that you can have one group create one understanding in the classroom and another group create another understanding for the same event and hold up those two different views as exemplars to the rest of the students and say, 'This is

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> wonderful that we've now got two different ideas. Now how do we decide as a group which one we're going to take and go with?' (U1)

One teacher described it as a time for students to "reflect in a science log kind of thing what it was that they did, what did they learn, what kind of questions do they still have about it that we could answer." (T11) Mary, the science supervisor for Spruce School District, said,

> I would like to see visual organizers being used, opportunities for them to concept map, that kind of thing. And why I say that is because I see that is really important for them later on in linking ideas together.... We need to be helping our elementary kids with, how do these ideas all link together? How do they make sense? (CF2)

In summary, in a Pattern C approach the teacher gives students some freedom in posing questions and planning their own investigations, supports and guides students during the activity, and helps students make sense of their investigations at the end.

The effort involved in teaching in such a fashion was commented on by Liz, a grade three teacher in Flax School District.

> I think it's my job to make sure that I get Amanda there who is not with us most of the time. Can she get something out of this? Does she have any idea what's going on? I think it's my job to make sure that everyone gets a little bit out of it. And so that means walking around, checking groups, checking this. You know, I think it's a very busy class. And sometimes I truly just get played out and it's easier to plunk in a video. (T10)

While the elementary science instruction described by the study participants had certain similar characteristics, there was a discernible difference in participants' views pertaining to the teacher's role, ranging from descriptions of the teacher as director to the teacher as an encourager of student creativity in asking and answering science-related questions.

Phrases Describing Each Pattern of Instruction

To analyze the participants' descriptions of exemplary science lessons, key words or phrases were designated for each pattern. A participant's use of these terms indicated support for one of the three patterns.

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Pattern A

For inclusion in this category, a participant indicated that a teacher would initiate a science lesson with a clear statement of goals and procedures. By the conclusion of the lesson, students should have learned "it," the science concept predesignated by the teacher.

Pattern B

I describe this as the "funnel" pattern. Proponents of this pattern indicated that students should be given some freedom in posing questions and planning investigations, as in Pattern C. The conclusion of the lesson, however, was similar to that described in Pattern A – students would be helped to come to "the conclusion that they needed to draw." (P5)

Pattern C

Participants placed in this category indicated that students should be given some freedom in posing questions and planning investigations intended to gather data to answer their questions. Discussions about their conclusions were held to help students make sense of this data. There was no obvious emphasis on developing prespecified knowledge.

A set of the participants' pattern-indicating statements is located in Appendix H.

Summary

This analysis indicates that beliefs about the teacher's role (and consequent student actions) in an exemplary elementary science lesson varied considerably among study participants. (See Table 1.) Only a minority of the study participants (those advocating Pattern C instruction) talked about elements of inquiry science -- science instruction involving students in creative, reflective, iterative science activities -- when describing an exemplary science lesson. Additionally, if, as the literature indicates (Briscoe, 1996; Haney et al., 1996; Yaxley, 1991), teacher beliefs have a strong impact on how teachers teach, many elementary school students in Alberta experienced science activities that were hands-on, but limited to what Tafoya, Sunal, and Knecht (1980) labeled confirmation and structured-inquiry.

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Not all science instruction will, or even should be, science inquiry (National Research Council, 2000). However, there is considerable agreement in policy statements (AAAS, 1994; CMEC, 1997; NRC, 1996, 2000) that students need to regularly engage in scientific inquiry if they are to develop the understandings and habits of mind referred to as scientific literacy, the primary goal of the literature addressing the issue of why science should be taught in schools today.

The table on the following page also graphically confirms a study finding regarding professional development: there is only limited consensus being developed in most school districts (and across the province) related to science teaching practice.
As one principal remarked, "We've tried to leave the ownership as much as we can with the teachers and then be the facilitators for them for what they need" (P9).

Table 1 illustrates the pattern of exemplary science instruction described by each study participant who answered the questions in enough depth for his or her responses to be analyzed. Pattern data are arranged by school district or profession.

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Table 1: Patterns of instruction described as exemplary by study participants.

Jurisdiction	Curriculum Facilitator	Principal	Teacher	Other
Spruce S.D.	CF2	P7 P10	T4 T11	
Elm S.D.	CF5	P4 P8	T3 T9	
Currant S.D.	CF3	P1 P9	T6	
Gooseberry S.D.	CF1	P2 P3	T12 T1	
Clover S.D.	CF4	P5	T2 T7 (T/P)	
Flax S.D.	CF6	P6 P11	T5 T10	
University				U1 U2
Provincial Curriculum Writer				CW
Science Service Providers				SP1 SP2 SP3

Participants are designated by the prefixes CF (curriculum facilitator), P (principal), T (teacher), U (university faculty), CW (curriculum writer) and SP (science service provider; e.g., provider of science professional development and/or resources). The combination of prefix and number identifies individual participants (see list of participants, Appendix B). The shape enclosing the identifier indicates the pattern of instruction described as exemplary by the participant.

	Shape	Example
Pattern A		SP2
Pattern B	none	T4
Pattern C		P7

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PART III

CLARIFYING THE PROBLEMS

AND

RECOMMENDING FUTURE DELIBERATIONS

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CHAPTER SEVEN

DISCUSSION

> We may be conscious that a practical problem exists, but we do not know what the problem is. We cannot be sure even of its subjective side – what it is we want or need. There is still less clarity on the objective side – what portion of the state of affairs is awry. These matters begin to emerge only as we examine the situation which seems to be wrong and begin to look … for what is the matter. The problem slowly emerges… (Schwab, 1978, p. 290).

I have written previously about the role conversations with "others" can play in stimulating thought and action. Joseph Schwab is one of my valued "others," a person who has suggested interesting, alternate ways of considering situations. John Dewey has served the same function. So, while thinking about the emerging problems, I returned to Schwab – and Dewey – rereading an article Schwab had written about Dewey and "The 'Impossible' Role of the Teacher in Progressive Education" (1959).

In contrast to merely being interesting (my former reaction), this time I found Schwab's discussion to illustrate both a desirable goal and a problem – the level of intellectual space in which students and teachers commonly function.

Schwab's interpretation of intellectual space is described below. This is followed by my translation of his language into terms I could use for interpreting the study findings, the topic of the remainder of this chapter.

Schwab, Dewey, and Intellectual Space

Explaining Dewey's concept of Pragmatic Intellectual Space, Schwab (1959) wrote that the first level of intellectual space involves "a mastered pattern of action to an end;" this, he contended, is unsatisfactory because "no two situations are precisely alike; single, rigid patterns of action will not continue to master situations" (p. 150).

To be able to master a variety of problems and situations, we need "flexible ways of acting, modified steps and alternative sequences," activities of the second level of intellectual space. And although this is a "marked improvement," because "we have not yet noted why certain actions were effective, others not" we remain "too responsive to the flux of materials and events; too little its master." To fill this gap, we must move to the third level of intellectual space, "the first level in which reflection appears….At this

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level, we take note of connections between different things done and different resulting consequences.... Thus reflection provides us with tested means by which to meet similar situations in the future and with alternative aims by which to guide the use we make of these situations."

However, even at the third level we remain "too chained to the past," unable to respond flexibly to problems if they are very different from ones we have dealt with in the past. If we wish to prepare for problems "instead of waiting on them," we must "invent a new form of organization which binds our bits together as coherent knowledge of some extensive part or aspect of the world.... The end is knowledge; the instrument is an instrument of enquiry....This is the activity of experiment and research" (pp. 150-151).

In abbreviated form, Schwab described this as:

First level of intellectual space
The activity: Mastery of problematic situation
The outcome: A way of acting in each such situation

Second level
The activity: Sensitive mastery of variable problematic situations
The outcome: Flexible ways of acting in each such situation

Third level
The activity: Reflection on actions and consequences
The outcome: Knowledge organized as tested ends and means

Fourth level
The activity: Reflection on ends and means; deliberate pursuit of experience
The outcome: Knowledge organized for pursuit of further knowledge

To help guide my evaluation of the emerging problem as a case of levels of intellectual space, I translated Schwab's language into the following descriptions.

Levels of Intellectual Space in Teaching

First level of intellectual space
Activity: Teacher finds a teacher's guide that 'covers' the mandated curriculum and appears 'doable.' (Major focus: mastery of a problematic situation – a lesson for teaching each mandated knowledge Specific Learner Expectation)
Outcome: A procedural way of acting in each such lesson

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Second level

Activity: Teacher assembles an extended set of activities and procedures for teaching the mandated curriculum outcomes. (Major focus: better activities for teaching the mandated knowledge Specific Learner Expectations)

Outcome: Flexibility in presenting lessons focussed on Specific Learner Expectation concepts

Third level

Activity: Teacher plans and carries out "systematic, intentional inquiry" (Lytle & Cochran-Smith, 1992) focused on lesson effects on student learning. Teacher reflects on actions and consequences (classroom experiences and student learning).

Outcome: Knowledge organized as tested actions and consequences. Heightened awareness of teaching and learning interactions and of a variety of teaching approaches and strategies with potential for enhancing student learning

Fourth level

Activity: Teacher reflects on ends and means, critically assesses curriculum goals, and plans instruction aligned to reasonable curriculum goals for his or her students.

Outcome: Better teaching based on warranted justification. Knowledge organized for pursuit of further knowledge.

For students, I interpreted intellectual space as:

Levels of Intellectual Space in Learning

First level of intellectual space

Activity: Students follow a given procedure to prove a predesignated science fact or concept. At the end, students receive a Correct Explanation.

Outcome: A procedural way of acting in each such lesson

Second level

Activity: Students seek answers to teacher-set questions or problems in a variety of ways. At the end, students receive a Correct Explanation.

Outcome: Awareness that there are a number of different ways to come to a single explanation

Third level

Activity: Students plan and carry out science inquiries and gather data. Students discuss evidence and conclusions.

Outcome: Knowledge organized as tested action and consequences.

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<u>Fourth level</u>
Activity: Students reflect (individually and collectively) on actions and consequences, evaluating the knowledge claims they have generated.
Outcome: Heightened awareness of nature of science and "big ideas" in science. Knowledge organized for pursuit of further knowledge.

The concept of inquiry being developed in current science education literature is very similar to the activity Schwab described as occurring in the third and fourth levels of intellectual space. Thus, the theory of intellectual space offered me a means of interpreting my findings. Concomitantly, it helped me identify "the desirable" (Schwab, 1978).

A Desirable Goal and Problem Identification

Schwab (1978) wrote about both the identification of problems and "the desirable" emerging out of an examination of a "situation that seems to be wrong" (p. 290).

Similarly, Greene (1985) observed, "We are only likely to bring values into existence in our experience when we identify a deficiency in an action or a situation, and we are unlikely to identify deficiencies if we are not able to imagine something like an ideal possibility" (p. 20).

The concept of intellectual space allowed me to imagine and name an ideal possibility, a desirable goal, and, at the same time, to characterize a set of problems.

The desirable, the ideal possibility, I have identified is support for students and teachers to commonly operate in the third and fourth levels of intellectual space. With the identification of a desirable goal, a realization of the problems, the barriers to the attainment of the desirable, co-emerged. I will now present those problems: problems with the science teaching practice commonly described as exemplary, problems with the professional development offered to educators, and problems with curriculum intents.

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Problem:

Participant-described exemplary science lessons involve students predominantly in the first and second levels of intellectual space

As explained in Chapter Six, participants' descriptions of exemplary science lessons fall into three patterns with those patterns differentiated primarily by the degree of freedom participants indicated that students should be given in designing investigations and interpreting results. Instruction in only one of these patterns, Pattern C, resembles the exemplary science lesson outlined on pages 59-60, a description drawing on current science education literature (e.g., Bloom, 1998; Duckworth, 1987; Hodson, 1998; Reardon, 1996). However, only a minority of the study participants described as exemplary a Pattern C-type science lesson. Indeed, many of the constituents of exemplary elementary science lessons advanced in current literature (for example, taking children's ideas and interests into account in planning science activities and actively engaging students in planning, carrying out, and interpreting the results of their scientific inquiries) were not mentioned by most of the educators and professional development providers interviewed.

When I interpreted the patterns using Schwab's (1959) theory of levels of intellectual space, I saw a close parallel between the three patterns discerned in the data and the levels of intellectual space outlined by Schwab. Pattern A was not just an approach to teaching science; it could also be described as a set of activities operating in the first level of intellectual space. In such Pattern A/Level 1 lessons, teachers choose an activity that they think will illustrate one of the concepts contained in the Program of Studies. Students follow teacher-designated procedures in order to demonstrate and "prove" a scientific fact or concept. In Pattern B, as in the second level, students are given more opportunity to investigate a question or problem in their own way; that is, teachers encourage more flexible procedures. However, in the end, students are expected to come to the same conclusion as students working within the first level of intellectual space; i.e., acceptance of "the right answer." Only in Pattern C lessons are students encouraged to plan and carry out science inquiries with the concluding discussion focused on making sense of the data collected, not on "the right answer" students should have discovered. This is similar to the third level in that students are expected to reflect

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on their actions and consequences in order to organize their understanding of those tested ends and means.

Instruction that consistently occurs in the first two levels of intellectual space does not engage students in the types of scientific inquiry described in either the literature on scientific literacy or that on teaching science. Scientific inquiry, as I wrote previously, does not refer exclusively to hands-on investigations. Like practicing scientists, students need to learn new procedures and develop background knowledge. However, I argue that only when lesson sequences help students plan and carry out investigations, take "note of connections between different things done and different resulting consequences" (Schwab, 1959, p. 150), and deliberate on the possibilities raised in their inquiries can they be categorized as inquiry-oriented. Such lessons engage students in the third, perhaps fourth, level of intellectual space. Even flexible procedures, those employed in the second level of intellectual space, in Pattern B lessons, fail to promote the ways of thinking Kuhn (1993) described as critical to meaningful science education. Nor are students likely in Patten B/Level 2 lessons to develop those habits of mind considered a major goal for science education in current science education literature (Atkins & Helms, 1993; Hodson, 1998; Jenkins, 1992; Millar, 1996) Furthermore, students consistently operating in the first and second levels of intellectual space in their science lessons (Pattern A and B lessons) are not being offered the experiences necessary to achieve the scientific literacy goals outlined in the reviewed literature and policy statements, Canadian, American, and British (AAAS, 1993, 1994; CMEC, 1997; Millar & Osborne, 1998; NRC, 1996).

There is, then, a problem, if students in Alberta are predominantly engaged in science lessons described by the study participants as exemplary because such lessons are unlikely to develop the scientific literacy and scientific thinking skills envisioned in the literature. The problem: such science lessons involve students predominantly in the first and second levels of intellectual space.

The knowledge base necessary to teach such lessons, as seen in Chapter Three, makes the teaching of exemplary science almost "impossible" (Schwab, 1959) for the generalist elementary school teacher. If teachers are expected to teach science in such a

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fashion, studies indicate (e.g., Appleton & Asoko, 1996; Neale, Smith & Johnson, 1990; Summers & Kruger, 1994) that many teachers will need to be offered a variety of professional development experiences to further develop their science teaching knowledge base.

I now turn to the professional development findings. Using the criteria of levels of intellectual space, I discuss the adequacy of the professional development offered to teachers in the two years following the release of the revised elementary science curriculum. As well, I suggest a possible contributing factor for the predominantly procedural focus of the available professional development described by the study participants.

Problem:

The available professional development involved teachers predominantly in activities in the first and second levels of intellectual space

As indicated in the literature review in Chapter Three, teaching science is a complex endeavour. Because of this, learning to become a better teacher of science is itself complex; teachers may need to be involved in activities where they can learn more about science inquiry lessons and are encouraged to initiate and reflect on inquiry-based instruction, taking "note of connections between different things done and different resulting consequences" (Schwab, 1959, p. 150), activities located in the third and fourth levels of intellectual space. Through such activities, teachers can develop the principled knowledge necessary to analyze and adjust instruction to "promote comprehension among students" (Shulman, 1987, p. 8).

The professional development interview data analyzed in this study indicate, however, that in the two and a half years following the release of the *Elementary Science Program of* Studies (Alberta Education, 1996b) many educators were not engaged in professional development activities operating in the third and fourth levels of intellectual space, activities most likely to help these educators develop a principled knowledge of science instruction. A further consideration of principled knowledge and its connection to levels of intellectual space may help clarify these points.

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Principled Professional Development

O'Haire and Thomas (1988) differentiated "technical" professional development which "provides pedagogical recipes, hints, or tips that can add to a teacher's skills of delivery .... [where] teachers come to know the 'facts' and become able to use their knowledge capably and efficiently" (p. 9) from "critical" professional development. Activities in the latter are geared "to generate a reflective understanding of teaching practice .... [involving] unlimited inquiry, constant critique and fundamental self-criticism" (p. 10). This distinction is similar to the one I make between procedural development (operating in the first and second levels of intellectual space) and principled professional development (operating in the third, fourth, and perhaps fifth levels of intellectual space).

This distinction is important because the level of intellectual space teachers occupy affects their ability to offer educative experiences (Dewey, 1938/1963) to their students. As Schwab (1959) observed

> It is not enough for the teacher to master certain ways of acting as a teacher. This is only a capable apprentice. It is not enough to be master of flexible ways of acting. This is only to be a competent "hand" who can function well when told what to do but who cannot himself administer. It is not even enough to possess organized knowledge of ways and means. This is to interpret a policy and tend to its efficient execution but not to be able to improve a policy or change it as problems arise.
>
> Only as the teacher uses the classroom as the occasion and the means to reflect upon education as a whole (ends as well as means), as the laboratory in which to translate reflections into actions and thus to test reflections, actions, and outcomes against many criteria, is he [sic] a good "progressive" teacher.
>
> Meanwhile, he must be a teacher too. As a teacher, he must aim to carry all his students to the third dynamic of intellectual space, some to the fourth, and be alert to find those few who may go still farther. (pp. 158-159).

What I am labelling principled professional development does not fall neatly into any one particular concept of professional development. It includes aspects of craft knowledge development (Grimmett & MacKinnon, 1992): "the construction of situated, learner-focused, procedural and content-related pedagogical knowledge through 'direct action'" (p. 393) as well as *inquiry as stance* (Cochran-Smith and Lytle, 1999): teachers generating "local knowledge of teaching, learning, and schooling when they make classrooms and schools sites for research, work collaboratively in inquiry communities, and take critical perspectives on the theory and research of others" (p. 18). The goal is

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development of the "high level of abstract and rationalized knowledge required for successful performance of work in the professions" (Rowan, 1994, p. 12), knowledge most likely expressed, as Fenstermacher (1994) described it, in "commonsense language."

Principled professional development focuses on "*learning from experience* as theory and practice interact, and [on developing] a *professional community* to monitor quality and aggregate knowledge" (p. 516, emphasis in original), two of the attributes Shulman (1998) named as characteristics of all professions. It is aimed at promoting better teaching where the teacher knows more about teaching, is more aware of actions and consequences in the classroom, and "is more purposeful in the pedagogical *decisions* that he or she makes" (Baird, 1992, p. 33). Developing such knowledge involves teachers in classroom inquiry, in level three and four activities.

The numerous studies I reported on in the review of the professional development literature were chosen because they collectively indicate that professional development is not easy. The message from this literature is that short term professional development can help teachers build skills; for example, learn how to teach an activity or to group students. In contrast, "teacher development focused on deepening teachers' understanding about the teaching/learning process and the students they teach" (Darling-Hammond & McLaughlin, 1996, p. 203) involves teachers in sustained inquiry into and reflection on teaching practice – activities in the third and fourth levels of intellectual space.

Teachers do, of course, need to develop procedural knowledge. Regularly receiving new curricula they are mandated to teach, teachers need immediate answers to such questions as, "What am I supposed to teach?" and "How can I teach this topic or concept to my students?" But answers to such procedural questions, while they help initiate teaching, will not necessarily lead teachers to the development of better teaching practice; that is, enhanced capability of evaluating and adjusting their teaching to meet student needs. Instead, teachers at the procedural level (the first and second levels of intellectual space) resemble the teachers Reardon (1996) described as "hard working and committed to teaching the weather unit well…. [but] who measure their success as science teachers by how well they and their students follow the [teacher's] guide" (p. 16-

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17). Here it is the author or authors of the published guides who are making the pedagogical decisions, not the teachers. The professional development currently receiving attention in the literature has a different goal; it is intended to help teachers themselves be thoughtful pedagogical decision makers in their classrooms (Darling-Hammond, L.& McLaughlin, M.W., 1996; Lieberman, 1996; Lytle, S. L. & Cochran-Smith, M., 1992).

If teachers are to be decision makers, learners "even unto the fourth level of Dewey's intellectual space" as Schwab (1959, p. 182) deemed necessary, the professional development offered to teachers in this study was far from adequate – there was a problem. This I will illustrate with examples of professional development taken from the interview data.

Professional Development in Alberta School Districts

Assuming, with Schwab (1959), that the level of intellectual space in which a teacher operates is an important factor in student learning, I returned to the data on professional development offered by school districts looking for indications of the intellectual space being supported through that professional development.

First, the two rural school districts did not offer centrally-planned professional development; nearly all professional development monies were sent to the schools to fund site-based decisions. The role of the curriculum facilitator had become one of curriculum information disseminator, not a planner or provider of professional development. The latter functions were left to schools or to the teachers themselves.

The teachers and principals interviewed reported that their efforts had been mainly directed at the gathering of resources and materials for teaching the provincially mandated student outcomes and on developing their own content knowledge. As these activities are located in the first and second levels of intellectual space, I conclude that teachers were not being offered support to develop "systematic, intentional inquiry" (Lytle & Cochran-Smith, 1992) or "reflection that illuminates the processes of learning and development" (Darling-Hammond & McLaughlin, 1996, p. 203), professional actions that help teachers make informed judgements to enhance student learning.

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Elm School District, one of the urban districts, offered a fairly extensive series of professional development sessions generally focused on how to use the teacher guides the district had produced, first level activities.

Currant School District, a suburban district, had constructed kits to help teachers teach hands-on science. There were, however, very limited funds available for professional development. Constance, the curriculum facilitator, was of the opinion, though, that "each kit is almost like having an in-service in itself"(CF1).

Spruce School District was distinctly different from the other participating school districts as this urban district had funded the professional development their curriculum specialists deemed necessary. Through professional development activities, teachers were supported to the second level of intellectual space and presented with ideas that could serve as topics for inquiry in their classrooms, leading them into the third level of intellectual space. This professional development process did offer one set of teachers activities in the third level. In their collaborative curriculum development projects, the lead teachers engaged in "systematic, intentional inquiry" (Lytle & Cochran-Smith, 1992) as they analyzed teaching resources, selected promising activities, used these activities in their own classrooms, and reflected on the adequacy of the lessons for developing desirable student learning.

The language used by Alice, one of the lead teachers, expressed how fulfilling she had found this directed inquiry to be; she had been excited, challenged, and thrilled while engaged in selecting activities and in "presenting it to the kids and seeing what works and what doesn't." It had been, she declared, "the highlight of my last five years or so" (T4). It is this kind of enthusiasm that has been described in other studies (for example, Baird, 1992; Barnes, 1992; Woodrilla et al., 1997) as necessary to sustain teacher interest in classroom inquiry.

This district, too, was organizing schools into clusters to encourage inter-school dialogue and was designing ways of introducing new ideas gained from professional literature into teacher conversations, activities which can help support teacher inquiry at the third level of intellectual space.

The curriculum facilitator in Gooseberry School District engaged a limited number of teachers in a unit writing exercise rather similar to that just described for the

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lead teachers in Spruce School District. I did not, however, sense in my interviews in this district the level of excitement in the unit writing exercise expressed by Alice. The close collaboration between Alice and her colleague, both teaching at the same school, may have been an important element in sustaining their inquiry and enthusiasm.

It was just this collaborative element, being part of a group, Kathy, a teacher in Gooseberry School District, distinguished as being central to her commitment to study and reflect on events happening in her classroom. The collaborative action research project she was involved in had been encouraged and funded by the principal. This funding allowed teachers to schedule meetings during school hours for collaborative planning and then for reporting to their project colleagues the results of their intentional inquiry. Here there was evidence of teachers moving into the fourth level of intellectual space, collaboratively reflecting on ends and means and using these discussions to plan further studies in their classrooms.

Thus, I found examples of professional development that supported teacher action in each of the four levels of intellectual space considered in this study. Data indicate, however, that few teachers were supported by four of the six school districts in this study to move beyond first and second level intellectual space activities. As indicated in the literature (Martens, 1992; Watters & Ginns, 1996), activities at these levels have not been found to help teachers develop appreciably "better teaching" practice in science. With Schwab (1959) and Darling-Hammond and McLaughlin (1996), Lieberman (1996), and Lytle and Cochran-Smith (1992), I argue that effective teaching, teaching focussed on providing educative experiences for students, requires teachers to be thoughtful pedagogical decision makers in their classrooms. There was, then, a problem with the professional development offered educators in this study if "better teaching" (Baird, 1992) or teachers as thoughtful decision makers is considered an important aim of professional development.

There were, undoubtedly, a number of reasons for the types of procedural/ level one and two professional development offered educators in this study. In the following discussion I will focus on one factor I have identified as possibly contributing to the lack of support in Alberta for principled professional development (that is, for professional

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development involving teachers in activities in the third and fourth levels of intellectual space) – namely, a bureaucratic approach to education.

A Bureaucratic Approach to Education

In an article on educational accountability, Darling-Hammond (1989) described a number of mechanisms that policymakers have used to try "to ensure that students learn" (p. 59). "It is easy," she wrote, "to see that legal and bureaucratic forms of accountability have expanded their reach over the past twenty years" (p. 62). Such a bureaucratic approach to education, Darling-Hammond maintained, is based on a number of assumptions, one being that "schools are agents of government that can be administered by hierarchical decision making and controls. Policies are made at the top of the system and handed down" (p. 63). These policies are viewed as unproblematic to implement and "if the outcomes are not satisfactory, the final assumption is that the prescriptions are not yet sufficiently detailed or the process of implementation is not sufficiently exact" (p. 63).

She outlined a number of other bureaucratic assumptions and practices based on these assumptions:

- "Teachers are viewed as functionaries rather than as well-trained and highly skilled professionals. Little investment is made in teacher preparation, induction, or professional development."
- "Because practices are prescribed outside the school setting, there is no need and little use for professional knowledge and judgment."
- "Teachers do not need to be highly knowledgeable … because they do not, presumably, make the major decisions."
- "Curriculum planning is done by administrators and specialists; teachers are to implement a curriculum planned for them. … and testing policies handed down to them." (p. 64).

Others have described this problem in a similar fashion, but have referred to it in somewhat different terms. Some have referred to the deskilling of teachers while others have used metaphors such as teachers as technicians and teaching as labour (Wise,

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Darling-Hammond, McLaughlin & Bernstein, 1985). In Wise et al.'s definition, those holding this view see a teacher's job as one of responsibility for implementing standardized instructional programs using "concretely determined and specified" effective practices, adherence to which, it is assumed, will "produce the desired results" (p. 65).

Gilbert (1994) described this as a "functionalist" view of education where "teachers are thought of as 'technicians' who have developed certain (specifiable) skills. These skills are defined in terms of their (perceived) capacity for the production of certain (predetermined) learning outcomes in students (Cobb, 1993). ... Teacher professional development is conceptualized as a process of 'training' teachers in such a way that they develop certain skills to a certain (pre-set) level of expertise" (p. 513).

Although Darling-Hammond (1989) was writing about the United States, examples of educational policy and procedures in Alberta were immediately recognizable as fitting her description of a bureaucratic approach to education. I now briefly discuss examples that I encountered while seeking to better understand the Alberta situation.

First, the title of the plan providing "direction for the future of education in Alberta" (Alberta Education, 1994b, p. 2) gives an indication of the provincial perspective on education: *Meeting the Challenge: Three-Year Business Plan.* The introduction starts with the statement, "Quality education for our young people is key to maintaining Alberta's standard of living and ensuring our competitiveness in a global economy" (p. 3), an economic goal. To deliver this quality education, "it is vital that we have the most efficient and cost-effective education system possible" (p. 3). Furthermore, "effective measurement and reporting of outcomes are critical to improving the quality of education for our children" (p. 3). The plan also addresses "education delivery" and the necessity for the education system to be accountable for ensuring that students meet high achievement standards.

The report continues, "Key to restructuring education is effective school-based decision-making. To achieve this, a number of actions are required, including a clear understanding of the roles and responsibilities of various levels in the education system" (p. 18). Among the roles assigned to the Department of Education is the responsibility to "establish clear provincial policy direction, goals, standards and measurements," to

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"establish and communicate clear learning expectations and standards," and to "conduct on-going assessments and evaluations of students and the education system" (p. 19). Among the list of school responsibilities are listed: "following the provincial Program of Studies" and "meeting provincial achievement and performance standards" (p. 18). The "Three-year business schedule for restructuring education" is reproduced in Appendix I.

The language and view of education used in this document are very similar to those Darling-Hammond (1989) used to describe a bureaucratic approach to education; that is, schools are seen to be agents of policies handed down by the government and teachers are implementers of curricula and testing procedures prepared by others.

Government responsibility for writing curricula, setting standards, and examining students, however, comes from an older document, *The School Act* (Province of Alberta, 1988 version), which states "the Minister may by order ... prescribe courses of study, including the amount of instruction time, and authorize education programs and instructional materials for use in schools; ... adopt or approve goals and standards applicable to the provision of education in Alberta ... [and] may make regulations ... respecting the examination and evaluation of students" (p. 19). (Actions principals and teachers *must* take are also listed in this policy document.)

A limited investment in teacher professional development for teaching the new science curriculum by the province and by many of the school districts in this study can be viewed as being in accord with such statements. If it is the "effective measurement and reporting of outcomes" that is critical to the improvement of educational quality, funds spent on engaging teachers in principled professional development not focussed on assessment and reporting might be seen to be an inefficient and ineffective way to improve education. Furthermore, provincial policy statements indicate that the role of teachers is to follow programs of study and "the school's primary responsibility is to ensure that students meet or exceed the standards defined by the provincial achievement assessments" (Alberta Education, 1994b, p. 6). A primary responsibility to meet provincially-set standards on provincially written and mandated achievement tests is a clear example of what Darling-Hammond (1989) referred to as a view of teachers "as functionaries, rather than as well-trained and highly skilled professionals" (p. 64).

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Greene (1985), too, spoke to teaching and "effectiveness": "The preoccupation with effectiveness (almost always linked to test scores and results) obscures the signal differences between teaching and training… teaching [is a] deliberate or intentional action on the part of a person committed to helping others act in an increasingly informed manner on their own initiatives" (p. 22).

As stated earlier, the Business Plan strongly advocated school-based decision-making. To this end, the province placed a cap of 4% of their budget on the amount school districts could spend for central administration, again exemplifying a view of schools as "agents of government that can be administered by hierarchical decision making and controls. Policies are made at the top of the system and handed down" (Darling-Hammond, 1989, p. 63). Participants in several school districts (see the studies of the school districts detailed in Chapter Five) described how an increase in school-based decision-making and budget cuts to administrative funding had led to a decrease in consulting services and an increase in the work load of those remaining in Central Services, including that of the curriculum facilitator. Whether emanating from a view of teacher as functionary or from limited funding, the result was similar: few teachers in this study had been provided with the support needed to help them further develop their science teaching practice in the third and fourth levels of intellectual space.

Rather, my data indicate that professional development in the two and a half years following the 1995 release of the revised elementary science curriculum involved teachers predominantly in activities located in the first and second levels of intellectual space. That, I maintain, is a problem if teachers are expected to be professionals as defined in the literature (e.g, NRC, 1996; Rowan, 1994; Shulman, 1998) or even to meet the provincial Quality Teaching Standards that state, "Teaching is an activity characterized by professional judgment and decision making" (Alberta Education, 1995c, p. 18). Professional judgment and decision making require teachers who operate in the third and fourth levels of intellectual space. To do so, professional development that supports them at these levels must be readily available.

Thus far I had determined that the exemplary science lessons described by many of the study participants would likely involve students in science activities located in the

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first or second level of intellectual space; that is, students would be following procedures rather than engaging in science inquiry.

There was, as well, a problem with professional development as this appeared to be frequently limited to developing teachers' procedural knowledge of ways to act in specific situations; that is, teachers were being supported in developing practice only within the first two levels of intellectual space. Seldom did the described professional development involve teachers in third and fourth level inquiry.

Were there, I wondered, indications in the Alberta elementary science curriculum documents that science education should involve students in inquiry activities in at least the third level of intellectual space? However, here, too, I found problems, the subject of the next section of this discussion of the situation that appeared to exist in Alberta.

Problem:

Curriculum guidelines place a limited emphasis on science inquiry

My analysis of curriculum guidelines – of the *Elementary Science Program of Studies* (Alberta Education, 1996b), provincially authorized materials, and the provincially-prepared elementary science testing materials – offers an insight into how these materials may have influenced the participants' views of science teaching. This analysis of curriculum intent as revealed through curriculum emphases convinced me that educators could certainly justify a belief that provincial curriculum guidelines place a dominant emphasis on Correct Explanations (Roberts, 1982, 1998), on students learning canonical science. As so few of the educators in the study had been involved in professional development that introduced other goals and inquiry teaching approaches, the assumption that only the method of transmission, from textbooks to hands-on activity, had changed could also be justified.

However, science education aimed predominantly at transmitting Correct Explanations is not in accord with scientific literacy goals outlined in either the science education literature or major policy guidelines reviewed for this study. Therein lies a problem.

As was indicated in the literature review, science education writers are advocating giving elementary school children "lots of experience *doing* science" (AAAS, 1993, p. 4,

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emphasis in original), and involving them in a range of inquiry activities (NRC, 1996) as a means for developing scientific literacy. Through such experiences, students are believed to construct "the basic representations and concepts on which a more sophisticated understanding of science and technology rests" (Millar & Osborne, 1998, p. 2008). In terms of intellectual space, science education that engages students in constructing concepts through active engagement in *doing* science inquiry encourages knowledge development in the third or fourth level of intellectual space depending on the degree of reflection and evaluation in which the students and teacher engage.

Some will argue that the development of Correct Explanations is an important goal of science education. Rather than arguing for or against such an emphasis, I maintain that it is more productive to focus on the intellectual space in which Correct Explanations are constructed. If scientific literacy is the goal, a recurrent theme in the literature related to that topic is the necessity for students to learn to use scientific knowledge, not just accumulate it (e.g., AAAS, 1993, 1994; CMEC, 1997). To learn to use knowledge or skills (including intellectual skills) in the sense outlined in the scientific literacy literature, students must engage in activities that necessitate a flexible use of scientific knowledge and habits of mind. That is, if the ability to use knowledge or intellectual skills flexibly is the goal, procedural activities, those located in the first and second levels of intellectual space, are inadequate as they lead only to an ability to use knowledge or skills in similar circumstances.

Reconsidering the dominant emphasis on Correct Explanations in the Alberta science curriculum documents using these criteria of intellectual space and scientific literacy goals, a problem was revealed: the procedural level of intellectual space suggested by the lists of specific learner expectations, the provincial test items, and activities in many of the authorized teaching resources suggested that.

If development of an *understanding* of designated science concepts is the educational focus, not rote learning, how and to what degree of specificity a concept is to be developed is a very important consideration. That is, it is important to ask if students are being given procedures to follow and "the right answer" at the end, a first level approach, or if they are expected to investigate a science phenomenon, gather data and

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rigorously discuss their conclusions (with "the right answer" perhaps offered for consideration), a third or fourth level approach.

Too Many Specific Learner Expectations

The number of specific learner expectations in the *Elementary Science Program of Studies* (Alberta Education, 1996b) contributes to this problem. As discussed in Chapter Four, the large number of mandated specific learner expectations limits the amount of time available for inquiry into science topics. Because inquiry requires a considerable amount of time, educators faced with the task of teaching many science concepts may decide that an inquiry approach is clearly impossible. The 2061 science project team, advocates of inquiry science, wrote, "Teaching should take its time" (AAAS, 1994, p. 207). The Canadian science curriculum framework writers called for engaging students "in active inquiry, problem solving, and decision making" (CMEC, 1997, p. 8). These process again take time – time that is unavailable if too many concepts are mandated to be taught.

Several study participants (teachers, principals, and curriculum facilitators) commented on the number of topics teachers were required to teach and the difficulty teachers have teaching the full program. To illustrate this problem, the mandated student learning expectations for the grade four topic Plant Growth and Changes (the unit with the fewest learner expectations of the three, grade-four topics I analyzed) are reproduced in Appendix F. The question is, how much time would be needed for students to develop this knowledge in at least the third level of intellectual space? Based on plant investigations I have done with grade four students and with university students, I maintain that knowledge development in the third level of intellectual space would require considerably more time than that allotted for this one topic of study.

Not only are there many learner expectations listed in the program of studies, many of them are also quite specific. (For examples, refer to Appendix F.) A reasonable teacher reaction would be to teach the learner expectations through a procedural approach, particularly since lessons located in the first and second levels are the most common approach in the teaching resources I reviewed. It would be equally reasonable to assume that the inquiry emphasis stated in the Program of Studies refers to selecting

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hands-on activities that illustrate and confirm science concepts, again a first or second level approach.

As well, because the provincially-prepared test items are predominantly focused on specific facts rather than broader conceptual understandings developed through inquiry, it would again appear reasonable to direct one's teaching at transmitting the specific facts and concepts outlined in the Program of Studies through carefully directed activities, a first or second level approach. This is, indeed, the approach I noted to be widely described as exemplary by study participants. This is of concern as it suggests that many students may be consistently operating in the first or second level of intellectual space in their science classes. As a consequence, students are unlikely to be engaged in experiences assumed necessary for achieving the scientific literacy goals outlined in current literature and policy guidelines.

A further contributing factor to this problem is the conceptual difficulty of some of the mandated science concepts.

Difficulty of Concepts

A growing body of research (reviewed in Chapter Three) indicates that some science concepts are more difficult for children to understand than others and that conceptual difficulty should be taken into account in curriculum planning.

Judged by this research, a number of the concepts in the 1996 Alberta elementary science curriculum would be considered difficult for children at the age mandated for topic study. An acknowledgement of this is found in the teachers' guide for *Explorations in Science* (Campbell et al., 1992), "The concepts involved in the study of light are not easy for children to understand. Students who are given opportunities to explore freely the properties of light, however, will find an understanding of the underlying principles easier to come by" ("Light Moments," p. 3). Subsequent suggested teaching techniques include direct teaching and drawing "students toward the conclusion" (p. 10). Inquiry appears to be curtailed in order to ensure students end up with a Correct Explanation, this being an example of procedural instruction.

A combination of too many concepts and too difficult concepts complicates any teacher's desire to engage students in inquiry science. As Gabel, Keating, and Petty

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(1999) wrote "appropriate instruction might help eliminate children's reliance on memorizing science and instead build appropriate foundations based on reason" (p. 15). Appropriate instruction to build foundations involves inquiry, a consideration of alternatives, and why certain alternatives are better than others. This takes time – time that is not available when a teacher must "cover" many different and difficult concepts.

In the end, the combination of many and too difficult specific learner expectations and the bureaucratic approach to education leads me to conclude that the overarching provincial elementary science curriculum intent is the transmission of Correct Explanations measurable by standardized testing. Of peripheral interest is the development of inquiry habits of mind and an understanding of the nature of science, important scientific literacy goals outlined in science education literature and policy guidelines.

The End of This Examination

The concept of intellectual space helped me name a desirable goal for both science education and professional development and to interpret the data I had collected. Identification of a problem and the desirable is, however, but the first phase of a longer process. As I explained earlier, I undertook this study believing that curriculum-based research in Alberta could produce findings of potential use in future provincial policy deliberations and professional development planning. Next, through an "interplay of ends and means, of problem, data, and solution" (Schwab, 1978, p. 290), consequences, costs, and feasibility need to be deliberated on in order to "choose, not the *right* alternative, for there is no such thing, but the *best* one" (p. 319, emphasis in original). This second phase is beyond the scope of my study. However, based on the problems I have identified, in the next chapter I offer a set of recommendations for deliberations intended to lead to the *best* alternatives for elementary science education in Alberta.

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CHAPTER EIGHT

RECOMMENDATIONS

In comparing my findings to recommended practice in both the science education and professional development literature, I detected the existence of a problematic situation. Interpreted in terms of intellectual space (Schwab, 1978), problems existed in the situation I had examined in that activities related to science education engaged in by both teachers and students appeared to be predominantly procedural in nature. That is, these activities did not seem to encourage on-going inquiry and reflection on evidence and conclusions, level three and four actions. Specifically, I concluded that

- the science lessons described by the majority of the study participants as exemplary would involve students predominantly in activities located in the first and second levels of intellectual space,
- the professional development available in the school districts in the study had involved most of the teachers predominantly in activities enhancing their procedural rather than their principled knowledge, and
- provincial curriculum guidelines restricted the provision of inquiry science lessons.

I consider bureaucratic accountancy to be a major contributor to this problematic situation in Alberta. However, given the popularity of the present government, the one that initiated the three-year business plans, I do not believe a direct challenge to provincial educational policy to be the best action to take at the present time. The following recommendations, therefore, do not focus on bureaucratic accountancy. Rather, I suggest that deliberative processes be undertaken to address the problems detected in this study in order to develop alternative considerations of potential value in future revisions of the Alberta elementary science program of studies and for engaging teachers in educative experiences.

As deliberation is central to all three recommendations, I will start with a brief description of my understanding of this process.

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Deliberation

Schwab (1983) wrote that deliberation is "an alternative to the pattern of debate, a process in which all pool their ingenuities, insights, and perceptions in the interest of discovering the most promising possibilities for trial, rather than forming sides, each of which look only to the strengths of a selected one alternative" (p. 255). Such deliberation, he had explained earlier, "is not at all a linear affair proceeding step-by step, but rather a complex, fluid, transactional discipline" (Schwab, 1978, p. 291) where "the desirability of each alternative must be felt out, 'rehearsed,' by a representative variety of all those who must live with the consequences of a chosen action" (p. 319). Furthermore, deliberation

> treats both ends and means and must treat them as mutually determining one another.... It must generate alternative solutions.... It must then weigh alternatives and their costs and consequences against one another, and choose, not the *right* alternative, for there is no such thing, but the *best* one (pp. 318-19, emphasis in original).

Margaret Asch, a prominent Edmonton community activist, explained the importance of this method in somewhat different terms: "It's the process that counts, damn it, it's the process" (personal communication, March 1990).

First, "the basic purpose of deliberation is to make sound decisions" (Gastil, 2000, p. 23). Second, deliberation offers a means for collectively resolving disagreements as it requires the presentation, justification, and consideration of alternative views (Gutmann and Thompson,1996). This involves not just talking about an issue, but carefully weighing both alternative possibilities posed by others and the consequences of those alternatives for action (Matthews, 1999). And, as Matthews further noted, the quality of the deliberation ultimately determines the quality of any consequent action. Third, the quality of the deliberation is dependent on a number of conditions, including: the diversity of the participants (Gastil, 2000), the participants' concern for making decisions for the common good (Marty, 1997), and, again, the participants' opportunities for productive interactions through talking and thinking together (Matthews, 1999).

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Gastil (2000) cited Habermas's (1979) "ideal speech situation" as a model for deliberative interaction, explaining that for Habermas, participants in such a situation "must have adequate opportunities to examine the meaning of one another's statements and challenge one another's 'validity claims'" (Gastil, 2000, p. 23). Because, as Knitter (1988) concluded, deliberation "is supposed to be an activity aimed at the fresh determination of the goods of particular situations. As we, with attitudes of suspended conclusion and measured constancy, deliberate, we learn more, not only of the world of possibilities and of ourselves, but also of the nature of deliberation and the virtues relative to it" (p. 491).

It is the type of deliberation being advanced by these authors that I envision in the following recommendations.

Recommendations

> First we need to decide *why* we want to teach science to our young people; from that we can perhaps work out *what* we want to teach them. Then research, linked closely to the development and evaluation of teaching materials and approaches, may be able to help us discover *how* best to teach these ideas (Millar, 1996, p. 17-18, emphasis in original)

I have used the order of decision-making suggested by Millar to position the three recommendations for deliberative processes that have emerged from my examination and analysis of the situation. Agreeing with Millar that we need to initially establish why, I first describe a process for deliberation on why science should be taught, followed by one for helping decide what should be taught, and finish with ways to help determine how "best to teach these ideas" (Millar, 1996).

Recommendation 1: Deliberations on why

As I have written, my analysis of provincial elementary science curriculum documents convinced me that the dominant emphasis therein is the development of Correct Explanations (Roberts, 1982, 1998), not the doing of science inquiry – the goal currently stressed in science education literature. This provincial emphasis has resulted in restricted opportunities for Alberta elementary school students to engage in science inquiry; that is, in science activities located in the third and fourth levels of intellectual

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space. In addition, past provincial curriculum development efforts appear to have focussed more on what to teach, rather than on why science should be taught (Panwar & Hoddinott, 1995). To address these issues, I recommend that a deliberative process be undertaken that focuses on why science should be taught to our elementary school children.

Deliberation on why could also address a number of other issues raised in this study, particularly those associated with bureaucratic accountability (Darling-Hammond, 1989). For example, deliberation could open the decision making process, possibly making the curriculum development process less hierarchical. It would allow alternative possibilities to be brought forward to challenge the present provincial focus on having "the most efficient and cost-effective system possible" (Alberta Education, 1994b, p. 3). Deliberation could, as well, offer a clearer picture to a broader public of the complexity involved in teaching and learning science, suggesting that professional development be offered commensurate with the needs of "well-trained and highly skilled professionals" (Darling-Hammond, 1989, p. 64).

A chance for meaningful deliberation on this issue exists at the present time in Alberta as the provincial Department of Learning (formerly the Department of Education) prepares to revise the elementary science curriculum. Furthermore, such a process would enhance public deliberation on educational matters, a concern being raised in the Strategic Education Research Program (Willinsky, 2001).

I envision this process initially entailing information dissemination about possible science education goals followed by broad-based opinion sampling involving a large number of individuals and groups with diverse interests. Large-scale attempts to gather public opinion on a variety of issues are common in Alberta. Conferences are held, focus groups convened, and province-wide opinion sampling is done each year. School Councils, too, have regularly received information-gathering booklets (many pages long) from the Department of Education that they are requested to fill out and return. In addition, prior to a revision of the secondary science curriculum in the late-1980s, polls were taken, questionnaires distributed, and a committee struck to consider desirable changes (Panwar & Hoddinott, 1995). Few of these exercises appear to have been

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deliberative in the Schwabian sense, but a deliberative process would be a logical extension to past opinion-gathering activities.

Deliberation on why elementary school science should be taught might also help to correct the cycle of curriculum decision making which leaves elementary science education in the position of the "poor stepsister," a recipient of hand-me-down science curricula. As stated above, a review of the junior and senior high school science curriculum initiated an earlier consultative process. Alberta Learning personnel have worked, and are presently working, with publishers and teachers to prepare, field test, and critique teacher and student materials prior to implementation of a revised junior high school science curriculum. Elementary science curriculum is left to "articulate" with secondary science curriculum. Input opportunities were limited in the last elementary science curriculum revision to selected groups (including teachers) who were asked to respond to a Needs Survey and to draft curricula. Although comments on these drafts were taken into consideration in future drafts (A. McGillis, personal communication, February 10, 2001), this process appears to have focused predominantly on what to teach, rather than on the basic question, why.

As indicated, the initial step would involve gathering opinions from a diversity of sources on why elementary science should be taught. Samplings of opinion give an indication of both the various views held on this topic and the proponents of those views, information important for planning the next step, the formation of a deliberative committee with a mandate to advance and consider alternative rationale and their consequences. In these deliberations, participants would be asked to reach consensus on a set of reasons for teaching science in elementary schools, reasons that can be used to guide the up-coming elementary science curriculum revision. I suggest that curriculum revision would benefit, too, from deliberation on the intellectual space desirable for students to operate in, as advocated levels of intellectual space potentially impact on curriculum objectives and on how teachers teach and students learn.

Drawing on Schwab's (1983) detailed description of the formation of a curriculum committee and on personal experience, I suggest some possibilities for initiating deliberation. First, a committee with eight to ten members representing a "variety of all those who must live with the consequences of a chosen action" (Schwab,

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1978, p. 319) would be chosen. Members of such a committee, composed of teachers, a principal, a parent, representatives from Alberta Learning, a school board member, a university faculty member from a department of science, and a representative from a business group that has in the past expressed interest in elementary school science, would be selected to represent a diversity of opinion and of experience to "make likely the invention of some diversity of appropriate alternatives" (Schwab, 1983, p. 244).

With Schwab (1983), I recommend that two or three teachers be named to the committee. To encourage the type of broad consideration of alternatives necessary for good decision-making (Moss & Schutz, 2001), I suggest that one of these teachers be an advocate of an inquiry approach to science, one an advocate of a more traditional Solid Foundations or Correct Explanations emphasis, and one a junior high teacher who can provide insight into the effect of elementary science learning on instruction in the next level of schooling. The principal chosen should also be in a position to talk with other principals, helping make other principals aware of the committee's deliberations and the committee aware of principals' ideas. A parent may be chosen by a School Council contacted on the basis of its response to the opinion survey. The Department of Learning could be asked to send a curriculum developer likely to work on the elementary science curriculum revision and a representative of the Ministry who can explain the government's position – the constraints and possibilities inherent in the business plan and department priorities. As well, the university science faculty member, school board member, and business representative might be chosen to represent alternative viewpoints useful to the deliberations. In addition, I suggest choosing members who live in different geographical locations in the province (including both urban and rural representation).

Schwab identified the curriculum chair, the person whose task it is "to move the group to effectiveness" (1983, p. 252), as crucial to the process. Since there are very few, if any, curriculum chairs with the qualifications Schwab outlined, I suggest that a curriculum facilitator might be chosen for this position, a person knowledgeable about elementary school science, experienced in facilitating meetings and keeping a meeting focused on a goal: focussed, in this process, on <u>why</u>, not what or how.

A number of potential contributors to the process could be invited to observe the sessions and assist the chair on request. Here I would include a university instructor

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engaged in elementary science education, an Alberta Learning assessment writer, possibly a philosopher of science, and, if deemed helpful by the chair or committee members, a critical theorist.

I will not venture an opinion on the number of meetings necessary to come to a decision about a balanced and reasonable rationale (that is, what is advocated can be done) for teaching science to elementary school children in Alberta. Based on experience working on issues of less import, the type of extensive deliberative process I envision (and for which I earlier professed a bias) may require two to four meetings a month over a year's time. While this type of on-going deliberation has received little attention in the literature, the Science Council of Canada's study on science education in Canada produced Proceedings of deliberative conferences held in every province and territory (e. g., Science Council of Canada, 1983) and reports (Orpwood & Souque, 1984) outlining rationale for and initiation of deliberative inquiry. These efforts and reports set an historical precedent for engagement of the many groups with interests in science education and provide useful examples of key issues that may need to be debated and of the range of stakeholders to invite to future deliberations on educational policy.

Having considered a way to address the issue of why science should be taught, I turn to the question of what to teach.

Recommendation 2: Deliberations on what – encouraging professional deliberation

The literature review convinced me that both students and teachers benefit from engagement in inquiry in the classroom. For elementary students, scientific literacy is best developed through engagement in scientific inquiry (e.g., NRC, 1996, 2000). Classroom inquiry helps teachers develop better teaching practice (e.g., Darling-Hammond & McLaughlin, 1996; Shulman, 1998). However, my findings suggest that the science instruction described as exemplary by many educators in this study would not involve students in scientific inquiry and that educators were generally not being introduced to either the rationale for scientific inquiry or to ways to implement this approach in their classrooms. Furthermore, my findings indicate that the curriculum guidelines themselves restrict scientific inquiry.

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To help ameliorate this situation, I recommend that collaborative, intentional learning communities (Lieberman, 1996) be formed to initiate teacher inquiry and deliberation on student conceptual understanding. For teachers, involvement in inquiry appears to be closely related to a sense that this is likely to help them teach something better to their students; as Bell and Gilbert (1996) stated, "Teachers want the best for their students" (p. 1). An issue relevant to students and better teaching currently exists: the problem of too many and too difficult specific learner expectations. To provide data on that topic for the up-coming curriculum revision, teachers in their classrooms could study the difficulty students have learning different concepts and the time frame necessary to teach these concepts through inquiry.

In studying student learning of science concepts, teachers become engaged in classroom research that helps enhance their professional knowledge. Teachers systematically investigating the effect of lessons on student learning, reflecting on classroom activities and student learning, and critically assessing curriculum goals based on these reflections will be working in the third and fourth levels of intellectual space. In order to study student concept development, teachers are also more likely to involve students in activities in the third and fourth levels of intellectual space.

This classroom research can help further develop teacher expertise and enable teachers to make a meaningful contribution to the revision of the elementary science curriculum. Many of the topics outlined for inclusion in an elementary science program in the *Common Framework of Science Learning Outcomes* (CMEC, 1997) are topics currently taught in Alberta classrooms. Teachers have experience teaching these concepts; they bring insights on which to build. Teachers are not being asked to develop entirely new unit plans, but to more closely examine the student learning that occurs in topics with which they are familiar.

As well, literature indicates we need to know more about the difficulty of science concepts taught to students of different ages and backgrounds (Gott & Johnson, 1999; Sadler, 1998). Through their deliberations, then, teachers can also contribute toward a better understanding of the "learning demand" (Driver, 1997) of selected concepts.

This should not be an individual endeavour; reading has convinced me of the importance of teachers establishing collaborative learning communities, as have

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statements made by teacher participants in this study. I believe, in addition, that deliberation with others leads to the "best decisions" (Schwab, 1978).

Briefly, I again recommend deliberative groups be formed of eight to ten members, most of these teachers. The mandate of each group will be to document teaching activities, approaches, and strategies and student learning in one topic of study, a topic currently taught that is also included in the *Common Framework of Science Learning Outcomes* (CMEC, 1997). Members of groups should be selected to represent different teaching situations, different approaches to teaching science, and differing beliefs about student learning. I would suggest that each group, when possible, include a principal, possibly one who is teaching science. Again, the principal chosen should be in a position to liaise with other principals, increasing awareness of these deliberations.

A curriculum facilitator may again be the best choice for the committee chair. (If a number of teacher groups are formed in a district, other educators could be trained for this position.) A chairperson will need to be knowledgeable about elementary school science, experienced in facilitating meetings, and adept at "evoking and maintaining an appropriately deliberative mode of discussion" (Schwab, 1983, p. 254) by helping the group "pool their ingenuities, insights, and perceptions in the interest of discovering the most promising possibilities" (p. 255). Such deliberation also incorporates the concept of 'the other,' as discussed in Chapter Three; that is, a person or persons who helps a teacher deliberate on and evaluate his or her thinking and action (Fenstermacher & Richardson, 1993). The chair may want to ask others knowledgeable about science teaching and learning to listen to the deliberations and offer advice when so requested. Scientists, science educators, and experts in cognitive development might be considered for this advisory role.

To enhance teachers' chances to engage in frequent collaborative discussions, it is preferable that more than one teacher in a school be involved in a deliberative group. There are also benefits to be gained by having teachers in different areas of the province study student learning about the same science topics; different insights and evidence offer chances to explore alternative solutions.

Both the literature and my data suggest that if teachers are to be engaged in a process of this sort, there is a better chance for productive deliberation to occur if

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teachers are sometimes provided with time during school hours to collaboratively plan and organize their inquiries. After engaging in systematic inquiry in their classrooms, additional release time would allow teachers to collaboratively deliberate on what they and their students have learned and to plan for the next phase of the teaching and learning inquiry. If different groups have considered the same science topic, these groups will also need time to meet and discuss their findings and conclusions.

Time is also necessary for teachers to develop their own understanding of science teaching and learning – time to try out new activities in the classroom, to observe and document their emerging findings, and to reflect on how these activities affect student learning. As many of the articles on professional development have reported (Marx, Blumenfeld, Krajcik, & Soloway, 1997; Mitchell, 1994; White, 1998), teachers often need several years to develop knowledge about new approaches and ways of looking at teaching, an idea consistent with the literature on the difficulty of conceptual change.

Another essential element is support; professional development literature refers to the benefits of being involved in a professional learning community where teachers can share and critique ideas, concerns, and successes. The notion of critical appraisal is crucial; it is this element that distinguishes this process from that of developing procedural knowledge. It is also an element present in deliberation.

I argue that a project of this scope and importance deserves province-wide support enabling teachers to meet and deliberate. School districts and Alberta Learning can also offer invaluable support in the form of resources and recognition of the value of the teachers' efforts. Compared to the $4 billion dollars spent by the provincial government in 2001 to reimburse Albertans for rising energy costs, the monetary support necessary to carry out a reasonably extensive deliberative process of the type described is relatively minimal.

Recommendation 3: Deliberations on how

Teacher collaborative deliberation on elementary science topics should not end with the drafting of a revised elementary science curriculum. I agree with Millar (1996) that after why and what have been established, "research, linked closely to the

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development and evaluation of teaching materials and approaches, may be able to help us discover how best to teach these ideas" (Millar, p. 17-18).

My findings indicate that many educators in this study were not being offered opportunities to enhance their principled knowledge of science teaching, nor were they being engaged in critical conversations about how science might be taught. Encouraging deliberation on how best to teach science would involve teachers in a potentially valuable professional development experience and contribute to their professional knowledge and classroom practice. It can, as well, generate data that add to our understanding of teaching and learning elementary school science.

As the process would be similar to that just outlined for deliberating on student learning, I refer the reader to that description.

Besides raising possibilities to consider in future deliberations and offering recommendations for translating study findings into processes leading to decision making and action, this study has also suggested new areas to explore. Three questions in particular intrigue me, areas of possible future research. These I outline in the next section.

FUTURE RESEARCH SUGGESTED BY THIS STUDY

1. Teaching science as inquiry to help students "understand science as a human endeavor [and] acquire the scientific knowledge and thinking skills important in everyday life" (NRC, 2000, p. 6) is a stated goal in much of the current literature on science education (AAAS, 1993, 1994; CMEC, 1997; Hodson, 1998; NRC, 1996, 2000; Reardon, 1996). Teachers involved in inquiry into their own teaching practice in order to develop "better teaching" (Baird, 1992) is also strongly advocated by an increasing number of well-respected researchers working in the field of teacher professional development (e.g., Cochran-Smith & Lytle, 1996; Darling-Hammond, 1998; Langer, 2000; Lieberman, 1996).

Schwab (1959) described inquiry, the noting of and reflection on "connections between things done and different resulting consequences" (p. 151), as an action enabling

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a person to move beyond mere habit, or even flexible habit. Furthermore, he suggested that teachers must engage in inquiry if they are to carry their students "to the third dynamic of intellectual space, some to the fourth" (p. 159).

While both the science education literature and the professional development literature advocate inquiry as an effective means for furthering knowledge development, I have not seen as clear a connection made between teacher inquiry and student inquiry as that suggested by Schwab. This leads to a research question: Must teachers themselves operate in the third or fourth dynamic of intellectual space in order to carry students to at least the third level?

Answers to that question require classroom studies that document levels of intellectual space occupied by both teachers and students; that is, studies of the types of inquiry engaged in by both teachers and students as they mutually 'do science' (Millar, 1989) in elementary school classrooms. Such a study would offer insight into a possible correlation between teacher and student inquiry levels, information valuable for better understanding the effects of teacher thinking and action on student thinking and action. This, in turn, can inform the design of professional development intended to enhance students' learning of science.

2. My data indicate that teachers participating in this study initially sought procedural knowledge (knowledge of teaching resources and specific content knowledge) to meet their immediate needs for teaching a new science curriculum. Literature, however, outlines a much more complex knowledge base "that underlies the teacher understanding needed to promote comprehension among students" (Shulman, 1987, p. 8). This includes knowledge of content (e.g., Alexander, Rose, & Woodhead, 1992; Osborne & Simon, 1996), curriculum materials (e.g., Roychoudhury & Kahle, 1999; Shulman, 1987), inquiry (e.g., Hodson, 1998; NRC, 2000), constructivist learning theory (e.g., Constable & Long, 1991; Driver, 1997), and what Shulman (1986, 1987) named pedagogical content knowledge (e.g., Lloyd et al., 1998; Parker & Haywood, 1998).
This more complex knowledge I have called, after Edwards and Mercer (1987) and Spillane and Zeuli (1998), principled knowledge.

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My 1998 findings that Alberta educators had initially predominantly expanded their procedural, not their principled knowledge, and the stress in the literature on the necessity for teachers to enhance their principled knowledge indicate a need to gain a better understanding of the types of science teaching knowledge developed by Alberta teachers after teaching the science Program of Studies for more than two years. (My interviews were done nearly two years after the mandatory implementation of the science curriculum.)

Research questions to consider include:

a. What changes do teachers report in their teaching practice and knowledge about science education after teaching a topic for more than (2, 3, 4, x) number of years?
b. What influenced those changes?
c. In Alberta, in what ways did the introduction of other new curricula influence science teaching practice and ideas about approaches and strategies for the teaching of science? (Both a revised mathematics and language arts curriculum have been mandated since 1998.)

This research can contribute valuable information to guide the design of professional development activities to enhance educators' knowledge base about teaching and learning in elementary school science and, where there is overlap, in other curriculum subjects.

3. Numerous studies describe teacher learning in university classes and professional development courses (e.g., Geddis, 1996; Jones, Rua, & Carter, 1998; Keiny, 1994). Other studies outline the advantages of teachers learning together in collaborative learning communities (e.g., Hargreaves, 1992; Shulman, 1998; Wolf et al., 2000). A few further studies have focussed on teacher discussions and learning about curriculum (e.g., Saunders & Goldenberg, 1996). I know of no studies, however, documenting and analyzing the discussions and learning of elementary teachers as they study and deliberate on children's learning of science concepts, a process I have outlined above. Such data can provide valuable information about opportunities and difficulties that occur while using this process to enhance teachers' principled knowledge about teaching

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science and to build collaborative learning communities. It can indicate, as well, conditions that appear to positively or negatively impact on teacher growth while they are involved in such a project.

Teacher-collected classroom data on children's learning of science concepts can also inform research on conceptual difficulty and progression in the development of children's scientific understanding.

ENDING THIS STUDY

As indicated earlier, I consider this an exploratory study; through my research, problems assumed shape and a desirable end was designated. Recommendations for future deliberations have been advanced to help make the desirable possible.

Now I need to take the next step. In order to contribute to the making of sound decisions (Gastil, 2000) about elementary science education, to choosing "not the *right* alternative, for there is not such thing, but the *best* one" (Schwab, 1978, p. 319, emphasis in original), I will introduce this research and recommendations to those given responsibility for provincial science curriculum decisions, to Alberta Learning. This is an undertaking of considerable significance as it can potentially affect why and how science is taught in Alberta and, through a documentation of the process, how science curriculum deliberations and decisions are made in other jurisdictions, as well.

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APPENDICES

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APPENDIX A

Letter to Participants

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XXX

XXX

Dear XX:

I am starting to collect data for a doctoral study in the Department of Elementary Education at the University of Alberta.

This study is intended to document views held in Alberta about how science should be taught in elementary schools and what knowledge and skills teachers need for teaching such science. In addition, I will be gathering information describing the professional development currently available to elementary school teachers of science. To collect this data, I will interview science education specialists, curriculum coordinators, administrators, teachers, professional development providers and others throughout Alberta who have taken a leadership role in science education policy, direction or teaching practice in elementary schools.

I would very much like to interview you as part of this study. The interview will take up to an hour. I will tape record each interview, transcribe the tape and then send the transcript back to you for comment and/or clarification before using it in the study. Participants are, of course, free to decline to answer any question and may withdraw from the study at any time without penalty. Pseudonyms will be used for all participants and locations in order to provide anonymity.

The information gained in this study will identify areas of strong consensus and those with more limited acceptance that pertain to the necessary teacher knowledge for teaching elementary school science. This can be used in designing future professional development capable of further enhancing quality teaching practice in elementary school science.

My telephone number, if you have any further questions, is XX. If I have not heard from you, I will be telephoning in approximately a week to schedule, hopefully, an interview.

Thank you, in advance, for your consideration of this project.

Sincerely,

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APPENDIX B

List of Participants

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Participants

Pseudonym	ID	Position	Employer
Constance	CF1	Director of Technology Services (1-12)	Currant S.D.
Mary	CF2	Supervisor of Science (1-12)	Spruce S.D.
Ken	CF3	Curriculum Facilitator (1-12)	Gooseberry
Russell	CF4	Supervisor of Curriculum and Instruction (1-12)	Clover S.D.
Susan	CF5	Elementary Science Consultant (1-6)	Elm S.D.
Davis	CF6	Chief Deputy Superintendent (1-6)	Flax S.D.
Muriel	P1	P (K-6), 100 students T: music, grade 5 / 6 math (.55)	Gooseberry
Deanna	P2	P (K-6), 500 students	Currant S.D.
Lena	P3	P (K-6), 145 students T: learning assistance, library, health (.5)	Currant S.D.
Bertha	P4	P (K-9), 245 students	Elm S.D.
Jeff	P5	P ((K-6), 340 students T: grade 6 math and health (.25)	Clover S.D.
Isabelle	P6	P (K-5), 425 students T: French (.2)	Flax S.D.
Peter	P7	P (K-6), 600 students T: grade 4 math (.15)	Spruce S.D.
Jackson	P8	P (K-6), 330 students	Elm S.D.
Ralph	P9	P (K-9), 640 students T: physical education	Gooseberry
Marlene	P10	P (K-6), 200 students T: grade 4 science (.15)	Spruce S.D.
Lyndon	P11	P (K-6), 170 students T: grade 6 science and math (.30)	Flax S.D.

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Pseudonym	ID	Position	Years teaching	Employer
William	T1	Teacher - Grade 6, Gr. 3 / 4 science	20	Currant S.D.
Tanya	T2	Teacher - Grade 4	15	Clover S.D.
Maryanne	T3	Teacher - Grade 3	14	Elm S.D.
Alice	T4	Teacher - Grade 2	20	Spruce S.D.
Rosemary	T5	Teacher - Grade 5 .2 teacher/librarian	20	Flax S.D.
Kathy	T6	Teacher - Grade 6	10	Gooseberry
Esther	T7	Grade K-4 Principal (K-9), 25 students	20+	Clover S.D.
Jane	T8	Teacher Grade 3 / 4	6	Gooseberry
James	T9	Teacher - Grade 3	30+	Elm S.D.
Liz	T10	Teacher - Grade 3 Gr. 1 science	13	Flax S.D.
Sharon	T11	Teacher - Grade 4	15	Spruce S.D.
Jennie	T12	Teacher – Grade 3	7	Currant S.D.
	C1	Curriculum writer		Alberta Learning
	U1	Associate professor	13 (univ.)	Alberta university
	U2	Associate professor	9 (univ.)	Alberta university
Art	SP1	Director of Science Education		Science organization
Florence	SP2	Student Outreach Coordinator		Professional organization
Ruth	SP3	Engineer, Company Outreach Rep.		Chemical industry
Floyd	SP4	Executive Director		AB Regional Consortium
Lucy	SP5	Coordinator of Professional Development		Alberta Teachers' Association

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APPENDIX C

Interview Questions

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QUESTIONS (for teachers)

I. Background and present duties

1. What is your present position? What are your responsibilities?
2 What is your personal, educational and professional background? (Ask for specifics - grade, location, etc. - if not given.)

II. Professional decision-making

3. Please describe what you did to prepare for the implementation of the recently mandated elementary school science program of studies. (Ask for specific sources of information, processes, etc.)
4. Did you feel there was an adequate amount of material available to you to make good decisions? What sources of information did you find particularly helpful? How did you narrow the available choices?
5. Were there other influences - for example, people or policies - that affected your decisions?
6. Is sharing curricular information with colleagues in positions similar to yours usual? (If yes, How is this done? - conferences, seminars, journals, newsletters)

III. Views on science education

7. Why do you think it is important to teach science at the elementary school level? (Possible further questions - How well do you think the present science curriculum achieves these ends? In content? In its inquiry approach? In problem-solving through technology?)
8. What would you describe as the most important elements of an exemplary elementary school science lesson?

IV. Views on science teaching

9. What is the teacher's role in such lessons? That is, what does the teacher do before, during and after the lesson? (Ask for concrete examples)
10. What does a teacher need to know in order to teach science this way?
11. How do teachers build the knowledge base necessary for quality science teaching? [Other teachers, consultants, conferences, ATA publications?]

V. **Developing professional development**

12. How is professional development in science education planned in your district?
13. Can you give me an example or two of professional development experiences you have had that you remember as being excellent? (What, in particular, made them so good?)
    If you were asked, what kind(s) of professional development would you recommend to the province or your school district as best capable of meeting your p.d. needs?
    What do you see as constraints to providing such professional development?

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APPENDIX D

Selected Interviews

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Interview – T1

I - Please describe your professional position.
AD - Full time grade 6 teacher. I also teach grade 3-4 science.
I - Does somebody else take your 6's when you're doing that?
AD - Yes, the grade 3-4 teacher teaches French to the 6's.

I - What's your background, please?
AD - University, special education and language arts or reading were my two cores. After that, many other things over the years. I taught a fair amount of special ed the first few years I taught. Besides that, I've taught grade 6 and I have taught junior high science.
I - So you have done quite a lot of science teaching?
AD - Yes, I started with the 7,8, then it was 7,8,9, then 8,9 science for 5 years.

I - How long have you been at this school?
AD - This is my fifth or sixth year.
I - Earlier in the same school district?
AD - Yes, I've always been in [this district]
I - How did you start out?
AD - My first year was grade 6, the next 7 years were special ed, either at the elementary or junior high level. And then from there, 5 years of elementary, grade 6, and then 5 years of junior high and then back to grade 6 with a year off in there.

Our county always used to promote making a change every 5 years – change a grade, change a school, whatever, and it seemed to make sense to me. I followed it until recently. I don't know if I'll change any more or not. Who knows?

The change into science wasn't anything I'd necessarily planned on doing. I got into the junior high. The first year in junior high was some language arts and some science, grade 8 science, grade 7 language arts. And I taught outdoor education all through my junior high years. I guess I just accepted more science as I was having fun with it and I enjoyed it. And then when the new junior high science curriculum came in, all those many years ago, 10 or more, I really liked that so I went with that and ended up just teaching science.
I - When you first taught science, was it just because they needed a science teacher?
AD - Yes, that basically is what it was. I'd always done grade 6 science, enjoyed that and science in special ed, as well. So I just moved into it.

I - When this most recent elementary science program of studies was ready to be implemented, what did you do to prepare for it?
AD - I think probably for me, the big thing for me was my grade 7,8,9 science had become much more activity-based compared to what it had been before. So this was just more of the same. When it was first started up, going to whatever kinds of materials I could get my hands on. The AIMS material was one of them and I've forgotten the names of some of the other material we had access to. I just went in there and built around the very basic, at that time, curriculum outline, the activities around that. And it changed quite a bit those first few years. Then it finally settled down the last few years

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as the district got more and more involved in the materials. Then, of course, the curriculum settled down pretty quick. I guess you could say, as the government got more involved in materials, the curriculum settled down pretty quickly.
I - When you were looking for, let's say AIMS, where were you able to find it?
AD - Here.
I - It was in the district?
AD - Yes, and even in the school. We had enough to know, yes this is useful, this is useful.
I guess, remembering back, I'm not sure just how much of one thing we had in the school, but we very quickly did get enough materials. And we planned across the grades for the different splits. So it really was up in the air from one year to the other with absolutely no idea. We knew what we were doing this year and at the end of the year again, we'd plan for the splits. They'd throw some kind of a curve and we'd jiggle and juggle. It's complicated enough with the splits, but finally we came out with some sort of a process that seems to be working.

I - In some of the larger schools, there is grade group planning. Is there a partnership of other grade 6 teachers that you know that you work with?
AD - At the beginning, and this is something our district did, they brought together grades of teachers into central office to plan and organize some of the units that they knew were coming up. I sat in on several of those and took part in the planning and building of those basics – what we wanted, and wanted in the Partner kits. In that way, yes, but otherwise, just what we get in school here.
I - Did you feel there was enough material available to you?
AD - For myself, I wasn't concerned about the materials. I felt OK about coming up with that. The thing I wanted, more than anything, was to know what to plan for. Coming up with activities never was a problem, just making sure they match the curriculum. But that settled down pretty quickly. As soon as we got the kits, those were excellent.
[short discussion on teaching the air and aerodynamics unit]

I - I've heard there is a professional development day in the fall in your district with a number of different sessions. Do they call on teachers to present information?
AD - They do sometimes. It's to the point now, I think that there's less of it. We're looking more for pd from the outside to bring more into it. There still are times; for instance, last fall, I was called and asked if I could be a backup if they weren't able to get this person for one of the areas. More and more it's bringing in people who specialize in the area to present another point of view. There are a number of organizations, like one of retired engineers. You can get these people in to do things, like levers and wheels. Those sessions are more of the ones I go to, done by people like that. "Here are some ideas you can use, you can call us to come in," those kinds of things. Expanding the – I think it's pretty well reaching the point where many of us prefer to go and see someone with a specialization who's looking at it from a little broader perspective than what so many of us at grade 6 do, because that's all we do. We do that little chunk of curriculum and then this chunk of curriculum and then that little unit and then this unit and then we move on and the rest of our time is reading, writing, arithmetic, other things. So, for me personally, it's useful to go and listen to, for instance, one of these engineers talk about

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these things and show some of the ideas, in sessions I've been to, that they use with their grandchildren. Of course, they take the time and they make wonderful things, not extravagant, not things we can't do, but wonderful from the point of view of "Wow! That's a simple idea and does it ever work well." Sometimes just bringing us back to basics. That's good.

I - What do you think we should be trying to achieve in our elementary school science lessons?
AD - Turning the kids on to science before they leave our elementary school is the bottom line. And I think we're on the right track with the activity-based, with the 'do it.' It's certainly not always easy because some things are just hard to find for anybody, the materials and what not, to show certain ideas, but the longer it's going on, the better it's getting here. And every time one of these kits comes around – and this is probably where the fellow elementary teacher part comes in – every year they come back, there are more ideas in it from other teachers who have added to the kits. So while we don't have the personal contacts in discussing it, as somebody works through a kit, they make a test, they come up with a good idea, they often put it in, so it's shared that way and the kits just get better and better each time they come around. There's an enormous difference between the first time a kit comes around and the third or fourth year it comes around. It's just [click, click, click with fingers]. It gets to be they're spoiling us so badly with the kits, that I'm looking at them the same way I do with software. If I have to look at it and find an explanation in a resource book, if I can't understand what the software wants me to do, I don't want it in the school. I don't want my kids around it. OK? It's useless. I want them to sit down and do it. That's the way I'm looking at the science kits. I want those kids to be able to sit down and to work with it. Sure, we still do our background on it, but the materials are there so the kids can just sit down and work with it without having to spend a lot of time doing the research and development kinds of things. That research and development is as much an activity, instead of reading, sitting at a desk research.
I - In the kits, how much supplemental reading is there?
AD - Minimal, there are only teacher materials in there. In some ways, that is getting to be less as they, again, sort of refine these things. Of course, the different school boards are developing their own. For instance, an example would be the Sky Science. Edmonton Public made a curriculum booklet for it, 'here's what to do.' Parkland had one, the Space & Science Centre had a curriculum book in there. There was another one in there I forget for the moment. Any one of these you could have picked up and done that unit out of, and the materials in the kit went pretty well with the core parts of those, anyway.
I - What do you do as a teacher when you have got 4 different resources?
AD - Pick the one you like. And it gets to be pretty easy because Edmonton Public seems to be putting a lot of resources into its and it has also been suggested that we may adopt those officially. We're buying them from them now and including them in the kits. Edmonton Public has been paying people to work on these, so they're pretty good. But the other ones were very good, as well. But it has been suggested that we'll probably go with the Edmonton Public, so that seems to help focus me, anyway, there. If that's the one I'm going to be using, let's start now.

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I - Do you find any difference between the science inquiry topics and the problem-solving through technology topics for doing what you want to do?
AD - Yes, the inquiry is much more successful in doing it. The through-technology part – first, there gets to be a time factor. Second, the technology isn't there. It just isn't there. Sure, we have a class set of computers and yes, we do have two different science encyclopedias on CD. So we have 2 computers that you could use this at and 26 grade 6's or 30 grade 3-4's. It's a waste of time to be thinking about it, quite frankly. Let them get in, let them do it, work with it, let them see, let them write, by hand. Once we get fiddling around with this other stuff -- thank heavens the fad is pretty near past.

They're wonderful pencils; they really are. Don't get me wrong, I'm also the computer person. And my first computer went into my classroom in 1981 or something. But it comes down to, it's a better pencil, like a calculator is, like a typewriter is, like a ball point is, for that matter.

When every student has one on their desk, then that's going to be totally wonderful. But, meanwhile, shuffling from the classroom down to that lab, trying to get together the materials, that's a period shot just on each end of that and we still haven't done anything yet.

[discussion continues on computer use]

I think the ideal would probably be, both. With the 3-4's, we're doing our butterfly unit. Our caterpillars showed up already mature. Within several days they were in their chrysalis stage and so there was very little that we got to see. Now we're going through pen and paper discussions and talking about all the things we didn't see. We saw enough to base our discussion on. I'm not happy – I'd rather have had the kids see them eat and eat and eat and eat and shed and eat and shed, pardon me, molt and go through stages. But we saw them eat and eat, molt and then they're hanging up already and turning into chrysalises. And we've only looked at them 4 school days. So we go through, "Here, on paper, are pictures of our different stages. We didn't see this little guy or see him this size and this size. So, colour in this part, colour in that part, look at it here. Here was the head you didn't get to examine with your magnifier and here's where the eyes are." But we saw enough that they're making the connection and it's real for them, but to be able to have them sit down at a computer with an appropriate program that showed them would probably be as good or better than what I'm doing now with paper, pencil, copied pictures, that type of thing. They could bring more animation to it and it could be good stuff. But I'd rather have a tiny caterpillar come to our school and a butterfly leave our school, because it's much more real for them, it's much more fun for them.

As I say, computers are great, they have their use. I don't want to be without one myself – to keep my grades on, to do my papers, to do my tests on, those kinds of things. For anything else, though - phutt. I'm a person who canceled my Internet after a year because there are so many thing I would rather do than sit at my computer in my spare time. Computers feel like work. This is not my free time. Good heavens, I'd even rather watch TV. Now, for me, that's quite a thing.

I - Obviously, what you would want to see in an exemplary science lesson is this hands-on aspect. But what else needs to go on in an exemplary science lesson?

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AD - I don't know if this is where you're going, but for me, as well as the hands-on and appropriate materials, it would be really nice to have lab space. To have a space to do this, where you could work, where you could do a project that didn't have to be a one period project. I've set the time table up so I do double periods. With my grade 6, almost all double periods or triple even, but with the grade 3-4's, double or single periods. So there's no 'get started on this project and leave it and go away.' No, it's 'take this project to here. Now put everything away in this box and try to find a space for it.'

Even in my own classroom, when there are 8 subjects happening, it would be really nice to have space. In my ideal situation, a science lesson would take place in a science lab, possibly even with things like running water or electricity or tables. Certainly we move our desks around to make tables or to work on the floor and it works and I like it a lot better than when we were just sitting at our desks working out of a book – way, way better than that. But, ideally, I'd like a lab, just basically, a room.

I - In the science lesson, what do you see as the teacher's role? I'm going to ask you to break this up. What does the teacher do before, even before you start, but also at the beginning of the lesson? Then during the lesson and what kind of follow-up do you see?
AD - The before – the planning, the organization, the having it all together. It's really essential to have this activity lab be able to go click, click, click and the only glitches that show up are the ones from the on-site student problems, "I lost this," "This broke," that kind of thing.

Then, from there, once the class is there, I believe in a brief overview so that the students know what the whole thing is, where we're going, a focus and that's the term I use. Probably 95 out of 100 of my individual science lessons will have a written component to them. They will have a title, a focus, materials, a planning section and observations, diagrams – you know, the basics will be there. But the focus is what we're going at right now. So, my planning is done, I go in and "Here's our focus. Get this down. This is what we're aiming at. This is what you will come out of it with. This is what I want to looking for." Those types of things. Then continue with the overview, what the expectations are in how they'll be spending their time, in what they'll be doing. How they'll be grouped. What is going to happen here while we're doing this. This is what's going to happen. I really find that not just useful for me, but very useful for the kids. It's been my experience that children are just like people, they like to know what's going on, and why they're doing it. Then from there, to get into it very quickly, even if it's a little longer and more complex and it's going to be necessary to stop periodically for more explanation or instruction or question period, or whatever, we get into it fairly quickly, get started, get it happening. And then, usually, I find that a period can be a nice break in that. If one period is all we have, the introduction, get started working on it, then a wind-up in it even if we're not close to finishing the project. A wind-up – here's what we've done today. Next day we'll be moving on, but here's where we are right now. And then the next day is review, you know where you are, here's what you've done, here's where you should be, if you're not, see me. Any questions before we get started. With the grade 6's that's 2 or 3 questions, with the 3-4's it's five thousand questions. And then away we go and back into it. Usually by the time we're into a second period of a project, on two days or back to back, usually, there's a stop place in the middle of it

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where we're catching up, where we're stopping now and we're getting more stuff down on paper. For some things, that can happen in one period, where we'll finish off whatever, have part of the period as activity, then do some writing down to keep track of what we've done today, some observations or whatever. It might even be recording our preparation, that type of thing. Then by the time we're half way through the next period, ordinarily I find that's when it's time for me to stop again with the group and start getting some things down on paper and the last half of that second period is "Here's our observations. What are some questions?" Maybe looking at fair tests, those kinds of things. So by the time we've finished two periods -- for me, I find a 2 period lesson works the best.

I - How long is a period?

AD - A period is around 35 minutes.

I - As a teacher, you've finished the class. What does the teacher do after that?

AD - There's always for me an evaluative process of some sort in there. Depending on what it is, they're going to hand in their activity and the evaluation will come from that. Again, with activity- based, when I say evaluation comes from what they hand in, quite often I'm talking about maybe 70% of the evaluation and the rest is, the current word is rubric, but informal evaluation in how they were working together, were they applying themselves, were they enjoying themselves, what problems were there? All of these different things come in. And for just about every assignment – no, there certainly are some where it's just the assignment itself, more with the grade 6's where the total mark comes from what they put down on paper. "The only thing I know is what you're going to show me on your write-up," but that's too cut and dried for most of the activity-based, though for some things it's fine.

Even with the 3-4's, I find that once in awhile it's applicable, not necessarily really good, but applicable. But one of those periodically does give me some idea anyway. Maybe because I'm from the old school and always have been and I'm used to the idea. But I think also because I'm one of those people who believes very strongly that nobody pays you for what you know, they pay you for what you can share. If you can't share it, it's of no use to anyone regardless of what field it's in. Science fits in there as much as anything else. So the communication process has to be a big part of it. And just because they are going to be continuing in the school system, the communication process has to be a big part of it. And for some of the students that really is challenging for them and in that case the rubric type of evaluation is certainly useful. And for some of my students it gets to be slanted where the rubric counts more, with the younger students more so than with the 6's.

I - Do you have something like log books you collect regularly, or something that they may do at the end?

AD - Some assignments are log ones. I personally don't do a whole unit of log books. I know people who do and that really works for them. For me, no; an assignment done as a log, yes. An assignment done in a more formal manner, yes. And I've found I've had really good success doing evaluation as in quizzes and tests in activity-based, where they go from station to station. For that, of course, you need a lot of bodies for each station to give me any feedback at all, especially at the 3-4 level. With the 6's I can send them around with a piece of paper where they can fill it out. The 3-4's, no, I like to have an adult at the station, student aides, and they'll ask a couple of questions on whatever and

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just observe what they do there. So that works really well. Not everything lends itself to it, but most things actually do. The big problem is finding the bodies to man the stations. I discovered that one person alone, I might just as well not bother, because I'm not getting any feedback. It may be good for them as a learning experience, but it's not good for me as an evaluator, none at all.

With the 6's I can make it work. Maybe that's more my experience, but I think it's more their communication skills at that level.

I - With your 6's, where you have them all day, do you use curriculum integration?
AD - Oh, just about all. All my language arts, for instance, is designed around my science. Fortunately, with the language arts book we have, two different books, there are sections in them that will match with each of my science units. Sometimes, perhaps, I'm stretching it a little, but I never have any trouble making the connection – I can stretch and make the connection for them and that works really well. The social and science – there's a fair amount of blending that can happen and does. But the math, less than with the social and science. The big, natural blend for me is with the language arts. It didn't use to be like that, but since it has become activity-based, much more so. And it works really well for me.

I - As we're discussing these lessons and what the teacher is doing, what background knowledge do you think teachers need in order to teach science in this way?
AD - They have to be literate.
I - And?
AD - That's it; they have to be literate. Literate in science; they have to have the vocabulary, which by the time you've got your teaching certificate, you should be able to read these things. But the way that these things are now, that would be it. It might have been more difficult when they were first coming out, when the curriculum was first coming out. It was more difficult and there was a lot more to it and more background reading. But, at this point, if you're literate, you can do it and you can do it fairly quickly and efficiently. Even with the 3-4 units that are brand new to me this year, the way they've come with the science kits, I would say, depending on the unit, between an hour to two hours of planning and you're ready to go with them. Sure, you're going to be fine-tuning and changing and doing all those things we all do, but 1 to 2 hours and that's it, you're ready to go, whether you've ever seen a caterpillar before in your life of not. It's there, the information is all there, it's just clickity-click.
I - How about those teachers in school districts without the kits?
AD – [pause] Again, now I'm speculating, with no science background or whatever, it's going to be more complex for them. They may have to do what we first did when they brought in the new curriculum in going to the different materials like the AIMS material I mentioned and go through and plan a lot more. In that case, I would say my unit plan for one of those probably took closer to 8 hours. That's the difference, but there are enough materials around and well enough organized that probably any teacher could put together one of these units in a few hours of sitting down with materials and planning.

I - You're talking abut the materials. Are there other ways teachers build this knowledge for science teaching?

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AD - I would say just living in our world it's pretty hard not to have picked up on most of the basics. I think most people by the time they have a university degree in anything are fairly literate in basic science. I would say now, anybody who has passed grade 9 science, and I'm including 7 and 8 in there, has the background that they need to teach elementary science.
I - Yes, if you've done reasonably well.
AD - No, if you've done it, if you've passed it. If you understand the particle theory of material and you have a basic understanding of life cycles and what's involved in the food chain and some sort of environmental, ecological literacy, hopefully background and interest, but literacy, anyway, you can go with it. There is no doctorate needed teaching elementary science, just a basic understanding. If you understand how when you flip that switch that light comes on or that fan comes on, you can teach electricity.
I - Some of my students at the university certainly don't. If I give them a battery, it doesn't take them long, but if I give them a battery, bulb and some wire, the majority are struggling at first. So they haven't had that background.
AD - Wow. That's kind of scary. The one's you're teaching now should have that Science Directions, they should have come through junior high when that program was there. That is something that they did in grade 8 science, I believe.
I - I think some teachers didn't bring in the activity part as early as others.
AD - Well, yes. Our school district -- I've changed my mind on this. I would have said fortunately a while ago, but now I'm saying unfortunately, is following this same thing of jumping quick to get started and let's waste a whole bunch of money before we find out what's going on. I'm saying that because of experiences in the last few years, since we've tried to get on the band wagon at the very front so that we can spend a lot of money and buy materials that aren't going to work or that they're going to charge us twice for somewhere down the line somehow. A little annoyance here and unhappiness on my part, not just with science but across the board. Again, go and buy math texts and then the next year have the same company come out with a completely different book and, yeah, they'll sell you what you need at the new, improved price. Or you end up teaching math out of 2 different math texts, which is really annoying and not all that great. The results just aren't – it's confusing for me and it's confusing for them. I used to always be one of the first – yeah, I'd do it. I'll pilot that, I'll pilot this. It took private industry to show me this was not a good idea. They were in it for the money, not for my students' well-being. Can't blame them; yes, they are in it for the money.

[turn tape]

That is a difference. The district always made sure the school students had what they needed. You don't want to get me going on this.

I - OK, I'll go on to my next question. You have alluded to some of this, but how is professional development handled in your district? You said that at one time they brought teachers together.
AD - To plan to organize the new units and to update them. Nowadays, these last couple of years, it's been go to the sessions, whether it's at the Institute or convention or the in-service ones. And this has happened – I know we've done things like that, too – where someone in the school has organized, "Here's everything we have in school" because the other teachers in the school have asked for it and nothing has met their needs in some of

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the other, larger in-services, professional development things. So meeting those specific needs within the school here worked pretty good.

But, in general, the larger professional development activities organized by the ATA, by the school district, by the schools, they are pretty decent stuff. By the time you've gone to -- for instance, a few years ago I went to 3 or 4 different sessions on the forest unit and came out with way, way more than I'd ever need. But the result is now it's there for me; when I'm planning my forest unit, I'm going through all these materials. I'm picking and choosing, as well as what comes in the kit. And that goes across the board with all of them. This year I went more to the things aimed at 3-4 science, but, again, really good stuff. I've been very pleased with the professional development level. I'm finding the things that I need to help me with the kids, to help me bring it alive for them, however you want to say it. It works for me, here, anyway.

I - If we were to speak about exemplary professional development, how would you – you say what's there is working for you. Could it work better?
AD - You bet it could. I can't see our school system or any school system in AB affording it now or any more, but to take and say, "All right, we're going to have a 1 day or 2 day in-service on the grade 5 science. We'll put a substitute in the school for that day. Let's get the grade 5 teachers out here. Let's go through it." Again, in a perfect world, not just 1 or 2 days, because if you can get through a couple of units a day, it would be great. So probably more like 3. Now that would be outstanding, but I don't foresee us having the money for those kinds of things.

Really, at the school level, there is no choice. At the school level, the money isn't there to even think about using it. And, I guess, I don't believe that at the school system level, the money is there to make those choices, either. I'm sure of that. At the provincial level, the decision has been made that the children now can have two thirds of the quality of education that their parents had and that's good enough for them because they're second rate citizens.

We're getting close to my soap box. I taught the parents of these students that I have now, or equivalent ages. They had at least one third more programs than are available to their children now. The grandparents of these children now paid for and had their children go through a really good, developed school system. The people now chose to have their students have a lesser quality of education, in my experience. It doesn't make me happy; I think these kids deserve more.

[further discussion on funding]

The government was then backing so much across the board, but in the science area, like a STEP program and all the other things, they were paying people to put things together, all of the development was there, the in-servicing, all that stuff was there. And if you needed a room to do something, there was room. The lab thing was not an impossibility. They believed in backing up their curriculum and giving what was needed for it. Now it just isn't happening. We get lots of these things [computers] with no software to go with them. You have to go begging through the community to get enough money to get the software to do anything with them and then to get applicable class sets is so beyond the price. But, as I said, it's a really good pencil and they can really do some good stuff with it and it's really important for them to be able to do those things. But I don't think that's where the education system should come to an end, turning on

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that switch and watching it blink at you. Which, it seems, is almost what the expectation was. I really think there were a number of people, the powers that be, who got horn-swoggled into spending enormous amounts of money on a fad. A really important tool if they approach it like that.

Now they're here, maybe the next step will come along. I know they promised us 5 years ago there would be a computer on every teacher's desk. I bet you over half the teachers in the province, I just know about our system, who say, "Yes, I have 1 in the classroom, but that's it. It's not for me; it's for the kids."

It's important stuff, but it isn't part of my science program or my l.a. program. It's probably more part of my math program. The word processor for l.a., for social and then different math programs for making graphs on. Given more time in a day, fewer other things for them to do, we could schedule them to take the science down and do some graphing, there are all kinds of thing I'd love to do on it. We could collate all the information, but it's a waste of time at this point. By the time I get them down there, get everybody operating and they can only do it here, they can't do it as homework as most of them don't have Macs at home. So it's very limited and very limiting.

But how could you know? Back in the early '80's when I brought the first one into my classroom, I like everybody else, was convinced that within months, months, every kid would have one. A year or two at the most. Here we are 20 years later and we have a lab, we have 18 Macs in our lab. That's quite decent. And we have a classroom set of Apples, although we're using those less and less. In science there's very little programming for any of these areas. Software is out there. It's expensive. I won't even look at buying most of that stuff anymore. I've gone away from CD-Rom. If you've got it on one of those little discs I can use on any Mac in the school, OK, I'll talk to you. If you've got it on the disc where it costs 1/3 as much, OK, I'll talk to you. But other than that, I have no time because I have no money. So I don't even look at it. One or 2 are useful for the library. I have one of the science encyclopedia things in my room and periodically, someone gets time to look something up on it. But most of the time we're too busy doing stuff. They want to be doing, they don't want to be sitting down; it's just a big book to them.

[further discussion on computer use, grouping students (levels of expectation), and giving grades to the 3-4's]

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Interview - P5

I - Please describe your present professional position and responsibilities.
JE - I'm presently the principal at Bennett. This is my first year here. Previous to this I was principal at [deleted].
I - What do you do as principal?
JE - Sit behind a desk and look important. [chuckles] Recently a lot of our time is spent on business management rather then on educational kinds of things. So, looking after the budget and that kind of thing, personnel, filling out forms for Alberta Education and for the school division, preparing reports and that kind of thing is taking up a big bulk of our time now. And educational leadership is being pushed to the back burner in lots of cases while we're going through this transition. Hopefully, once we've gone through the transition, we'll head back into more emphasis on the educational part of it, rather then the business management part of it.
I - Is this transition to more site-based management?
JE - Yes, and I think it started a few years ago, but I think it's really starting to hit the schools now. And this is what we're dealing with, where the staff are to make their plans, and their goals, and it's just filtered down and is finally hitting the schools in a big way now.

I - If the principal isn't the educational leader, is it devolving to teachers or do you just find a gap?
JE - Well, teachers have to take on more responsibility themselves, I think. I'm looking forward to the professional development plans that they'll be developing along those lines. And I think most teachers do, at least the ones on this staff, take the initiative to do professional development on their own and are very dedicated in that way.
I - So within the school then, are there staff decisions made such as, somebody will be looking at science, maybe somebody else will have more of a focus on language arts, so there can be some of that sharing?
JE - There's a little bit of that, but I think that we tend to go, like the last couple years there's been a big push to really look at the science curriculum. Now I'm trying to de-emphasize that and move on to the math curriculum and emphasize that for the next year or two. Meanwhile we have the language arts curriculum, so … I don't know how that's going to fit in quite yet, but we're going to have to do the math and the language arts probably together with an emphasis on both. But I think in the language arts we can integrate some of the new material along with some of the old that we've been using. So it's not as crucial that we emphasize that. But the math we really need to spend some time on.

I - Could you tell me the size of your school? And do you do any teaching?
JE - Yes, I teach about a quarter of the time. We have 340 students here, counting ECS.
I - What do you teach?
JE - Grade 6 math and health.

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I - What is your background, your educational background, your professional background? You spoke of your former position, but could you give me a little broader idea?
JE - Basically, I've been probably in administration most of my career in some form or other. I taught 2 1/2 years and then I took a position as a principal in the small rural school and then moved on into a larger elementary school as vice principal. I then moved up to principal and then transferred here last year. So I've had some aspect of administration for a number of years.
I - Where did you go to university?
JE - I have sort of a combination of business/administration from McMaster University. Elementary education from the U of A. And a Master of Administration from San Diego State.

I - When the newly mandated science program was being brought in, what did you do to prepare to implement that?
JE - I think the transition was really easy because people were so frustrated with the old curriculum and with the testing programs and things like that. The old curriculum was so general and so non-specific that people were happy to move into a program that I think provided a lot better goals and was more specific and yet, at the same time, was a lot of fun to teach.

My main role was to encourage staff to get out and go to as many different conferences or workshops that were on at that time. We'd put it in our budget at the school. We purchased – we already had a well-stocked science lab, so we just supplemented what we needed in there for that. The other thing was we ordered a number of units from Grande Prairie and Edmonton Public and used those as sort of our basis for adding on to what we already had.
I - One reason to come to a more rural area is to ask questions like, How do you find the resources? People in Edmonton can come to, like the University of Alberta library, and a lot of them are there. But how do you find it this far away? Or does your district buy them?
JE - We have some resources. We do have a good IMC, but I think for the science type curriculum so many of the resources you just find locally, anyway. So our science budget has certainly gone up over the last few years just spending on local kinds of things.

So, I think using the resources and ordering in the books that we need to do it and the units that help us do that. It hasn't been, as far as I'm concerned, a problem in the rural areas to implement the science curriculum. In fact, I think all it takes is a little bit of enthusiasm on the part of the teacher and planning together, the staff work together on it, and it comes along.
I - You just mentioned the Grande Prairie and Edmonton units. I know somebody else mentioned Red Deer. How do you have access to those?
JE - Well, Edmonton is quite open and they sell their units. I think our school division purchased the Grande Prairie units and made them available to all the schools through the IMC. Same with the (?Red Deer) units.

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I - So someone in the Central Office is picking up that and making these available? Have you felt there was an adequate amount of material available to you?
JE - I think so in the majority of the units. Though there's the odd one like forensic science which we're still pulling in resources for, but for the majority, there are lots of resources out there. Lots of resources.
I - Did you find any of these particularly helpful?
JE - I have a bias toward the Edmonton Public ones. I think they're very well put together, easy to use and easy to supplement and are set up so you have short 30 to 45 minute lessons that are very much student hands-on.

I - I'm curious if there were other influences, there might have been people or policies -- one you mentioned is that the school division itself brought in and had available some of these resources. Were there any others that helped or may have influenced decisions that you made?
JE – [pause] I think there were resource listings out of books and we always purchased a number of those books for the library and reference materials so, you know, there's quite an extensive selection of support materials in the library as well as the units that are prepared. I think those are the main ones.
I - I personally have a frustration that the LRDC is right in Edmonton, but there's nothing there where I can even look at the books. I hate on a limited budget to order in a $20 book because it's on the authorized list. You may find, "No, this isn't..."
JE - I think the Science Foundation was doing – we'd go through there and if there were recommended books and that kind of thing, we'd take those kinds of resources and make sure we had them. Wherever you can find recommendations, resources, like that. Teachers at Convention go to different speakers, and different workshops they've been to. I think Science Alberta has held a number and the Grande Prairie chapter has held a number of workshops. Any of those places that you go to, you see the books that they're using and you get a chance to look at them. But, you're right, to just look at the catalogue is / useless.

I - Are there other means for sharing curricular information among people in similar positions, like with other principals?
JE - Not really, no.
I - So you're all kind of on your own?
JE - We're all sort of on our own right at the moment, though we're looking at setting up things through our e-mail and our own school district Internet for doing that kind of thing. But, no, there isn't anything at the present time.

I - What do you think we should be trying to achieve in our elementary science lessons?
JE - What should we be trying to achieve? [pause] Well, the ability to think through a process and the ability to solve problems are the two areas that I'd really like to see happening. And also, there's a lot of basic knowledge there that students need to know in addition to the thinking and the problem-solving skills, an awareness of their environment, of what's around them, how things work, those kinds of things are the basic knowledge aspect of it that are pretty important.

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I - What would you expect to see in an excellent science lesson? When I say lesson, it could be a series of lessons.
JE - I would like to see the students probably develop some form of question or reason why, looking at why they're studying what they're doing. And the teacher leading them through some activities, guided activities, where they're going to be manipulating things. Some instruction to fit along with that that covers the knowledge aspect of it. And then drawing some sort of conclusions as to what they've learned. With the teacher helping and facilitating that conclusion of what they're learning through those activities.

I - What do you see as the role of the teacher in these lessons? What does the teacher do before the lesson, what do you see the teacher doing during the lesson, and what at the end?
JE - Before the lesson, I think the main thing is the gathering of resources and making sure everything is there. Of course, the planning aspect of it so they have a feel for what's going to happen during the lesson. I still believe in instruction and I think the teacher has a role to play in instruction, but in science I think they have to facilitate the questioning, the thinking, the problem-solving so that the students are doing that and they're not being just told the answers. So I see two things: the facilitator of those kinds of things and also as an instructor of some of the knowledge, the background knowledge that they need to build on to do those problem-solving and thinking activities. So a combination of two things.
I - And after the lesson?
JE - After the lesson is over? Wrapping it up and making sure that the students understand the concepts that they've been covering, the conclusions that they needed to draw. Again, facilitating it and instructing if they see that it's needed, that students haven't picked up all the things that they need to know.

I - What does a teacher need to know to be able to teach science in this way?
JE - Lots about levers and machines. [laughs] [pause] What does a teacher need to know? I think in elementary schools, over the past number of years we've been shifting more in math and in all subjects to more of the student centered [interruption]

So I think most of our teachers have started to move that way and if they haven't started to move that way already, they need to start developing the skills to lead students into problem-solving, the problem-solving skills and other techniques to lead to higher thinking skills. They need those kinds of skills. They need to be able to manipulate and handle groups and that kind of activities. In lots of ways a lot of cooperative learning-type activities. They need the skills to do that. I think most teachers have started to move in that direction.

I - Which leads into my next question. How do teachers build this knowledge?
JE – [pause] The ones I see doing it successfully are the ones that take the time and effort to go to the science conferences, to the workshops, to the different types of activities at the science conferences, at their conventions. Take that initiative and get in there and start doing it. In lots of ways, I don't know if you can -- -- you can pick up ideas, but actually to do it, you have to be in the classroom just doing it.

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But it is important, again, the ones that are successful are the ones that take that time and make that effort, for the most part, to get out and find out a few ideas here and there and see how other people are doing it, picking up a little bit here and there.

I - How is professional development planned in your district? Also, with the regional consortium?
JE - Within our district there's very little district-wide professional development. As far as I'm concerned there's not a coordinated effort by any means within the district. There is a district one, I guess put on by the ATA, a fall pd day, but whether that hits everyone's needs is debatable.
I - It's more something the ATA comes in and says, this is what ...?
JE - No, it's set up by the local professional development committee of the ATA. But, again, it has its limitations as any one day pd type of activity would have.

But [pause] it's much more site based now. So the professional development money is in the schools and once schools identify a need, they need to as a school work on that need.
I - So as a staff you sit down?
JE - Yes. And the Consortium, I think, has been a real plus for the north here, because it has coordinated and brought in so many professional development activities that it's worth lots to the rural northern areas.

[interruption - request for scoring criteria for Provincial Achievement Tests]
I - We have just talked about staff development, professional development, and you were talking about what you do as a staff, how you might plan.
JE - Now with our school setting goals and looking at that for the school, during that process I think we have to identify the professional development areas that we want to concentrate on. As a staff we need to focus on those areas through either our achievement test results or through areas that we feel we are not delivering the program or the quality that we'd like to. As a school, we have a focus and as individuals, I think teachers have a focus, too.
I - So once you identify these, what's available? What do you do then? It's nice to have something on a page, but how do you access...
JE – [short pause] We, one of the things we do is, because we have site based, we can bring in resource people. So, I mean, one of the goals we've identified for next year is our writing program, so we're bringing in a writing specialist from Edmonton to work with our staff. We do that kind of thing. Last year I'd set up a program that we were doing reading, so we'd set up with somebody from Grande Prairie to come up and do 4 or 5 days of in-services, you know, before school started during the school year. We do that kind of thing. It takes money and it takes some effort on the part of the staff to do it.
I - How do you get these professional development moneys?
JE - It's part of our budget. It's up to the school how much we set aside for professional development, but we do set aside a certain amount of our budget for professional development.

I - What is your view of exemplary professional development?
JE - I don't know if I have one of one that's exemplary.
I - To rephrase that, what seems to work really well?

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JE - What works really well? Teachers that want to improve and then they will find the resources and the workshop will come along and we will find the people if there's that initial enthusiasm or interest by the teachers to do some improvement. So I see my role as administrator to try to facilitate that enthusiasm, and to build it and to encourage it and to support it and to tweak it in whichever way I can to get people interested in pursuing it. And once we have that interest, there are resources out there. Maybe not as easy as in Edmonton to find, but they certainly are there and we do it.
I - Do you find if someone becomes interested and enthusiastic this builds? Other teachers say, "Oh, yeah"?
JE - Oh, definitely. I think this staff has done a fantastic job here. The new science curriculum is a good example. The achievement test scores, the results of the school, were terrible in science three or four years ago and they brought them right up, well above provincial average, just because a few people were interested and started going out and were enthusiastic about it.

I - Thank you. That's my series of questions.

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APPENDIX E

Overview to Program of Studies

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SCIENCE

A. PROGRAM OVERVIEW

RATIONALE

Children have a natural curiosity about their surroundings—a desire to explore and investigate, see inside things, find out how things work and find answers to their questions. Learning about science provides a framework for students to understand and interpret the world around them.

An elementary science program engages students in a process of inquiry and problem solving in which they develop both knowledge and skills. The purpose of the program is to encourage and stimulate children's learning by nurturing their sense of wonderment, by developing skill and confidence in investigating their surroundings and by building a foundation of experience and understanding upon which later learning can be based.

Elementary and secondary science programs help prepare students for life in a rapidly changing world—a world of expanding knowledge and technology in which new challenges and opportunities continually arise. Tomorrow's citizens will live in a changing environment in which increasingly complex questions and issues will need to be addressed. The decisions and actions of future citizens need to be based on an awareness and understanding of their world and on the ability to ask relevant questions, seek answers, define problems and find solutions.

PHILOSOPHY

The science program of studies is built on the following principles.

- **Children's curiosity provides a natural starting point for learning.**

  Young children are natural inquirers and problem solvers. They have a keen interest in the materials around them and move naturally into activities that involve manipulation of materials, exploration and discovery. Science in the elementary school years should nurture and extend this curiosity, so that students continue to question, explore and investigate, with increasing levels of insight and skill.

- **Children's learning builds on what they currently know and can do.**

  Children's initial concepts of the world influence what they observe and how they interpret the events they experience. They enter school having learned a great deal about their world through play and exploration. They show extensive practical knowledge about materials in their environment, as well as the ability to observe, question, test, construct and create. Science experiences in the elementary years are designed to build on the knowledge that students already have and to extend and sharpen their investigative skills.

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As children progress in learning, they add to their knowledge and modify their ideas and ways of viewing the world. Where, in the early years, children view their experiences as personal and immediate; in later years, they become aware of order and continuity in the world extending beyond their personal experience. As they grow in this awareness, they discover new patterns in things—patterns of structure, patterns in the order of events and patterns in the way that materials interact. The science program is designed to assist students in discovering and interpreting these patterns and to help them connect new ideas with their existing knowledge.

- **Communication is essential for science learning.**

Language provides a means for students to develop and explore their ideas and to express what they have learned. By communicating their questions, observations, discoveries, predictions and conclusions, they can refine and consolidate their learning and identify new connections and avenues to explore. As children relate their experiences and ideas to one another, they naturally make new connections that are not fully realized until they are put into words.

Language also plays a role in developing the skills of inquiry and problem solving. The actions of identifying problems, asking questions and proposing ideas requires the use of a particular kind of language. The ability to define problems and ask clear questions is a keystone to growth in this area.

- **Students learn best when they are challenged and actively involved.**

Students learn best when they become personally involved in their learning—not just when they mechanically follow a set of steps or read and hear about things learned and done by others. Active inquiry and problem solving can be stimulated by providing an initial focus and challenge for learning, by engaging students in developing or adapting a plan of action and by involving students in evaluating results. By participating in activities and reflecting on the meaning of what they do, students develop the skills of learning how to learn and achieve depth in their understanding.

- **Confidence and self-reliance are important outcomes of learning.**

Children develop confidence when their ideas and contributions are valued and when there is a supportive climate for learning. By providing opportunities for students to explore ideas and materials, engage in open-ended activities and evaluate their own progress, they can be encouraged to take initiative in learning. When questions and problems are referred back to students and their ideas and decisions are supported, they learn to become more self-reliant. Confidence is achieved as students recognize that the knowledge and skills they have gained enable a measure of independent action.

The personal skills that students develop in school—the ability to make decisions, to plan and to evaluate their own progress—are skills that apply throughout life.

PROGRAM EMPHASIS

Children learn to inquire and solve problems in a variety of contexts. Each subject area within the elementary program provides a rich source of topics for developing questions, problems and issues, that provide starting points for inquiry and problem solving. By engaging in the search for answers, solutions and decisions, students have a purpose for learning and an opportunity to develop concepts and skills within a meaningful context.

The learner expectations for the elementary science program are linked to two main areas of skill emphasis: science inquiry and problem solving through technology. The skills developed

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in these two areas are related, but have a somewhat different focus. In science inquiry, the focus is on asking questions and finding answers based on evidence. The outcome of inquiry is knowledge. In problem solving through technology, the focus is on practical tasks—finding ways of making and doing things to meet a given need, using available materials. The outcome of problem solving is a product or process that a person can use.

Science Inquiry

Inquiry is the process of finding answers to questions. The skills of science inquiry include asking questions, proposing ideas, observing, experimenting, and interpreting the evidence that is gathered. Observation and evidence are key elements.

An inquiry may be initiated in a variety of ways. It may be based on a question brought to the classroom by a teacher or student; or it may arise out of an activity, an interesting observation, an unexplained event or a pattern that appears worth pursuing. Engagement in inquiry is not a linear process; it can have a variety of starting points, and the steps followed may vary from one inquiry activity to another. When an unexpected observation is made or a procedure does not work, there is opportunity for new ideas to emerge and a new set of procedures to be followed.

Problem Solving through Technology

Problem solving refers to a variety of processes used to obtain a desired result. The skills of problem solving include identifying what is needed, proposing ways of solving the problem, trying out ideas and evaluating how things work.

In problem solving, as in inquiry, the process is usually not a linear one. Often, processes that will be needed to solve a problem are not foreseen in advance; and there may be repeated cycles of reflection, developing new ideas and trying new approaches, all within the larger pattern of the activity.

Challenging problems require persistence. An idea may not work at first; but with careful observation, adjustment, reflection and refinement, a solution that is close to the original idea may be found. Student success in inquiry and problem solving is enhanced when students have the opportunity to explore materials in an unstructured way, before starting formal investigations. Progress frequently involves trial and error, in which initial ideas are discarded and new ideas and processes are developed. A supportive climate for trying new ideas can be critically important to the development of student confidence and competence in their investigative skills.

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APPENDIX F

Grade Four Learner Expectations

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GRADE 4

SKILLS

These skills apply to the five topics of study identified for Grade 4. The organization of these skills reflects a general pattern of science activity, not a fixed instructional sequence. At Grade 4, students normally will show independence and the ability to work with others in exploratory activities and, with guidance, a beginning level of independence in investigating questions and problems. At this level, students should be able to recognize the purpose of most steps followed in investigating questions and problems.

Science Inquiry	Problem Solving through Technology
General Learner Expectations *Students will:* **4–1 Investigate the nature of things, demonstrating purposeful action that leads to inferences supported by observations.** **4–2 Identify patterns and order in objects and events studied; and record observations, using pictures, words and charts, with guidance in the construction of charts; and make predictions and generalizations, based on observations.**	**General Learner Expectations** *Students will:* **4–3 Investigate a practical problem, and develop a possible solution.** **Note:** *The problem will involve building a structure with moving parts, using available materials.*

Specific Learner Expectations	Specific Learner Expectations
Students will: **Focus** • ask questions that lead to exploration and investigation • identify one or more possible answers to questions by stating a prediction or a hypothesis **Explore and Investigate** • identify, with guidance, ways of finding answers to given questions • carry out, with guidance, procedures that comprise a fair test • identify materials and how they are used • work independently or with others to carry out the identified procedures • identify, with guidance, sources of information and ideas and access information and ideas from those sources. Sources may include library, classroom, community and computer-based resources	*Students will:* **Focus** • identify the purpose of problem-solving and construction activities: What problem do we need to solve? What needs must be met? **Explore and Investigate** • identify steps followed in completing the task and in testing the product • identify materials and how they are used • attempt a variety of strategies and modify procedures, as needed (troubleshoot problems) • engage in all parts of the task and support the efforts of others • identify, with guidance, sources of information and ideas and access information and ideas from those sources. Sources may include library, classroom, community and computer-based resources

continued

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continued

Reflect and Interpret	Reflect and Interpret
• communicate with group members, showing ability to contribute and receive ideas • record observations and measurements accurately, using captioned pictures and charts, with guidance in the construction of charts. Computer resources may be used for record keeping and for display and interpretation of data • state an inference, based on observations • identify possible applications of what was learned • identify new questions that arise from what was learned.	• communicate with group members, showing ability to contribute and receive ideas • evaluate a product, based on a given set of questions or criteria. The criteria/questions may be provided by the teacher or developed by the students. Example criteria include: – effectiveness—Does it work? – reliability—Does it work every time? – durability—Does it stand up to repeated use? – effort—Is it easy to construct? Is it easy to use? – safety—Are there any risks of hurting oneself in making it or using it? – use of materials—Can it be made cheaply with available materials? Does it use recycled materials, and can the materials be used again? • identify possible improvements to the product • identify new applications for the design or method of construction.

ATTITUDES

These attitudes apply across the five topics of study identified for Grade 4.

General Learner Expectations

Students will:

4–4 Demonstrate positive attitudes for the study of science and for the application of science in responsible ways.

Specific Learner Expectations

Students will show growth in acquiring and applying the following traits:
- curiosity
- confidence in personal ability to explore materials and learn by direct study
- inventiveness and willingness to consider new ideas
- perseverance in the search for understandings and for solutions to problems
- a willingness to base their conclusions and actions on the evidence of their own experiences
- a willingness to work with others in shared activities and in sharing of experiences
- appreciation of the benefits gained from shared effort and cooperation
- a sense of responsibility for personal and group actions
- respect for living things and environments, and commitment for their care.

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UNDERSTANDINGS

Topic A: Waste and Our World

Overview

Students learn about wastes produced through natural processes and human technology. In studying natural systems, students learn that all plants, animals and other living things are made up of materials that are recycled through the environment again and again. In studying human consumption and wastes, students identify wastes produced within their community and learn the methods used for disposal. They learn that some waste materials are biodegradable, that some are reusable, and that others are toxic. They learn that personal action in reducing, reusing and recycling materials can help decrease the waste we accumulate.

General Learner Expectations

Students will:

4–5 Recognize that human activity can lead to the production of wastes, and identify alternatives for the responsible use and disposal of materials.

Specific Learner Expectations

Students will:

1. Identify plant and animal wastes, and describe how they are recycled in nature. For example, plant leaves serve as a source of food for soil insects, worms and other creatures. The wastes of these animals may then be further broken down by molds, fungi and bacteria.
2. Identify and classify wastes that result from human activity.
3. Describe alternative methods of disposal, and identify possible advantages and disadvantages of each.
4. Distinguish between wastes that are readily biodegradable and those that are not.
5. Compare different kinds of packaging, and infer the relative advantages and disadvantages of that packaging. In evaluating different forms of packaging, students should demonstrate the ability to consider a consumer perspective as well as an environmental perspective.
6. Identify methods of waste disposal currently used within the local community.
7. Identify kinds of wastes that may be toxic to people and to the environment.
8. Identify alternative materials and processes that may decrease the amount of waste produced; e.g., reducing wastage of food, using both sides of a sheet of paper.
9. Identify ways in which materials can be reused or recycled, including examples of things that the student has done.
10. Develop a flow chart for a consumer product that indicates the source materials, final product, its use and method of disposal.
11. Identify actions that individuals and groups can take to minimize the production of wastes, to recycle or reuse wastes and to ensure the safe handling and disposal of wastes.
12. Develop and implement a plan to reduce waste, and monitor what happens over a period of time.

Topic B: Wheels and Levers

Overview

Students learn about basic components of simple machines: how they are assembled, how they operate, how they are used. Students explore different techniques that can be used to transfer motion from one component to another, using simple connectors and various levers, gears, pulleys and band driven systems. As they work with these components, they learn the functions that each can perform, including sample applications and ways that they can be used in a larger system. As part of their studies, they examine how these simple machines are used to change the speed or force of movement.

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General Learner Expectations

Students will:

4–6 Demonstrate a practical understanding of wheels, gears and levers by constructing devices in which energy is transferred to produce motion.

Specific Learner Expectations

Students will:

1. Explain how rollers can be used to move an object, and demonstrate the use of rollers in a practical situation.
2. Compare the wheel and the roller, and identify examples where each are used.
3. Construct devices that use wheels and axles, and demonstrate and describe their use in:
   - model vehicles
   - pulley systems
   - gear systems.
4. Construct and explain the operation of a drive system that uses one or more of the following:
   - wheel-to-wheel contact
   - a belt or elastic
   - a chain
   - cogs or gears.
5. Construct and explain the operation of a drive system that transfers motion from one shaft to a second shaft, where the second shaft is:
   - parallel to the first
   - at a 90° angle to the first.

   Students who have achieved this expectation will be aware of changes in speed and direction that result from different ways of linking components. Introduction of gear ratios, however, is not recommended at this grade level. Students will have an opportunity to develop the concept of ratio as part of their junior high mathematics program.
6. Demonstrate ways to use a lever that:
   - applies a small force to create a large force
   - applies a small movement to create a large movement.
7. Predict how changes in the size of a lever or the position of the fulcrum will affect the forces and movements involved.
8. Construct models of levers; and explain how levers are involved in such devices as: teeter-totters, scissors, pliers, pry bars, tongs, nutcrackers, fishing rods, wheelbarrows.

Topic C: Building Devices and Vehicles that Move

Overview

Students apply simple techniques and tools in building devices and vehicles that move. In constructing these objects, students apply previous learnings about structures and explore new applications for wheels, rollers, gears, pulleys and a variety of levers and connectors. They learn that different forms of energy can be used to propel their model devices: in some cases, a direct push; in other cases, the stored energy from a compressed spring or falling weight. On completing their projects, students learn to evaluate their work, by describing the effectiveness of the device and the appropriateness of materials used.

General Learner Expectations

Students will:

4–7 Construct a mechanical device for a designated purpose, using materials and design suggestions provided.

Note: One or more components of the task will be open-ended and require students to determine the specific procedure to be followed.

4–8 Explore and evaluate variations to the design of a mechanical device, demonstrating that control is an important element in the design and construction of that device.

Specific Learner Expectations

Students will:

1. Design and construct devices and vehicles that move or have moving parts—linkages, wheels and axles.
2. Use simple forces to power or propel a device; e.g., direct pushes, pulls, cranking mechanisms, moving air, moving water and downhill motion.

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3. Design and construct devices and vehicles that employ energy-storing or energy-consuming components that will cause motion; e.g., elastic bands, springs, gravity, wind, moving water.
4. Recognize the need for control in mechanical devices, and apply control mechanisms where necessary.
5. Compare two designs, identifying the relative strengths and weaknesses of each.
6. Identify steps to be used in constructing a device or vehicle, and work cooperatively with other students to construct the device or vehicle.
7. Design and construct several different models of a device and evaluate each model, working cooperatively with other students. Suggested evaluation criteria are identified under the Specific Learner Expectations, Reflect and Interpret, page B.18.

Topic D: Light and Shadows

Overview

Students learn about light by studying the effects of light on things within their environment. They learn about light sources, about materials that light can pass through and about what happens when a material blocks or changes the path of light. By observing shadows and their motions relative to a light source, students discover that light and shadows fall along a predictable path. They discover that mirrors, prisms and a variety of other materials can affect that path by reflecting and refracting light and by splitting light into colours.

General Learner Expectations

Students will:

4–9 Identify sources of light, describe the interaction of light with different materials, and infer the pathway of a light beam.

Specific Learner Expectations

Students will:

1. Recognize that eyes can be damaged by bright lights and that one should not look at the Sun—either directly or with binoculars or telescopes.
2. Identify a wide range of sources of light, including the Sun, various forms of electric lights, flames, and materials that glow (luminescent materials).
3. Distinguish objects that emit their own light from those that require an external source of light in order to be seen.
4. Demonstrate that light travels outward from a source and continues unless blocked by an opaque material.
5. Describe changes in the size and location of Sun shadows during the day—early morning, to midday, to late afternoon.
6. Recognize that opaque materials cast shadows, and predict changes in the size and location of shadows resulting from the movement of a light source or from the movement of a shade-casting object.
7. Distinguish transparent materials from opaque materials by determining if light passes through them and by examining their shadows.
8. Classify materials as transparent, partly transparent (translucent) or opaque.
9. Recognize that light can be reflected and that shiny surfaces, such as polished metals and mirrors, are good reflectors.
10. Recognize that light can be bent (refracted) and that such objects as aquaria, prisms and lenses can be used to show that light beams can be bent.
11. Recognize that light can be broken into colours and that different colours of light can be combined to form a new colour.
12. Demonstrate the ability to use a variety of optical devices, describe how they are used, and describe their general structure. Suggested examples include: hand lens, telescope, microscope, pinhole camera, light-sensitive paper, camera, kaleidoscope. Students meeting this expectation will be able to provide practical descriptions of the operation of such devices, but are not required to provide theoretical explanations of how the devices work.

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Topic E: Plant Growth and Changes

Overview

Students learn about the structure and growth of plants by raising plants in the classroom and by observing plant growth within the community. They learn to recognize and describe different forms of leaves, stems, roots and flowers and learn their functions in supporting the growth and reproduction of the plant. They learn various ways of starting new plants and the plants' requirements for growth. Through hands-on activities, students learn that different plants have different needs, and they gain skills and attitudes for their care.

General Learner Expectations

Students will:

4–10 Demonstrate knowledge and skills for the study, interpretation, propagation and enhancement of plant growth.

Specific Learner Expectations

Students will:

1. Describe the importance of plants to humans and their importance to the natural environment. Students who meet this expectation should be able to give examples of plants being used as a source of food or shelter, and be aware of the role plants play in the environment; e.g., preventing erosion, maintaining oxygen.
2. Identify and describe the general purpose of plant roots, stems, leaves and flowers.
3. Describe common plants, and classify them on the basis of their characteristics and uses.
4. Recognize that plant requirements for growth; i.e., air, light energy, water, nutrients and space; vary from plant to plant and that other conditions; e.g., temperature and humidity; may also be important to the growth of particular plants.
5. Identify examples of plants that have special needs.
6. Recognize that a variety of plant communities can be found within the local area and that differences in plant communities are related to variations in the amount of light, water and other conditions.
7. Recognize that plants of the same kind have a common life cycle and produce new plants that are similar, but not identical, to the parent plants.
8. Describe ways that various flowering plants can be propagated, including from seed, from cuttings, from bulbs and by runners.
9. Nurture a plant through one complete life cycle—from seed to seed.
10. Describe the care and growth of a plant that students have nurtured, in particular:
    - identify the light, temperature, water and growing medium requirements of the plant
    - identify the life stages of the plant
    - identify the reproductive structures of the plant.
11. Describe different ways that seeds are distributed; e.g., by wind, by animals; and recognize seed adaptations for different methods of distribution.

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APPENDIX G

Achievement Test Questions

Examples from: Alberta Education, 1997, Grade 6 Achievement Test, Science

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Knowledge-based questions

7. Peter and Natalie found the takeoff exciting. When they reached the correct altitude, the pilot made the airplane fly horizontally by

   A. tilting the ailerons up
   B. tilting the elevators down
   C. adding more weight to the tail
   D. reducing the weight on the nose

18. As they walked, Uncle Jake explained that although trees provide shelter, food, fuel, and tools for humans, they are **most** important for giving off

    A. oxygen
    B. carbon dioxide
    C. nitrogen
    D. hydrogen

25. While consulting the science book, Peter and Natalie found that compared with planets far away, the four planets **closest** to the Sun have **more**

    A. surface area than do the planets farther away
    B. gravity than do the planets farther away
    C. atmosphere than do the planets farther away
    D. intense sunlight than do the planets farther away

49. Inspector Drake told his assistant to perform a chromotography test on the ransom note. She knew that for this test it is necessary to control the

    A. shape of the coloured pattern
    B. dye colour of the ink
    C. size of the paper
    D. type of the paper

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Skill-based questions

Use the following information to answer question 6.

Before their flight, the pilot asked the air traffic control tower for the wind speed and air temperature. He had Peter look at the following wind chill chart.

Wind Chill Chart

Wind speed km/h	Temperature °C							
	0	-5	-10	-15	-20	-25	-30	-35
10	-2	-7	-12	-17	-22	-27	-32	-38
20	-7	-13	-19	-25	-31	-37	-43	-50
30	-11	-17	-24	-31	-37	-44	-50	-57
40	-13	-20	-27	-34	-41	-48	-55	-62
50	-15	-22	-29	-36	-44	-51	-58	-66
60	-16	-23	-31	-38	-45	-53	-60	-68

6. If the outside temperature is -5°C, how cold would it feel with a wind speed of 40 km/h?

A. -7°C
B. -13°C
C. -20°C
D. -40°C

That night, while looking at the stars, Natalie decided to consult her science book. She found the following table, which shows the distance of some planets from the Sun and the time required for each to circle the Sun.

Planet	Distance from the Sun (million kilometres)	Time for planet to circle the Sun
Mercury	58	88 days
Venus	108	225 days
Earth	150	1 year
Jupiter	780	12 years
Uranus	2 870	84 years
Neptune	4 500	165 years

24. From this information, Natalie hypothesized that the planet Saturn, 1 430 million kilometres from the Sun, would circle the Sun about once every

A. 100 days
B. 10 years
C. 30 years
D. 100 years

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While flying over the Rocky Mountains, they noticed that all the trees had been removed from many mountain slopes and valleys. Natalie remembered that clear-cut logging could result in wind and water erosion.

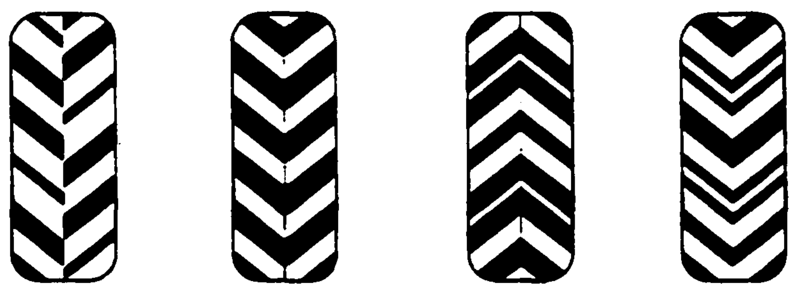
32. Natalie inferred that in forested areas trees

A. decrease wildlife
B. increase wind currents
C. decrease rainfall
D. increase soil stability

Use the following information to answer question 46.

The footprints stopped a short distance from the school. Megan looked closely on the ground and found a partial bike tire track in the mud.

She visited a local bike shop and obtained samples of four different bike tire tracks.



AKKO PYRON DESCAN FOSTIER

46. The partial bike tire track that Megan found in the mud matched the

A. Akko tire
B. Pyron tire
C. Descan tire
D. Fostier tire

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APPENDIX H

Pattern-indicating statements

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Participant		Pattern-indicating statements
William	T1	This is what we're aiming for. This is what you will come out of it with.
Tanya	T2	If you don't understand what they're trying to discover, it's hard to ask them the right question or point them in the right direction so they can do the discovering.
Maryanne	T3	You know, this happened and we didn't think it was going to happen. If we tried, could we make it happen again? And if we can....can we explain this? Does it lead to another question?
Alice	T4	There's a time for kids to explore... a time for discussion and sharing....The lessons are designed to sort of channel you into that one main conclusion.
Rosemary	T5	The idea of discovery... not telling them how it's going to turn out, letting them do some discovering on their own. Making sure they're recording their findings and they're handling the materials as intended.
Kathy	T6	I see myself as creating situations.... Setting the scene and then letting them go off and do things. And then taking a look at what happened and why do they think that happened.
Esther	T7	There are always some kids doing the experiments and not quite getting out of it what they should be and they aren't really drawing the conclusions.
Jane	T8	Answers too abbreviated to classify
James	T9	They have to kind of feel free....not just rigidly bound by your thought. ... In a log book, they tell me what they've done and they tell me why, whatever they did, and why they think it worked, in their own way.
Liz	T10	I find science a real challenge....I don't do it [teach science] easily.... I think it's my job to make sure everyone gets a little bit out of it.
Sharon	T11	Teaching science is a very hands-on activity where people learn different things and we learn more when the experiment doesn't go the way it's supposed to in the book than we do when it does work.
Jennie	T12	Starting off we had a discussion.... They're thinking about what we're doing. ...We have to have some kind of a worksheet every day.... We meet in grade groups and try to write the same tests and quizzes...so when we have a percentage at the end, we feel there won't be a big difference in the rooms.
Muriel	P1	It's important that kids know what their purpose is, what we're going to look at, what we're going to learn. And at the end, [the teacher] is pulling answers, the conclusions from the kids.
Deanna	P2	Finding ways to celebrate what children can do well. I think at some point, good old direct teaching still has an important role to play....In follow-up, making sure the activities actually achieved

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		the outcomes you were hoping for....Teachers have had to work on developing notes for the kids to support the learning.
Lena	P3	Discussing ideas with the children. ... At the end, asking what did we learn, what worked, what didn't work. Is this the true answer or did it just not work because something wasn't put together right?
Bertha	P4	Science just made no sense to me....I want the kids really engaged in the exploration. And I want it to stimulate all kinds of thought.... I don't much want to see them taking notes and memorizing scientific principles.
Jeff	P5	I'd like to see students probably develop some form of question or reason why....Some instruction to fit with that [guided discovery] that covers the knowledge aspects of it....Wrapping it up and making sure that the students understand the concepts they've been covering, the conclusions that they needed to draw.
Isabelle	P6	At the end, summarize it.... Having the teacher say, "Ok, it worked. What worked? How did it work? It didn't work. What could you have done?"
Peter	P7	She has to take that information and bring it down to something that is meaningful to these students....You have to take them where they [students] are at, start exploring.... using the natural curiosity that the child has.
Jackson	P8	You have to have a product....Having enough of a framework for those students that need to be lead through – this is step one, step two, step three, step four. That would be wonderful to see.
Ralph	P9	During the class, they have to have some way they're going to either present the information or have the child discover the information.... At the end, you have to ask yourself the question, did they learn it?
Marlene	P10	Working towards finding out what's true, which is the solution, and to be able to observe and really see what's going on. And trying to put it all together.
Lyndon	P11	Knowing ahead of time what they're trying to accomplish, what the purpose is for the investigation. You have to know what they have to do, and they have to know why they are doing it. Doing some documenting at the end. I guess you'd see a little bit of theory, whether it's from a back-up text or something...application type of theory.
Constance	CF1	Teacher starts by leading her students, "Today this is what we're going to learn. This is what we're going to discover; this is what is going to happen....[At the end] If the experiment didn't work, why didn't it work, what happened? The book said it should happen this way, well it didn't. What happened?

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Mary	CF2	They're asking the questions, they're saying, "Well, I've got this stuff. What could I be doing?"... They [students] need time to talk to each other... where they're talking about their understanding and listening to other people's understandings and trying to figure something out.
Ken	CF3	Students sharing ideas with each other...stopping and saying, "Do I understand what's going on?"... Opportunities for students to do a variety of different kinds of things.
Russell	CF4	The majority of the lesson would involve the children exploring, in their own way, the topic. The teacher would then draw them back in again and discuss not just what they had found out, but how they explored. And the results of the exploration would be relatively minor.
Susan	CF5	The teacher needs to be very clear, this is the concept that I want the children to come out with...this is the way it goes, this is what we're trying to do here....And go through the lesson with the kids. "You know you can expect to see this, you know, be prepared."
Davis	CF6	Teachers have it pretty well set what their objectives are. And by objectives I mean, "Students will be able to ____ by the time they're done." It would be written on the wall what they're trying to accomplish today.
	C1	Students are interacting with things in the environment ... seeing patterns emerge....being caused to reflect and maybe look for some extensions into other things....A lot of what is happening is not according to plan.
	U1	Develop their thinking ability, their reasoning ability....Make sure that their understanding is accurate.
	U2	A classroom where kids are doing the thinking... The teacher is not the main director of what's happening.
Art	SP1	Opportunities for students to come up with questions....Ensuring that the outcomes or the important parts of the lesson or activities are documented by the students in preparation for the provincial exams or whatever assessment vehicle you might be using.
Florence	SP2	Hands-on problem solving....ensuring they understand the concept
Ruth	SP3	We want to make sure we're allowing them to discover, not necessarily teaching them there are all right and wrong answers. That there probably are several answers.

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APPENDIX I

Three-year Business Schedule

From: Alberta Education, 1994b

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Three-Year Business Plan Schedule for Restructuring Education

	Selected Key Strategies	Fiscal Years 1994/95	1995/96	1996/97
Goal 1	**Set High Standards for Education**			
	• Clear learning outcomes and high standards for core subjects are completed and communicated			X
	• Career and Technology Studies, involving business in delivery, implemented			X
Goal 2	**Provide More Choice and Increase Parental Involvement**			
	• Local attendance boundaries removed			X
	• Charter schools piloted		X	
Goal 3	**Improve Coordination of Services for Special Needs Children**			
	• Recommendations from pilot projects implemented		X	
Goal 4	**Improve Teaching**			
	• Teacher certification requirements updated		X	
	• Competencies for beginning and experienced teachers established			X
Goal 5	**Restructure Education System**			
	• Legislation to restructure education enacted	X		
	• Site-based management implemented			X
	• Number of school boards reduced to about 60		X	
	• Roles and responsibilities of schools, school boards and the Department clarified	X		
	• Francophone governance implemented	X		
Goal 6	**Ensure Equitable and Adequate Funding**			
	• Provincial requisition and distribution of education property taxes	X		
	• Uniform provincial mill rates			X
	• New provincial funding framework implemented		X	
	• Funding distributed to schools through school boards		X	
	• Incentives to schools to recognize student achievement		X	
Goal 7	**Reduce and Restructure Education**			
	• Education reorganized and downsized 20%		X	
	• Cost recovery of Department services increased		X	
Goal 8	**Cost of Education is Reasonable and Under Control**			
	• Budget reduction target of $255 million met			X
	• School board spending on administration and capital reduced	X		
	• The provincial education mill rates are at or below the 1993 averages			X
Goal 9	**More Accountable Education System**			
	• Provincial assessment program expanded		X	
	• Value for money audits fully implemented			X
	• School and board public reports on designated measures initiated		X	
	• Joint selection of school superintendents by the province completed			X
	• School jurisdiction business plans required		X	

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