SCIENCE IN THE MOST CURIOUS PLACES:
AN ANALYSIS OF AN IN-SERVICE SCIENCE EDUCATION PROGRAM FOR ELEMENTARY SCHOOL TEACHERS

by

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B.Ed., Simon Fraser University, 1979

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in the Faculty

of

Education

SIMON FRASER UNIVERSITY

July 1993

APPROVAL

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Degree: Master of Science

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ABSTRACT

According to recent reports, few elementary school students receive an adequate education in science, particularly in physical science. These reports go on to suggest that sustained and structured in-service programs can assist teachers who want to teach more science in their classrooms.

This thesis is an exploratory, qualitative analysis of the effectiveness of an in-service science program for elementary teachers, specifically focussing on the experiences of some of the participants. The program consisted of a one week institute, conducted at Science World, British Columbia in August, 1991, and a subsequent field-based implementation course offered by Simon Fraser University, during the Fall term of 1991. Was this combination of summer institute and implementation course an effective and appropriate way to assist teachers who want to do more and better science with their students? How well did it address the "problem of elementary science education"?

My relationship with the teachers evolved over two years from "participant" in the summer institute to "facilitator" during the implementation course and to "researcher" in the follow-up study. This multi-role perspective enabled me to develop a substantial and unique database for the study. Three aspects of the participating teachers' experiences focussed the analysis of the database: their perceptions of what constitutes science education, the nature of their own development as science teachers, and how children learn science.

The results indicate that the teachers perceived a dramatic shift in their science teaching due to their experiences in the program. Several perspectives on the purposes of science education were evident in teachers' discussions about their teaching, suggesting a broadening of the participants' scientific literacy. The study suggests that, while the changes were apparently meaningful for the teachers, they were neither superficial nor complete. The teachers also expressed an appreciation of a constructivist perspective on the learning and teaching of science in the classroom.

It is argued that these changes are principally due to the teachers' experiences in the classroom-based implementation course, which provided them with an on-going, supportive environment, based in their own practice. The study also indicates that the need for collegial, professional interactions in the working lives of elementary classroom teachers is seriously under-estimated. These insights have implications for the design and structure of teacher in-service programs, particularly in science education.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the assistance and support of a number of other people. My thanks to Dr. Allan MacKinnon; no matter how busy you were, you always made me feel that my work was the most important thing on your mind. Thanks also to Dr. Marvin Wideen whose contributions, particularly in the later stages of the thesis, were greatly appreciated.

I am particularly grateful for the support and encouragement of my wife Anne, and my daughters Jean and Suzanne. You will all be relieved, I am sure, to find that I no longer spend my waking hours in the basement sitting at the computer.

I must also express my gratitude to the teachers with whom I worked over the past two years, who cheerfully made the time for meetings and interviews in their busy schedules to help me in my research. Thank you April, Charly, Dick, Ingrid, James, Lynne and Sarah.

Table of Contents

Chapter 1

INTRODUCTION

This thesis has its origins in a parent-teacher interview in November, 1990. My daughter Jean was in grade 3 and had proudly brought home her report card which documented her progress in math, social studies, language arts, P.E. and music, but there was no mention of science. When we asked her teacher about this, she replied, "Well, since we haven't done any science this year, I felt a comment would be inappropriate." For the remainder of the school year, Jean's "science" consisted of written assignments and reports on topics within the themes of Space or Whales. Unfortunately her situation is all too common in elementary classrooms where science is often neglected or "integrated" into humanities-based themes, and "the problem of elementary science education" is well documented and acknowledged (American Association for the Advancement of Science, 1989; Bateson *et al.*, 1992; Lapointe, Mead & Phillips, 1989; Loucks-Horsley *et al.*, 1989; Science Council of Canada, 1984).

Most of these studies indicate that much of elementary science teaching, when it does occur, is unsatisfactory and does not correspond to the science component of the prescribed curriculum. They also recognize the classroom teacher's pivotal role in any attempt to improve the situation, and recommend the provision of appropriate, in-service support for science education. At the same time, however, there has been a loss of confidence in "top-down" prescribed curriculum and implementation models that are technical and reductionist in their approach. This thesis examines the problem of providing and assessing an in-service professional development program for elementary teachers that is designed to enhance the science teaching in their classrooms.

What *can* be done to get more "real science" into elementary classrooms? Real science is more than a report copied from an encyclopaedia and embellished with pictures cut from magazines. "Science plus thinking equals sciencing [and] in sciencing, the emphasis is on finding out. We don't look for the answers we already know" (Wasserman & Ivany, 1988, p. 6). Science is a process of wondering, questioning and investigating the world around us. It involves all the senses in practical hands-on activities so that each child develops a set of personal experiences which serves as a base and context for future learning. How can teachers be helped and supported so that more of their students – our children – experience this kind of science education?

My interest in these questions led to my involvement in the week-long summer institute "Science in the Most Curious Places" in August,

1991. The institute was a collaboration of the Education staff at Science World, British Columbia – a science centre in Vancouver – and the Faculty of Education at Simon Fraser University (SFU). It attracted twenty-four primary and intermediate teachers who had not had extensive preparation to teach science (i.e., science courses and science education classes) but who were motivated to bring more science into their teaching. Nine of the teachers also enrolled in the field-based implementation course, Education 384 – also known as "Comet" – offered by the Faculty of Education at SFU in the fall term as a follow-up to the summer institute.

The Research Problem

Is this combination of summer institute and implementation course an effective and appropriate way to assist teachers who want to do more and better science with their students? How well does it address the "problem of elementary science education?" This thesis will examine the effectiveness of the summer institute and the follow-up Comet course as a science in-service program. In particular, it will try to gauge the long term effects of the program on the teaching of the participants. The examination will focus on the perceptions of the participants and how they make sense of their experiences during the course and in the year of teaching which has elapsed since the program ended.

Three key aspects of the teachers' experiences have been selected to analyse the database: their perceptions of what constitutes science education, their perspectives on how children learn science, and the nature of their own development as science teachers. Each of these aspects will now be described in more detail to provide a theoretical framework for the thesis.

What Constitutes Science Education

During a four-year study of science education in Canadian public schools undertaken by the Science Council of Canada (1984,a,b,c), a number of discussion papers were produced. In one of them, Roberts (1983) argued that a science curriculum intended to promote scientific literacy should reflect a balance among the different curricular intentions that have appeared in science teaching over the years. He pointed out that science teaching has two interwoven components: the *content* and the *intent*. The content is what is to be learned by the student and the intent is why it should be learned. Roberts called these intentions "curriculum emphases" and, by analysing science texts and curriculum documents from the past century, he identified seven distinct emphases, each of which represents a different purpose for learning science.

The *Everyday Coping* emphasis orients science teaching to an understanding of objects and events which are familiar and relevant to the student. A *Structure of Science* emphasis presents science as an intellectual enterprise and is concerned with the relationship between evidence and theory, the adequacy of models and other such issues in the development of scientific knowledge. *Science, Technology and Decisions*, also referred to as Science, Technology and Society, is currently quite fashionable in North America, Britain, Europe and Australia and looks at the limitations and implications of science as it is used by society.

The *Scientific Skill Development* emphasis teaches science content in order to develop skills such as observing, measuring and hypothesizing. The emphasis is on the *means* of scientific inquiry. In contrast, the *Correct Explanations* emphasis is concerned mainly with the *ends* of scientific inquiry. Another pragmatic approach is the *Solid Foundation* which justifies the learning of this year's content as preparation for next year. The *Self as Explainer* emphasis compares the student's own efforts to explain scientific phenomena with those of scientists, and takes the cultural contexts of the student and scientist into account. The development of scientific ideas is presented as a function of human purpose.

Scientific Literacy, according to Roberts, has been variously defined as different combinations of the seven curriculum emphases outlined above, until it eventually has become "an umbrella concept to signify comprehensiveness in the purposes of science teaching in the schools" (p. 29). Others, however, view scientific literacy in very different ways. Miller (1983) for example, takes a political perspective and examines the implications for policy-makers of scientific literacy in different societal groups. Layton *et al.* (1986) argue for a democratization of science education which takes into account the interests and needs of specific social groups in order to increase the scientific literacy of the entire adult population. In the context of this study, I prefer Roberts' model which is based on the role of science education in the school system and how it can best address the scientific literacy of the students and, by extension, the scientific literacy of their teachers.

In a later publication, which drew heavily on his earlier discussion paper, Roberts (1988) examined some of the implications of adopting his balanced formulation of curriculum emphases. He claims that many practising teachers may not be familiar with curriculum emphases other than the one(s) they have experienced in their own schooling and pre-service training. If this is the case for those who took part in the summer institute and Comet course, then the study should try to establish which curriculum emphases were recognized by the incoming teachers, and to what extent, if any, their views were modified by their involvement in the program. Roberts' scheme provides the framework for analysing the intentions for science teaching which the teachers hold. An effective in -service science education program should broaden the scientific literacy of the teachers so that they recognize other perspectives of what constitutes science education.

> At the very least, teachers deserve to be taught that different curriculum emphases are possible, and that a particular view of what counts as science education has been selected from an array of alternatives. (Roberts, 1988, p. 51)

Roberts' argument that a curriculum designed to foster scientific literacy should show a balance among the seven curriculum emphases was embraced by the Science Council of Canada in its deliberations, and it is also apparent in the *British Columbia Assessment of Science, 1991*.

> We hope that, through the study of science, students will develop an understanding of their everyday world, that they will develop some appreciation for the nature and history of science as an area of human inquiry, and that they will become informed citizens, capable of making sound decisions with respect to science and societal issues. We hope that, through the study of science, our young people will come to know what "active inquiry" is all about, so they will learn about their own potential as rational people, and learn to trust their ability to think problems through for themselves. (Bateson *et al.*, 1992, p. xiv)

This vision of science, and why it should be part of my daughter's education, is an eloquent summary of my personal position. A science education which is a balanced combination of the appropriate curriculum emphases can be more than the sum of its parts. It can promote the growth of the individual as a competent and confident learner, and help each student towards the goal of taking responsibility for his or her own development. This ideal of science education is far removed from the reality of too many of our classrooms and, unfortunately, bears little resemblance to my daughter's experiences with her own teachers. This thesis, and other studies like it, can make a significant contribution towards a better understanding of how teachers can best be helped to develop their science teaching in coming closer to this vision.

How Children Learn Science

If "teachers teach as they were taught" (Goodlad, 1983, p. 469), then perhaps it is not surprising that much of what passes for science in elementary classrooms is unsatisfactory. Many practising teachers' experiences in science in their own schooling were traditional, content-loaded exercises in memorisation. In recent years, however, a perspective on teaching and learning known as constructivism has become a major organizing framework in curriculum reform (for example, *The Year 2000* policy documents published by the British Columbia Ministry of Education). In science education, the emphasis is shifting from "teaching by telling" to "exploring relationships, constructing meaning and developing understanding." The learner is no longer considered as a "passive recipient of knowledge" but as an "active participant in constructing knowledge," and the focus on getting the "result or right answer" has been replaced by an emphasis on the processes which will be useful in obtaining results (Bateson *et al.*, 1992, p. 62). A recent study suggests, somewhat tentatively, that teachers who hold constructivist views on the nature of science are more likely to teach science in what the authors consider to be an exemplary manner (Wideen *et al.*, 1992).

Constructivism has developed in conjunction with extensive empirical research in science education which has demonstrated that children come to school with a set of deeply held conceptions about how the natural world operates. These ideas are often quite different from conventional scientific views and are sometimes referred to as "childrens' science" (Osborne & Freyberg, 1985).

The main premise of constructivism is that a learner "constructs meaning out of new information and events as a result of the interaction of that individual's prior knowledge and experiences with current observations" (MacKinnon, 1990). Because of the variation in their past experiences, their ways of representing those experiences, and differences in their ways of thinking, individuals will construct different interpretations of the same events. New constructions are more likely to be retained, displacing or modifying previously held views, if they are considered by the learner to be more plausible and fruitful in explaining natural phenomena.

In addition to considering the presently held views which the children bring to the classroom, teachers should also take into account the emotions and feelings of the students.

> The sense of achievement, power and satisfaction, which comes from learning how to do something; the emotional satisfaction of seeing patterns in what was previously confusion; the feeling of warmth deriving from ideas and viewpoints similar to one's friends – all influence the desire for conceptual change, and the very ideas we construct and accept as of value. (Osborne & Freyberg, p. 85)

The constructivist perspective is by no means limited to childrens' learning of science and is useful in any teaching and learning situation. Loucks-Horsley *et al.* (1989) propose that:

> the process of teacher development should incorporate a theory of learning that mirrors that of student learning. Like all learners, teachers need to construct their own knowledge and theory of science learning that is developmental and that is based on experience, reflection, interaction with others and exposure to effective teaching models. This means that current teaching strategies must change, from science coursework through in-service opportunities. (p. 21)

The design of the summer institute, and especially the follow-up Comet course, reflect this recent thinking about teacher development. The question remains as to whether these were effective in promoting alternate perspectives on how children learn science and a richer understanding of, and competence in, the teaching of science in elementary schools.

<u>The Nature of Teacher Development</u>

In *The New Meaning of Educational Change* (1991) Michael Fullan presents a comprehensive argument that much of what passes for effective in-service programming is largely ineffective because it does not take into account the social and personal aspects of "real" change.

In order for a real change to take place in the practice of a teacher, there must be a period of "loss, anxiety and struggle" as the teacher works through the process of "attaching personal meaning to the experiences" (Marris, 1975, cited in Fullan, p. 31). This process requires a significant amount of time, which varies with individuals, but is an essential, social component of meaningful change. In Fullan's words:

> Real change ... represents a serious personal and collective experience characterised by ambivalence and uncertainty; and if the change works out it can result in a sense of mastery, accomplishment and professional growth. The anxieties of uncertainty and the joys of mastery are central to the subjective meaning of educational change, and to success or failure – facts that have not been recognised or appreciated in most attempts at reform. (p. 32)

The summer institute and Comet course were developed with these notions of the nature of teacher change in mind. The summer institute, designed so that it could stand on its own, was also meant to serve as the starting point of a longer initiative – a classroom-based implementation course – which would "provide some coherence and continuity for the classroom teacher who takes seriously a sustained professional development in the teaching of science-related themes" (MacKinnon, 1990, p. 1).

The activities and presentations at the summer institute were selected to focus on the teaching and learning of science, rather than on science content. The instructors were acclaimed teachers, university science educators and presenters at Science World. The emphasis on teaching was seen by the participants as a strength, lending credibility and applicability to the program. The Comet course, based on the teacher's own classroom practice, continued to emphasise the teaching and learning of science.

Teacher development which is *sustained* and *based in practice* is more likely to result in real, meaningful change, in which the participating teachers feel a sense of *ownership* (Fullan, 1991). The sense of ownership or possession of a new teaching strategy is recognized as compelling evidence that the learner is undergoing the process of real change (Joyce & Showers, 1983). These aspects of staff development will be explored in greater detail in Chapter Three.

To what extent have the participating teachers undergone real, meaningful change in their science teaching as a result of their involvement in the summer institute and Comet course? This is a significant aspect of the overall effectiveness of the in-service program which will be addressed in this study.

The Summer Institute and the Comet Course

The institute at Science World involved the teachers in a series of presentations, discussions, hands-on workshops and investigations. These activities were designed to meet the following objectives:

> To promote activity-based science instruction at the intermediate level, and develop teaching approaches that reflect science as a holistic, human endeavour, with broad concepts that are linked to other subjects.
>
> To initiate "sustained" support for intermediate teachers' professional development in science teaching.
>
> To initiate school-based curriculum development in science education. (MacKinnon, 1990)

During the institute I participated in all the activities with the teachers and also took on the role of workshop leader for some of the sessions. At the end of the week, nine of the teachers enrolled in the follow-up Comet course, for which I was the instructor.

Comet courses are equivalent to three credits of undergraduate coursework at Simon Fraser University, and are intended to "embody the principle of regarding teachers as autonomous professionals, in charge of their own teaching and learning" (Case *et al.*, 1991, p. 2). Each course begins with a week long seminar or institute – the "head" of the metaphorical comet – in which the participants are exposed to content, techniques and teaching strategies. During this intense experience, networks and support groups are established as the teachers gain confidence in a curriculum area which is new to them.

This is followed by a three-month opportunity – the "tail" of the comet – for the teachers to implement and reflect upon a self-directed project within their own school. This extended implementation period encourages utilisation of the newly learned material and provides supportive feedback from the instructor and the other members of the support networks.

The teachers who enrolled in Comet were required to design, implement and evaluate a science unit in their classroom which embodied some of the content, skills or approaches to which they had been exposed during the institute. These included hands-on activities for the classroom, "science in a bag" experiments to take home, teacher demonstrations to stimulate curiosity and questions, "Science Night" for students and families, among other activities and projects.

An integral part of the Comet course was a monthly meeting at Science World of the participants and the course facilitators from Simon Fraser University, during which they discussed their projects, progress, problems and plans. As their instructor, I had ample opportunity to observe the professional growth of the teachers as they took the giant step of doing science with their students. I was also able to visit their classrooms on several occasions, meet their colleagues and students and read the journals and progress reports which they wrote during the term.

I was particularly impressed by the supportive sense of community which quickly developed in the group as experiences were shared, materials and ideas traded and plans made for people to get together outside the scheduled monthly meetings. This enthusiasm and effort, which originated in the summer institute, was maintained by the teachers throughout the three months of the Comet course. However, if an in-service program is to be truly effective, it should produce *lasting* change. One of the major goals of this study was to gauge the long term effects of the program on the science teaching of the participating teachers.

Sources of Data

During the fall term of 1991, the Comet participants kept journals and provided written updates of their progress to the facilitators. Field notes and videotapes were recorded during the monthly meetings. Throughout the Comet course I kept a journal in which I made notes on classroom visits, group meetings, telephone conversations and exchanges on electronic mail. At the end of the course, participants filled out feedback forms for the organisers and these are on file in the Project Development Office at SFU.

I contacted the teachers again in November, 1992, arranging a group meeting to discuss the impact of the in-service program over the previous year, after which I visited and interviewed each of the teachers in their classrooms. Thus, the database for the study consists of interviews, classroom observations, field-notes, videotapes of meetings, journals and course assignments – all of which were gathered in my continuing relationship with the participating teachers.

Methodological Stance

The complementarity of qualitative and quantitative research in science education was examined by Roberts (1982) in terms of "argument patterns" (Toulmin, 1958) and the "world hypotheses" of Pepper (1942). In Toulmin's pattern of arguments, a distinction is made between those statements which are facts or *data*, and those which are claims or *conclusions*. The move from data to conclusion requires a *warrant*, which is usually a statement representing a rule or convention which authorizes the move. The *backing* for the warrant includes its philosophical underpinnings. This is a somewhat simplified version of Toulmin's (1958) argument pattern, but it will suffice for the present purpose.

Roberts then uses Pepper's (1942) world hypotheses to illustrate the different nature of backing required by quantitative and qualitative arguments. The six world hypotheses identified by Pepper are different metaphysical systems which have been employed throughout human history to interpret reality: animism, mysticism, formism, mechanism, contextualism and organicism. Since animism and mysticism do not entail the concept of evidence, Roberts discards them and goes on to associate quantitative arguments with formist/mechanist backing, and qualitative arguments with contextualism and organicism.

Formism and mechanism are essentially preoccupied with the form of *things* and how they interact to influence each other. These are important considerations when dealing with inanimate objects, particularly in the physical sciences. Moreover, they can be measured and quantified to an appropriate degree of precision, and the process may be repeated under controlled conditions for corroboration. Formist/mechanist warrants are found in statistics manuals and classics on experimental design.

Contextualism and organicism are more concerned with *events* rather than things, and how the context and totality of the events determine their interpretation. The main preoccupation is in making sense of a particular event, so that contextualist warrants are generated "by considering reasonable situational expectations of people who are in this specific context" (Roberts, 1982, p. 285). Rather than repeated checking of the same phenomenon, corroboration is obtained by the cross-checking of different sources at varying times. Roberts argues that qualitative research is a legitimate counterpart to quantitative research, since "science education is done by people to other people, not by machines to other machines" (p. 289).

Of course, much has been written about qualitative research since Roberts' seminal work in legitimizing this general stance to science education research. For now, however, this is sufficient for characterizing this study as a qualitative analysis of the experiences of the teachers who took part in the summer institute and follow-up Comet course, in order to examine the effectiveness of the in-service program.

One of the main objectives of the institute and Comet course was to promote activity-based teaching in the classrooms of the participating teachers. In examining the effectiveness of the program, therefore, it is essential to ascertain to what extent such science teaching is now taking place and whether the in-service program was instrumental in promoting it. By focussing on the participating teachers' perceptions of their experiences, grounded in the context of their own classroom practice, I was able to gain a unique perspective on the effects of the in-service program on their science teaching.

The analysis of the interviews, journals, and other elements of the database required a subjective and personal interpretation of what was primarily self-reported information from the teachers. This is characteristic of all qualitative studies, and the researcher is constantly testing the trustworthiness and value of the data against his or her own judgement. In this case, my own judgement was based partly on my twenty years of teaching experience, but mainly on the relationships which I had developed with the participants during the summer institute and the Comet course. This study, then, may be considered to be an interpretive account of the effectiveness of the in-service program on the science teaching of the participants, based on their experiences and perceptions.

In order to make sense of the prodigious volume of data which was generated in the study, three aspects of the teachers' experiences were selected to guide the analysis process.

> Have the participants' views of science, science teaching and "children's science" changed significantly as a result of the program? Does this imply a broadening of their "scientific literacy"?
>
> What is the character and quality of the science teaching which is now taking place in their classrooms? Are the Comet teachers using a constructivist perspective when they talk about their students' learning of science?
>
> Have the teachers experienced the anxiety and stress which accompanies significant, meaningful change? How influential are their perceptions of science as a difficult and threatening subject in this process of professional growth?

In examining these aspects of the teachers' experiences, insights were gained into the effectiveness of the summer institute and Comet course in providing a sustained and supportive framework for the development of the participants' teaching of science. It is my hope that the results of this study will be useful and informative in the planning of future in-service programs designed to address the problem of elementary science education.

An Overview of the Thesis

This thesis is arranged in five chapters. Chapter One has been an introduction to the study, in which the problem of elementary science education was described and the research problem stated. Three theoretical aspects of the research problem were then laid out in greater detail: What constitutes science education? How children learn science, and The nature of teacher development. This was followed by a description of the summer institute and Comet course taken by the teachers in the study. The components of the database and research methodology were then discussed.

Chapter Two presents a review of the literature on the problem of elementary science education. It examines the reasons why science is an established component of the elementary curriculum and whether or not it is being taught. The review then goes on to look at the barriers facing teachers who want to teach science, and the role of in-service programs in helping to overcome the barriers.

In Chapter Three, I review the traditional training model of teacher in-service and contrast it with a more recent concept of teacher development. The training model is characterised by a top-down, managerial approach, whereas the development model assumes that teachers are autonomous practitioners in charge of, and responsible for, their own professional development. The summer institute and Comet course are examined in the context of these two very different staff development models.

Chapter Four, Analysis and Findings, opens with a brief review of the in-service program before introducing the teachers who participated in the study. The methodology of the research process is then discussed. A single quotation is analysed to address the selected aspects of the research problem and the emergent themes are examined in the light of further evidence from the database.

Chapter Five presents the conclusions of the study and their implications for the planning of in-service programs. The limitations of the study are briefly discussed and some suggestions for further research are offered.

Chapter 2

THE PROBLEM OF ELEMENTARY SCIENCE EDUCATION: A REVIEW OF THE LITERATURE

This chapter reviews a selection of the literature which is essential to a deeper understanding of the research problem. The examination of the experiences of the teachers who participated in the summer institute and the Comet course will be set in the broader context of the teaching of science in elementary schools and the role of in-service programs in supporting teachers who want to improve their science.

Why Teach Science

The place of science in our schools has been scrutinized in a number of studies at the national, provincial and state levels throughout North America in recent years. The comprehensive, four-year study undertaken by the Science Council of Canada (1984a) found that all of the interested parties – educators, parents, students, ministry officials and others – agreed upon the following rationale:

> Science education can benefit all students. But the fullest benefits will only be realized from a science education appropriate to individual needs and designed to enable students to:
>
> - participate fully in a technological society as informed citizens;

- pursue further studies in science and technology;
- enter the world of work;
- develop intellectually and morally. (p. 2)

This study, criticised by some as policy statement rather than scholarship (Ivany *et al.*, 1987), brought together a vast amount of information on the state of science education across the country. The rationale given above, which embodies a number of Roberts' curriculum emphases, is firmly grounded in the view that science should be taught as a means of attaining certain goals. There is no indication that science is good in its own right, not only as a means to other ends but as a worthwhile end in itself. For example, preparing students to live in "a technological society as informed citizens," – the "Science, Technology and Decisions" curriculum emphasis – has been a common goal of science educators throughout the twentieth century (Hurd, 1986), and appears once again in the *British Columbia Assessment of Science 1991*:

> There is a need for a scientifically literate population which must be more and more knowledgeable about and concerned with environmental and other socioscientific issues of the world. (Bateson *et al.*, 1992, p. 81)

In the elementary school, however, this aspect of scientific literacy is de-emphasized in favour of other curriculum intentions which correspond to the developmental level of the students and indicate an appreciation for science as an end in itself.

> Science should be presented as a human endeavour; it can be seen as an attempt to search out, describe and explain patterns and events in

> our environment ... [Elementary science] should convey the essentially experimental nature of science ... and is best achieved through learning experiences that are inductive, concrete and manipulative. Young children respond well to activity-centred inquiry. (British Columbia Ministry of Education, 1987, pp. 5-6)

The value of hands-on science which engages the mind of the child in the elementary classroom is well established in the research literature (Loucks-Horsley *et al.*, 1989; National Science Board, 1983; Wasserman & Ivany, 1988). Erickson *et al.* (1992) stress that "students, as well as teachers, should recognize the role played by [hands-on] investigations in the construction of more elaborate and powerful ways of thinking about phenomena," and they go on to recommend that students should be given more opportunities "to work with materials in problem solving contexts" (pp. 255-256). Others claim that, since manipulative "tinkering" is no longer part of growing up for many children, it is the responsibility of the school to provide such opportunities in its science program:

> As short a time ago as a hundred years, most people spent most of their time dealing with nonsymbolic problems that presented themselves as physical problems ... The easy example is the child growing up on the farm. Today this out-of-school experience with physical reality is no longer true of most people. There needs to be an experiential and challenging connection between individuals today and the natural world ... this task should be taken up by the schools [which] should give the children what they need today, which is different to what the farmer's children needed. (Morrison, cited in St John & Knapp, 1988, p. 2)

The weight of these arguments has ensured that inquiry-based, hands-on science is well represented in the curricula prescribed by school boards and ministries of education in all jurisdictions and at all school levels (Science Council of Canada, 1984).

Is Science Being Taught in Elementary Classrooms

Despite the prominent place given to science in the "intended" curriculum, study after study has shown that science is lacking in the "achieved" curriculum (Connelly *et al.*, 1985). In the United States, Anderson and Smith (1987) drew on the National Science Foundation's series of status studies of the late 1970's and the National Commission on Excellence in Education, 1983 and concluded that, "Almost everyone who has examined the available evidence agrees that our present system of science education isn't working very well" (p.102). The Pre-college Commission of the National Science Board also "bemoaned the fact that science was largely absent from the [elementary] classroom" (NSB, cited in St. John & Knapp, 1988, p. 3).

The Science Council of Canada (1984) found "a wide gap between ministry intentions and classroom practice" (p. 30) with the result that "most children from kindergarten to the end of elementary school only receive a token education in science" (p. 33). This was not an isolated situation: "... information gathered at each of the provincial conferences tells the same story: very little science – and often, none at all – is taught in

Canada's elementary schools" (p. 25).

In British Columbia, seven years later, the situation is not much better; in many districts science is still "on the back burner" (Wideen *et al.*, 1992).

> ... science has become a marginal subject ... the current Year 2000 emphasis has tended to move science off the list of priorities ... Science, particularly at the elementary grades, occupies a position of importance far behind subjects such as mathematics and language arts ... [there is] a general lack of emphasis and support for science teaching from the district level. (Bateson *et al.*, 1992, pp. 77-80)

The lack of emphasis on science in the classroom often means that time ostensibly allocated to teaching science is spent doing something else, a situation which seems to be accepted by many administrators.

> Districts leave it to the schools to see that science as laid down in the curriculum guide is being accomplished. School principals generally leave it to the classroom teacher to devote whatever time or develop a format for science teaching that the teacher feels is appropriate. (Wideen *et al.*, 1992, p. 68)

The National Science Board (1983) study found that, on average, about one hour per week was spent doing science – less than the time devoted to either art, music or P.E. The short amount of classroom time spent on science relative to other subjects (Shrigley, 1977; Wier, 1988), and relative to the time allocated in the prescribed curriculum (Science Council of Canada, 1984; Wasserman & Ivany, 1988), is a concern for the authors of the 1991 B.C. Science Assessment, "particularly at the lower grades" (Bateson *et al.*, 1992, p. 80).

In addition to examining the *quantity* of science being taught at the elementary level, it is appropriate to examine the *quality* of the science teaching. The most recent science assessment in British Columbia found that, in about one-third of the classrooms they visited, science was being done using a variety of strategies and activities which engaged the children in "hands-on, minds-on" learning. Another one-third displayed science teaching which did not seem to engage the students in any meaningful learning, and the remainder fell somewhere in between (Wideen *et al.*, 1992). The range of learning activities also appears to become narrower as students enter the higher grades, with a steady decrease in hands-on and laboratory activities from grades 4 to 10 (Bateson *et al.*, 1992).

Similar findings were reported in the United States by St. John and Knapp (1988) who claim that the curricular ideal of hands-on science and the classroom reality of textbook-based science have remained unchanged for twenty years, and that this standoff is not likely to change soon. This pessimistic conclusion is based in part on the unwillingness of the "educational mainstream" to embrace curriculum innovations. Their definition of the educational mainstream – administrators, principals, publishers, testers – is somewhat suspect in that there is no mention of teachers or students.

In some classrooms, science is integrated into a particular theme rather than being taught as a separate subject. The Science Council of Canada (1984) study found that "... when science *is* taught at the elementary level, it is mostly done in an integrated fashion" (p. 30). This practice of integrating science is open to criticism if the science component is watered down or "softened" in the integration process (Science Council of Canada, 1984b) or consists simply of reading a story or poem about science (Wasserman & Ivany, 1988). The trend towards integration of subject matter is readily apparent in *The Year 2000* curriculum initiatives and, since most integrated themes tend to be language arts-based, rather than science-based, there is a concern that science will get lost (Bateson *et al.*, 1992).

In any examination of the reasons why the science in the classroom does not correspond to the intended curriculum, it quickly becomes apparent that the teacher is the key. Given that most teachers – particularly in the early grades – enjoy the autonomy of their own classroom, it should come as no surprise that "regardless of the approach to science curriculum planning, individual teachers determine the amount of science actually taught and the manner in which science content is treated" (Schoeneberger & Russell, 1986, p. 534). Other studies have confirmed the crucial role of the teacher's attitude to science in determining the quality and quantity of science teaching in their classes (Loucks-Horsley *et al.* 1989; Stone, 1986).

> First, it was assumed that classroom teaching lies at the heart of the science education students receive; external policies and interventions will have little effect if we fail to take into account what occurs in classrooms and the views and aspirations of those who work there. Most of our study, therefore, focussed on classroom teaching and the concerns of those in schools. (Wideen *et al.*, 1992, p. 132)

Any serious attempt to improve science education in elementary classrooms must involve the teachers from those classrooms if it is going to meet with any measure of success.

Why Aren't Teachers Teaching Science

In their examination of barriers to the teaching of hands-on science at the elementary level, St. John and Knapp (1988) employ a useful distinction between immediate, practical reasons and deeper, pedagogical conflicts. Science, for many elementary teachers, is a special subject which is very different to math, language arts and the rest of the curriculum. In order to teach science effectively, a teacher must not only deal with the logistical difficulties of equipment, materials and the time associated with setting up the activities, but also overcome the mental barrier of feeling threatened, under-prepared and inadequate in knowledge of the subject.

> In spite of the recent thrust made by *The Year 2000* initiatives, this [Director of Curriculum and Instruction] felt that the curriculum was designed for people who have been trained in science rather than for the generalist and that this situation holds true even at the primary level. Perhaps for this reason many teachers told us that, of all the curriculum areas they were obliged to cover, it was in the area of science that they felt least comfortable. (Wideen *et al.*, 1992, p. 64)

Practical constraints can be classified under three headings; lack of time, lack of facilities and lack of support. Obviously, an effective science program requires more time to implement than a subject which requires only a textbook. There are, however, other dimensions to the problem of time for science. Schoeneberger and Russell (1986) refer to two situations in which science was postponed or avoided. In one case, a large number of special needs children required too much of the teacher's time to allow her to do the planned group activities. In a similar situation, another teacher reported that the level of reading and mathematics was so low that she felt she had to concentrate on those topics to the exclusion of science (p. 535). Given the present trend towards integration of special needs students into regular classes, it appears that this may become a significant barrier to hands-on science for more teachers in the province (Bateson *et al.*, 1992a).

Pressure to concentrate on other subjects can also come from administrators at the school level (Wier, 1988; Bateson *et al.*, 1992) or from district and state officials keen to promote other curriculum reforms (Martin, 1987; St. John & Knapp, 1988). This conflict is also apparent in teacher responses to *The Year 2000* principles, some of which are seen by teachers as being immediately transferable to science teaching. Others, however, "reported that *The Year 2000* initiative had taken priority away from subjects such as science" (Bateson *et al.*, 1992, p. 70).

Facilities for hands-on science are, in general, inadequate in many elementary classrooms in the United States (Martin, 1987; Schoeneberger & Russell, 1986; Shrigley, 1977; St. John & Knapp, 1988; Wier, 1988). In Canada too, "most early-years science teachers feel that the quality of the facilities and equipment available to them is inadequate" (Science Council of Canada, 1984c, p. 75). The recent assessment of science in British Columbia indicated that most elementary teachers do not have easy access to even simple equipment and supplies for science. In addition, "sloped desks, limited space and poor classroom arrangement all contribute to a mileau that works against active science classes" (Wideen *et al.*, 1992, p. 66).

Support for teachers who want to do more science seems to be very difficult to obtain. Science supervisors and helping teachers have been eliminated by many school districts in the United States (Weiss, 1978; Wier, 1988) and in Canada (Science Council of Canada, 1984c; Stronck, 1986). "The support that comes from having someone at the district level ... has virtually disappeared over the last decade" (Bateson *et al.*, 1992, p. 77). This need for support is arguably the greatest barrier to be overcome if teachers are going to be able to tackle the other constraints, mainly pedagogical, which collectively contribute to the lack of self-confidence in teaching science (Cohen, 1987).

> At the district level, strong leadership seemed critical to the maintenance of any [science] program ... where support for science appears marginal, the message received is that the back burner is an acceptable place for science and, not surprisingly, that is just where we found it. (Wideen *et al.*, 1992, p. 71)

An alternative interpretation, perhaps more instructive, of St. John and Knapp's division of barriers into practical or pedagogical is to classify the constraints as external versus internal. External constraints, as outlined above, may often be cited as reasons for not doing science. However, those teachers who *do* teach hands-on science are, presumably, operating under similar conditions but have found ways to deal with inadequate facilities and time constraints. External barriers do exist and play a large part in the problems of doing elementary science but other obstacles are internal – a poor background in science, the perception that only experts can do science, or a misunderstanding of the nature of science itself.

Most of the literature lists a lack of confidence as one of the reasons why many elementary teachers do not teach science, but only a few researchers seem to distinguish it from the external barriers in its importance. For example, Schoeneberger and Russell (1986) report that "When personal confidence is lacking ... this can be a significant deterrent to teaching science" (p. 534), but they then go on to discuss equipment, leadership, time constraints and other factors. On the other hand, Wier (1988) suggests that "science may have been missing in classrooms more because of lack of confidence than because of other barriers" (p. 14).

The lack of confidence expressed by many teachers is usually attributed to a poor background in science at the post-secondary level coupled with inadequate experience in science teaching methods during pre-service training. It is common to hear teachers associate the teaching of science with being an "expert" in science, and that only those with the right background and preparation should be expected to teach science (Schoeneberger & Russell, 1986).

Various studies have shown that many elementary teachers perceive themselves to be "handicapped by inadequate preparation in professional [science] coursework" (Wasserman & Ivany, 1988, p. 2). In the United States, only one in five elementary teachers felt well qualified to teach science, according to Weiss (1986, cited in St. John & Knapp, 1988, p. 6) and the level of confidence is even lower with regard to physics and physical science (Clayton *et al.*, 1982).

In Canada, the situation was studied extensively in the preparation of the report by the Science Council of Canada, *Science for Every Student.* When asked to give reasons for avoiding science teaching, over 54% of early-years teachers cited inadequate background as the main reason. (Science Council of Canada, 1984c, p. 44). An analysis of university background of teachers by gender (on page 39 of the same study) found that only 20% of the female, early-years teachers reported taking any science since high school. The term "early-years" refers to grades K – 7 where 77% of the teachers are female (p. 31).

These figures are somewhat at odds with those given by Stronck (1984) in his analysis of the British Columbia Science Assessment of 1982. While he notes that 51% of elementary teachers felt "not at all prepared to teach science" – close to the figure of 54% of respondents across Canada mentioned above – he also points out that 77% of them had taken at least one university science course (p. 39). This figure is in marked contrast to the 80% of female teachers who had no university science as reported in the national study. The 1991 assessment seems to confirm this difference in the background of British Columbia teachers when compared to the rest of the country. According to this study, 75% of grade 4 teachers, of whom two-thirds are female, have some science at university level, and 77% reported taking at least one science methods course during pre-training (Bateson *et al.*, 1992a, p. 277). It appears, however, that exposure to science content in university does not necessarily lead to effective science teaching, a point made by Anderson and Smith (1987), since the fraction of classrooms where good science was observed during the 1991 study was far less than 75% (Wideen *et al.*, 1992).

It may be more useful not to focus on the quantity of science courses taken by teachers but rather on the *quality* and *nature* of those courses.

> Science was something teachers "took" in college, but it was not something they experienced as a process of inquiry, certainly seldom a participation in inquiry. It was not surprising, then, to find that creative inquiry was not what we found - except in rare instances. (Stake & Easley, 1978, cited in St. John & Knapp, 1988, p. 7)

A similar point is made in the 1991 science assessment where some teachers reported that their pre-service training had been highly influential in shaping the kind of process, minds-on science which they taught. They were, however, very much in the minority of the teachers interviewed in the study, and "teacher preparation was not generally mentioned as a major factor in having influenced teachers in their teaching of science. More commonly, teachers reported that courses they had taken *since they began teaching* (italics added) had had an important influence upon them" (Wideen *et al.,* 1992, p. 71).

Can In-service Programs Help Teachers to Teach Science

> Great teachers are not made at the University of Illinois or Stanford, they are made in the schools and for that reason it's awfully easy to overlook the consummate importance of in-service because it is the in-service activity which makes or breaks a great teacher. (Rubin, 1979, p. 36)

What, then, of the majority of those sampled? How can they be helped to overcome their perceived lack of science background and inadequate preparation? Is it possible to increase their levels of confidence to the point where they feel able to tackle the constraints of equipment, time and materials? A number of studies and assessments have indicated that it is possible to assist these teachers if the support is made available and is appropriate to their needs.

Many researchers have recommended in-service programs as a way to combat the lack of science in classrooms, particularly at the elementary level (Wier, 1988; Loucks-Horsley *et al.*, 1989). In some cases, the need for such programs is automatically assumed and the recommendations are directed at the nature of the programs (Lindberg, 1971) and the importance of hands-on experiences for the participants (Hone & Carswell, 1969). Where new science curricula are being developed, the importance of in-service as a means of preparing teachers to implement the new programs has long been recognised (Stronck, 1986; Neale *et al.*, 1990).

Similar sentiments are found in the recommendations of major studies and assessments. The Science Council of Canada (1984) pointed out that since few new teachers are entering the schools, in-service for existing teachers is as important as pre-service training, otherwise "science teachers may never develop beyond the stage at which they first entered the classroom" (p. 57). In particular, the report recommends that summer in-service science programs be instituted and that "teachers needing to attend them are able to do so" (p. 58). In British Columbia, the Science Assessment of 1982 gave the highest priority to a recommendation to the Ministry of

Education to "co-ordinate the design, development and delivery of in-service programs which will focus on ... areas of need" (Stronk, 1984, p. 40). A similar recommendation is found in the 1991 Science Assessment which recognizes that "the key to better quality science teaching in the province lies in the professional development of teachers" and calls for continuing programs for teachers in order to "reform and upgrade science education in the schools of British Columbia" (Bateson *et al.*, 1992, p. 81).

Much of the information upon which these reports and research studies are based comes from teachers in the classroom. Teachers themselves *want* to teach science effectively (Wasserman & Ivany, 1988) and their desires have been expressed by several studies (for example, Anderson & Smith, 1987; Hurd, 1986; Guskey, 1986). Stronck (1986) points out that "teachers' responses have consistently demonstrated that many want in-service programs," and he concludes that "most of the science teachers in the province have the potential of becoming excellent teachers if they had a supportive environment" (p. 206). These comments are echoed in the 1991 Science Assessment when the teachers interviewed were asked what they would recommend to improve science teaching in the province. More than half "asked specifically for a greater level of district support in the form of in-service" (Wideen *et al.*, 1992, p. 71).

Apparently, all interested parties agree that "there is no single strategy that can contribute more to meaning and improvement than ongoing professional development" (Fullan, 1991, p. 318). But agreement, in principle, does not necessarily translate into action and the provision of the required programs. The Science Council of Canada found that most teachers were dissatisfied with the quality of the in-service programs provided and "at least two out of three teachers find their in-service education program non-existent or ineffective" (1984c, p. 67).

Similar comments are found in the responses to the provincial assessment in 1982, where many teachers complained of reduced support services and insufficient in-service opportunities (Stronck, 1986). The situation does not seem to have improved since then, as "very few of the teachers interviewed reported having had any in-service in science within the last five years" (Bateson *et al.*, 1992, p. 77).

When in-service has been offered, it has often been "primarily focused on reinforcing content knowledge of teachers at the secondary level" (Wier, 1988, p. 3) and has usually ignored the needs of teachers in elementary schools. The list of 74 workshops offered to elementary teachers in Burnaby, for example, includes eight in modern languages and eleven in mathematics but only two in environmental science, one in technology education and none in physical science (Burnaby: School District 41, 1992).

Summary

It appears that the justification for science in the "intended" curriculum in elementary schools is well established and supported, but that the current state of elementary school science instruction falls far short of the vision expressed by policy makers. The key to resolving this mismatch is the classroom teacher, whose attitude to science and confidence in teaching it are crucial factors which can best be addressed through appropriate, ongoing, in-service support. This support, however, is not widely available despite repeated recommendations in research studies and science assessments.

Chapter 3

PROFESSIONAL DEVELOPMENT

In the previous chapter, I reviewed some of the literature that informs the problem of why many elementary teachers are not teaching science in their classrooms. I argued that, since classroom teachers are the key, any efforts to improve the situation should focus on their knowledge of and about science, and their attitude and self-confidence about teaching science. Given that these are the goals of an in-service program, how can it be made effective? What are the essential elements of successful in -service and how do they address the various aspects of teacher development? In order to make sense of the experiences of the Comet participants, it is helpful to examine the processes of in-service teacher development, particularly those aimed at improving elementary science education.

A Framework for Effective In-Service Programs

The categories employed by Sparks (1983) in her review of research on staff development are a useful starting point in the establishment of what constitutes effective in-service professional development for teachers. Sparks considers staff development as a "nested process," consisting of

Goals and Content, the *Context* and the *Training Process*. Goals and Content have been addressed in the previous chapter, where a case was made for improved in-service programs for elementary science teaching. How do these other factors – Context and Training Process – correspond to a view of teacher development as being *sustained, based in practice* and, in which a sense of *ownership* is fostered among participants?

The Context

Context refers not to the physical environment in which training takes place – although the surroundings do play a part in promoting effectiveness (Henderson, 1978; Wood & Thompson, 1980) – but to the organizational context of the in-service program. Sparks argues that two of the more significant aspects in the context of successfully implemented programs are administrative leadership and school collegiality.

She cites Berman and McLoughlin (1978) who examined hundreds of federally funded programs for a Rand Corporation Study, and concluded that the major factor which affected successful implementation was administrative support from superintendents and principals. The role of the principal as leader in supporting teacher development was also emphasised by Fullan (1991), Lieberman and Miller (1991), and Schoeneberger and Russell (1986). Effective leadership need not compromise the ownership of a program deemed necessary for the participating teachers, for, as Loucks-Horsley *et al.* (1989) point out, "One of the most important tasks of leadership is to involve people from all levels in decisions" (p. 65). The authors of the 1991 British Columbia assessment also commented on the importance of leadership:

> The role of the principal, both in helping to set the tone for the school and in acting as curriculum leader, appeared to be central in supporting and promoting science teaching. [The principal's] concern and enthusiasm appeared to galvanize the teachers into assuming responsibility where science is concerned. Leadership of this sort, by example rather than directives, seems to be vital if a strong science program is to be maintained in the school. (Wideen *et al.*, 1992, p. 71)

Effective leadership by a principal, involving teachers in decision making at more than a superficial level, is also seen as being crucial to the development of a collegial relationship in a school (Sparks, 1983; Wier, 1988). Collegiality can be considered as the opposite of teacher isolation, or more powerfully, as the most effective means of reducing the professional isolation in which most teachers operate (Cohen, 1987; Guskey & Sparks, 1991; Little, 1987). Significantly perhaps, one of the British Columbia teachers whose teaching was judged to be exemplary in the recent assessment, reported that the "opportunity to work as a team with other staff members" had been the most influential factor in her development as a science teacher (Wideen *et al.*, 1992, p. 62).

What Fullan (1991) calls "interactive professionalism" (p. 142) may involve many diverse ways of teachers working together. Teaching partnerships within a school might be fostered during an in-service program as a means of continuing mutual support (Franks, 1991: Martin, 1987). Peer teaching, mentoring and coaching are well researched as effective means of sustaining the implementation of teaching innovations in the classroom (Joyce & Showers, 1983; McKeel, 1979). The benefits of collegiality in a school extend to all teachers, experienced as well as novice (Little, 1987), and teachers recognize this, believing that "they learn most from other teachers" (Science Council of Canada, 1984c, p.69). Not only do they learn most from other teachers, they "learn *best* from other teachers," according to Fullan (1979, p.125). The importance of teacher-teacher interaction was also stressed in the 1991 science assessment:

> We propose that to improve science education, we create opportunities for teachers to investigate other approaches to teaching, to watch other exemplary teachers, and to have opportunities to talk to others about their teaching. (Wideen *et al.*, 1992, p. 136)

At this point, a note of caution may be appropriate. True collegiality involves much more than superficial interaction between teachers within a school. Hargreaves (1990) distinguishes between true "cultures of collaboration" and "contrived collegiality" which he characterises as:

> administratively contrived, formally bounded in time and space, and bureaucratically predictable. Contrived collegiality preserves the hierarchical separation between development and implementation, creating a system whereby teachers can deliver others' purposes

> instead of developing their own. And, in doing so, it retains a system whereby (mainly) female teachers remain the technical servants of predominantly male administrators and their purposes. (Hargreaves, 1990, p. 26)

This is far from the collegial context of "sustaining structures" (Strong *et al.*, 1990, p. 28) in which teachers are best able to develop new skills, within their own classrooms and schools, and achieve professional growth based in their own practice.

The Training Process

What are the components of a successful training process and how can they best be scheduled and organized to maximise teacher development? These questions have been exhaustively studied and there is a marked consistency in the findings and recommendations of the researchers. The notion of sustained teacher development implies an ongoing process, rather than a single training session. This distinction, in which change is perceived as a *process* rather than an *event* (Fullan, 1991), is seen to be crucial in the scheduling of effective in-service programs.

Most of the research which has looked at instructional improvement has concluded that in-service programs consisting of a single session are largely ineffective (for example, Bateson *et al.*, 1992; Cruickshank *et al.*, 1979; Goldenberg & Gallimore, 1991; Orlich, 1984; St. John & Knapp, 1988). "One-shot" workshops, offered in isolation without any follow-up, will not usually produce any lasting change in teaching behaviour (Joyce & Showers, 1983; Sparks, 1983). In general, these single sessions – traditionally the most common type of in-service offering – will achieve no more than a heightened awareness of the content of the workshop or presentation in the minds of the participants (Wideen *et al*, 1979). But a heightened awareness is better than no awareness at all, and if a one-shot workshop can encourage some teachers to try out science activities in the classroom, it would be successful, to be sure. Given the dearth of science in-service referred to in Chapter Two, "one-shot efforts are certainly better than nothing" (Wideen *et al.*, 1992, p. 136). Achieving a greater level of impact, however, requires more than a single session, but "the lack of follow-up in the classroom or job setting after training takes place is almost universal" (Wood & Thompson, 1983, p. 375).

The importance of providing ongoing support is a recurring theme in the literature, particularly in the context of the nature of teacher change. Guskey (1986) argues that teachers' beliefs and attitudes do not change until after they have implemented the innovation in their own classrooms and convinced themselves of its worth. I doubt whether this is true for all teachers and it should not be generalised as such. For many teachers, however, the provision of ongoing support is crucial in implementing newly learned content or techniques, and similar conclusions were reached in two studies of elementary science in-service programs where the importance of follow-up support was stressed by the participants and credited with an increased commitment to teaching science (Stone, 1986; Wier, 1988).

A number of rationales have been proposed to explain the relationship between extended in-service training and successful implementation. Berman and McLaughlin (1978) introduced the concept of "mutual adaption" which suggests that, as teachers try out new practices in their own classrooms, they gradually adapt and modify both the techniques and their own environment. Over time, the gradual changes in the practice and the setting in which it took place result in a greater incidence of acceptance and use.

Michael Fullan (1979, 1990, 1991) has long been associated with scholarship on the nature of teacher change and how in-service programs need to be designed around the different stages of the change process. Referring to the work of Berman and McLaughlin (1978) and Hall and Loucks (1978), Fullan draws on a "Concerns Based Adoption Model" (CBAM) of staff development. This rationale for effective long-term change considers the concerns of teachers at various stages in the change process and suggests training activities which will address specific concerns. Consideration for the individual, as he or she passes through discrete stages of change, is often lost in the design of the overall training program, resulting in diminished effectiveness (Loucks-Horsley & Stiegelbauer, 1991).

The Training Activities

There is considerable agreement in the research literature on the nature of activities to be included in the training process (Cruickshank *et al*, 1979; Fullan, 1991; Goldenberg & Gallimore, 1991; Joyce & Showers, 1983; Loucks-Horsley *et al*, 1989; Tindill & Coplin, 1989; Wood & Thompson, 1980). There are various views on the relative emphasis that should be placed on these, but many agree on the list of potential staff development activities given by Joyce:

1. Presentation of theory or description of skill or strategy.
2. Modelling or demonstration of skills or models of teaching.
3. Practice in simulated and classroom settings.
4. Structured and open-ended feedback.
5. Coaching for application.

Giving information and demonstrating are the "meat and potatoes" of the majority of in-service workshops or presentations. A simple presentation of the material or technique is not enough, however, to effect a change in the behaviour of the observers, according to Joyce and Showers (1980) who stress the importance of demonstrating the content in an effective application in order to reinforce the transfer process. Demonstrating, in this context, could include activities such as showing a videotape of the practice in classroom use, a detailed description of actual use or modelling the technique in the presentation itself. Modelling is recognized as an important component in the training process as it "facilitates the understanding of underlying theories by illustrating them in action" (Joyce & Showers, 1983, p. 16). Fullan (1979) also notes the usefulness of modelling but points out that it is often missing from many in-service presentations.

The presentation of information, coupled with appropriate demonstrations is considered "necessary, but not necessarily sufficient, for the success of staff development efforts" (Sparks, 1983, p. 67). Such presentations, where the participants usually play a passive role, are hardly examples of the experiential learning advocated by Loucks-Horsley and others. This is particularly true in the case of elementary science workshops where active involvement with equipment is considered by many to be essential (Abell & Krueger, 1991; Clayton *et al*, 1982; Hone & Carswell, 1969; Wier, 1988). In his list of criteria for positive in-service science programs, Orlich (1984) includes active participation "rather than making [participants] passive listeners" (p. 33), a sentiment echoed by Lindberg (1971) who stresses the dependence of transfer on the hands-on experiences of the teachers.

The other activities on the list – practice, feedback, discussion of application and coaching – are all ways to involve teachers in experiential learning. Practice may take place in the workshop itself – in role-play or micro-teaching situations – or in the teacher's own classroom. Whatever the context, practice should take place immediately after the new skill has been introduced if it is to be of maximum benefit. A further outcome of immediate practice is "a clear understanding by the teacher of the amount of new learning that is going to be required to achieve full transfer" (Joyce & Showers, 1983, p. 18).

Another benefit of practice is the provision of feedback for the teacher (Loucks-Horsley *et al.*, 1989). Feedback may come from students, colleagues or the in-service providers but, whatever the source, it is most effective if it is structured and scheduled (Joyce & Showers, 1980). Most classroom teachers are gathering feedback from their students all the time but unfortunately it is more difficult to create opportunities for colleagues to spend time in each other's classes, observing and discussing their progress.

Discussion between teachers is held up as a desirable component of effective in-service by a number of studies. The provision of time and opportunity for teachers to engage in professional discussion is a valuable support mechanism (Cruickshank *et al.*, 1979; Guskey, 1986), and, if structured into an extended in-service program, can do much to further a context of genuine collegiality, especially if the program is school-centred rather than district-based (Franks, 1991). Other teachers are valued as sources of ideas, advice, material resources and peer evaluation (Holly, 1982; Zigarmi *et al.*, 1977), contributing to an enhanced worklife through professional interactions (Griffin, 1991). These interactions can also provide the social aspects of the learning process (Loucks-Horsley *et al.*, 1989; Strong *et al.*, 1990), without which the teacher must cope in isolation. As Fullan (1991) observed, "It is hard to be a lone innovator" (p. 316), but isolation, however, tends to be the norm for the majority of classroom teachers (Goodlad, 1983).

Another form of interaction which has been shown to further teacher development is coaching by an "expert," usually a member of the team which initiated the in-service program (Neale *et al.*, 1990). The process of coaching is dealt with in detail by Joyce and Showers (1983) who consider that it serves four main functions: the provision of companionship, the provision of technical feedback, the analysis of application, and assistance with the process of adapting the technique or innovation to the students. They go on to suggest that effective coaching does not necessarily require an "expert" from outside the school. In many cases, the best coaching comes from coaching teams formed during the initial in-service sessions amongst the participants. Thus, peer coaching fosters an interdependent interaction between and among colleagues as they progress along their own paths.

Are all of these activities – giving information and demonstrating, practice, feedback, discussion of application and coaching – necessary for every in-service program? In their review of the effectiveness of various combinations of these activities, Joyce and Showers (1980) draw a distinction between training for fine tuning of existing skills and training for redirection of teaching style or content. In the former case, some teachers require no more than a clear presentation of theory coupled with appropriate demonstrations to make the change in their teaching. Other teachers may require some practice and feedback before they are comfortable enough to use their new skills in class. More complex techniques involving less familiar content, however, require all of the activities to be incorporated in the program structure for maximum implementation and transfer.

Most elementary science training programs would fall into this latter category, since the scientific content and the teaching strategies are new and unfamiliar for most of the participants. The subject matter of the training program, however, is not the main factor in determining the activities required for succesful implementation. If the program aims to change the teaching of the participants in a significant way, then "continuous practice, feedback and the companionship of coaches is essential to enable even *highly motivated* persons to bring additions to their repertoire under effective control" (Joyce & Showers, 1983, p. 4).

Sparks concludes her synthesis of the research by listing her recommendations for effective staff development.

1. Select content that has been verified by research to improve student achievement.

2. Create a context of acceptance and ownership by involving teachers in decision making and providing both logistical and psychological administrative support.

3. Conduct training sessions (more than one) two or three weeks apart.

4. Include presentation, demonstration, practice and feedback as workshop activities.

5. During training sessions, provide opportunities for small group discussions of the application of new practices, and sharing of ideas and concerns about effective instruction.

6. Between workshops, encourage teachers to visit each other's classrooms, preferably with a simple, objective, student-centred observation instrument. Provide opportunities for discussions of the observation.

7. Develop in teachers a philosophical acceptance of the new

practices by presenting research and a rationale for the effectiveness of the techniques.

8. Lower teachers' perceptions of the cost of adopting a new practice through detailed discussions of the "nuts and bolts" of using it and teacher sharing of their experiences with the technique.

9. Help teachers grow in their self-confidence and competence through encouraging them to try only one or two new practices after each workshop.

10. For teaching practices that require very complex thinking skills, plan to take more time, provide more practice, and consider activities that develop conceptual flexibility. (Sparks, 1983, p. 71)

Teacher Training or Teacher Development

This list of recommendations is a comprehensive summary of the traditional view of teacher training – a top-down, managerial style in which it is condescendingly assumed that teachers are somehow lacking something which can best be supplied by curriculum designers or educational researchers.

> ... too often in the past, teachers have been treated as empty vessels, who, once filled with the "right stuff," would perform their teaching duties with fidelity until the next new conception of the "right stuff" was poured in. Knowledge of good pedagogy came from outside of teachers and their experiences. (Loucks-Horsley *et al.*, 1990, p. 19)

Too often this type of training fails to recognise that teachers, like all adults, come to any learning situation with a wide range of previous experiences, knowledge, beliefs and skills. This background must be acknowledged and taken into account when planning in-service which is appropriate for each learner. Elementary teachers have already established a wide and diverse repertoire of skills and strategies for the classroom which must be recognised and built upon (Martin, 1987). Moreover, most teachers "are perceptive about their shortcomings and strong points" (Griffin, 1991, p. 247), an obvious factor often overlooked by the strategic planning of curriculum architects.

More recently it has been suggested that, since this training model has had limited success, a different approach is required if teacher development is to be succesfully achieved. This would employ a constructivist perspective on teachers' learning, with a greater emphasis on the knowledge which teachers bring to the learning process, and on bringing teachers together to work on their practice (Wideen *et al.*, 1992). Loucks-Horsley *et al.* (1990) offer the following principles for effective, teacher-centred staff development for science teachers:

> Staff development should be continuous and on-going, starting from where a teacher is in terms of knowledge, skills and beliefs, and providing opportunities for growth.
>
> Teachers should have opportunities to choose among staff development activities that match their interests, stage of development, and competence.
>
> Staff development should provide opportunities for teachers to examine and reflect on their practice and on their schools and work together to formulate new and better learning opportunities for their students.
>
> Staff development should model the constructivist perspective on

learning. (Loucks-Horsley *et al.*, 1990, pp. 25-28)

This is a very different set of guidelines than the summary offered earlier by Sparks and gives teachers themselves control of, and responsibility for, their own professional growth. The same authors go on to identify five common models of staff development which they claim can meet the principles given above *when used appropriately* (italics added).

> The *training* model (Joyce & Showers) most frequently equated with staff development [which] includes (1) development of the theory and rationale behind the new behaviours to be learned; (2) demonstration or modelling; (3) practice in the training setting; and (4) guided practice in the classroom with feedback on performance.
>
> The *observation and assessment* model involves the careful observation of teaching, with particular attention to certain behaviours, and open discussion of the results. As a form of supervision, this model has received much attention for its potential for formative rather than summative evaluation. As coaching, usually among peers, it encourages norms of collegiality and experimentation.
>
> The *inquiry* model incorporates such practices as action research and reflective enquiry. Based on the work of Schön (1983) and others, teachers are encouraged to reflect on their own practice, gather data to better understand the phenomena of interest, and consider changes based on careful analysis.
>
> Another model is the involvement of teachers in the *development of curriculum and/or programs.* Teachers begin with a problem or challenge [and then] usually in a coordinated group, gather information, materials and other resources, consider existing knowledge about effective science teaching and learning, and develop a solution.
>
> *Individually guided staff development* is based on the assumption that individual teachers need different interventions to help them improve their practice. Here teachers, either as individuals or with others who share their interests or concerns, establish a goal and

> seek input by way of coursework, workshops, library research, visits, and other forms of self study to reach the goal. Self determination and support by their principal, peers, or others in the use of their new knowledge and/or skills makes this model different from more traditional staff development. (Loucks-Horsley *et al.*, 1990, pp. 22-23)

Although they are somewhat perfunctory, these descriptions span a broad range of possibilities for teacher development. There is, however, a curious internal inconsistency in the list of models given above – I refer to the presence of the *training* model alongside the others. Having spent a good deal of time advocating the treatment of teachers as autonomous practitioners, in charge of their own professional development, the authors then refer to a prime example of the traditional, top down style which requires the expertise of outsiders to effect meaningful change. This anomaly is neither recognized nor adequately addressed by the authors.

The Summer Institute and the Comet Course

Which aspects of teacher training or teacher development informed the planning of the summer institute and Comet course? According to the original proposal:

> The Summer Institute would consist of a week of workshops and seminars designed to introduce participants to issues surrounding the teaching and learning of science in an interdisciplinary fashion, to curriculum resources and materials that are currently available, and to computer software and telecommunication technologies available for use in the classroom. Seminar and workshop leaders will include master teachers in activity-based science, practising scientists who are actively involved in public school education, university

> science educators, and science education researchers. (MacKinnon, 1990, p. 6)

From this description, it is apparent that the summer institute was planned along the lines of a *training* event. The dependence on outside "experts," and a predetermined agenda are indicative of the traditional approach. A closer examination of the institute, however, reveals other aspects which correspond to the "principles of good staff development" given earlier.

First, the summer institute was planned to be more than just a one-shot event. All the participants were brought together again for three Friday afternoon follow-up sessions at Science World during the fall of 1991. In this sense, it was at least partially "continuous and on-going." Second, many of the activities in which the participants took part involved hands-on, experiential learning opportunities. The teachers were actively engaged in the science processes which, it was hoped, they would then be able to use with their own students. As such, the institute was planned to "model a constructivist perspective on learning." Perhaps this version of the training model is what Loucks-Horsley *et al.* had in mind when they listed it alongside the teacher-centred models of staff development which, "when used appropriately," have the characteristics of good staff development.

The Comet course, on the other hand, is less problematic in its origins, which were described in the proposal as follows.

> Each course begins with an intensive seminar or conference. This is followed by a three-month opportunity for teachers to carry out and reflect upon self-directed projects within the school setting. This extended implementation period provides for greater assimilation of knowledge and skills, feedback from the instructor, and is a time for reflective practice. The course encourages teachers to design and implement a project that contributes substantively to their own professional development within science education.
>
> The self-directed learning process has been described (Hopkins & Norman, 1982; Knowles, 1975) as one in which individuals take the initiative, with or without the help of others, to diagnose their learning needs, formulate learning goals, identify human and material resources for learning, choose and implement appropriate learning strategies and evaluate learning outcomes. (MacKinnon, 1990, p. 14)

Clearly, the Comet course fits the "individually guided staff development" model described by Loucks-Horsley *et al.* and represents teacher development rather than teacher training. There was, however, an extra dimension to the Comet course, designed to enhance its potential effectiveness. Central to the structure of Comet were the regular group meetings which brought the participants together once a month over the duration of the course. (These meetings were scheduled for the mornings of the Friday follow-up sessions for all the institute participants). The purpose of the meetings was two-fold; first to provide "opportunities for teachers to examine and reflect on their practice" as advocated by Loucks-Horslet *et al.*, and second, to combat the difficulties of being a "lone innovator" by building a peer support network.

Science Programs: Are they any different

This thesis set out to examine the effectiveness of the summer institute and Comet course on the development of the participants as science teachers. The distinction between teacher training and teacher development, illustrated by the summer institute and Comet course respectively, has been discussed in terms of the models and principles suggested by Sparks (1983) and Loucks-Horsley *et al.* (1990). Those models and principles, however, are generic in nature and could be applied to staff development at any level in all areas of the curriculum. The summer institute and Comet course, on the other hand, were designed specifically to support the teaching of science at the elementary level. As we saw in Chapter Two, the teaching of science is considered by many elementary teachers to be the domain of "science experts" with a solid grounding of content knowledge. Does this have any significant implications in the design of staff development programs for elementary science?

It is interesting to compare the views of teachers and researchers on the relative importance of scientific knowledge required to teach elementary science effectively. Studies of the perceived needs of teachers report a variety of opinions. Burke (1980), for example, found that the teachers surveyed in his Massachusetts study were almost equally divided in their choice of focus for in-service programs between science content, manipulative activities and curriculum projects. Neale *et al.* (1990) reported that a majority of the primary teachers they worked with were "perilously low on subject-matter knowledge, and they knew it" (p. 126). On the other hand, Martin (1987) claimed that, since knowledge of science content was not raised as an issue by any of the teachers he interviewed, it is not a significant factor in changing attitudes and confidence levels of elementary teachers in a science in-service program.

While these studies present a somewhat diverse range of opinions, the case for science content is more forcefully presented in other assessments (Finson, 1989; Loucks-Horsley *et al.*, 1989).

> Teachers need to know both science content and pedagogy to teach science well ... it is not enough to have good generic teaching skills; rather, each discipline requires its own teaching strategies. Teachers' content knowledge as well as their pedagogical content knowledge are both of concern. (Loucks-Horsley *et al.*, 1989, p. 17)

The relationship between teachers' knowledge of science content and their understanding of science and science teaching appears to be somewhat problematic in any discussion of in-service professional development programs for teachers. Its significance will be examined further in Chapter Four within the context of "scientific literacy."

Summary

In this chapter, I have reviewed the traditional in-service program, often referred to as a *teacher training* model, and a more recent concept of *teacher development* which is teacher-centred and teacher-controlled. The training model was described using the categories of Context and Training Process employed by Sparks (1983). A supportive Context is characterised by effective leadership at the district and school levels, and a collegial working environment within the school. The Training Process recognizes the long term nature of teacher change and calls for follow-up support to enhance the effectiveness of the commonly found one-shot workshop. The Training Process should include: presentation of theory, demonstration or modelling, practice, feedback and coaching.

Teacher development moves away from the top-down, managerial style inherent in the training model and assumes that teachers are autonomous practitioners in control of, and responsible for, their own professional development. Loucks-Horsley *et al.*, (1990) propose that good staff development should be continuous and on-going, and should provide teachers with a choice of activities so that individuals can tailor their development programs according to their own interests and capabilities. There should be opportunities for teachers to work together to share progress and perspectives, and the activities should model the constructivist perspective of learning. They suggest that these principles can be found in the following five models of staff development: a Training model, an Observation and Assessment model, an Inquiry model, a Curriculum Development model, and the Individually Guided model.

The summer institute contained a number of elements of the training model, whereas the Comet course was seen as an example of an individually guided model of staff development. The summer institute and Comet course were designed specifically to foster the teaching of elementary science. It was suggested that teachers' attitudes towards science may be a significant factor in the design and delivery of teacher development programs, a situation which might not be the case in other curriculum areas.

Chapter 4

ANALYSIS AND FINDINGS

I now turn to the results of the research and how they inform our understanding of the research problem. I will review the structure of the in-service program and introduce the participating teachers who contributed to the research study. The methodology of the research process is then discussed before moving on to an analysis of the findings.

The In-Service Program

"Science in the Most Curious Places" was a five-day summer institute which took place at Science World in August, 1991. Twenty-four elementary and intermediate teachers, none of whom had an extensive background in science and science teaching methodology, participated in hands-on activities and workshops intended to promote science teaching in their classrooms. The activities, which included "Experiments you can eat", "Amusement Park Physics" and "Science in a Bag" amongst others, were led by Science World education staff, members of the Faculty of Education at Simon Fraser University and prominent science teachers from the Vancouver region. The participants were also invited back to Science World for three afternoon follow-up sessions in September, October and November, 1991.

Nine of the teachers enrolled in the Comet course which was scheduled over the Fall term, 1991. Designed to extend and consolidate the summer institute, the Comet course required the teachers to create, implement, and evaluate a science unit or science-based theme in their classroom which embodied some of the content, techniques, or strategies they had learned. I was the instructor for the course, visiting participants in their classrooms and co-ordinating the monthly progress meetings which took place at Science World during the mornings of the three follow-up sessions.

The Teachers

Seven of the participants agreed to assist in the research study (see Appendix A for the letter of consent) and met together at SFU on the evening of February 3rd, 1993 to discuss their experiences during the year following the end of the Comet course. Individual interviews in their own schools took place over two months following the February 3rd meeting. All the teachers work in different schools in the suburbs of Vancouver and four of them – April, Charly, Dick and Sarah – are in the same school district. The following brief introductions to these participating teachers include excerpts from their transcribed interviews, in which we find them looking back on the past year and a half.

April

April is the youngest of the group; she has been teaching grade 6 and 7 for about six years in the same school. She wanted to be a veterinarian and enjoyed biology in high school but, after failing chemistry twice at university, she switched to teaching. She had included some science in her teaching – familiar topics from biology and always teacher-directed and controlled – and felt that she should be teaching science differently but didn't know where to start. At the end ot the summer institute, she listed her objectives for the Comet course: "(1) get the students excited about science, (2) try and foster critical and creative thinking, and (3) try and foster student questioning and hypothesizing." She started the Comet course with very mixed feelings, which she describes below:

> All that feeling of anxiety that I have to really try and do something that I've never done before, especially this way, and that's kind of nerve-wracking. You know, when I went into the course, OK, if I'm going to take this course, I have to change what I'm doing, I have to change. I'm not happy about it, but you know, you get in that pattern, that habit. So that was a little bit of anxiety, that I knew I was going to have to force myself to learn something new and to change and what if I couldn't do it and all that kind of stuff. But once I got through that, then going to those monthly meetings was fine because we *had* been doing science, and we *had* gotten better at it, and it had become a lot of fun. (April, interviewed February 22nd, 1993)

Charly

Charly teaches thirty grade 6 and 7 students in a small, portable classroom – one of eleven at a school which is being totally rebuilt and expanded. She is the most experienced teacher in the group, having spent many years as a pre-school teacher before moving to her current position about five years ago. She wanted to do the kind of hands-on science that was taught in pre-school with her intermediate students but she didn't know how to make the shift and be able to justify it. She described her plans for the Comet course as "increasing enthusiasm for science, especially with girls, using learner-focussed, hands-on science activities, while I continue to worry about translating discovery into letter grades." At the beginning of the summer institute, she was quite concerned about her lack of science background.

> I don't think I realized it *was* hands-on science – I thought it was just science for teachers who were non-science backgrounds. And that terrified me a little bit because I said, "Well, non-science backgrounds doesn't mean absolutely nothing, nil. They probably had a little bit somewhere." I don't, so, like how much is no science background? There's degrees of no science background. (Charly, interviewed March 10th, 1993)

Dick

Dick is another grade 7 teacher; he has a class of thirty students in a regular classroom and his school is also being expanded. He majored in geography but switched to a B.Ed. program after marrying a teacher – he credits his wife as being the most influential person in his own development as a teacher. He had always felt that science was lacking in his classroom and the summer institute sounded promising. Dick has taught in the same district for about fifteen years. His project for the Comet course was "a series of hands-on activities focussing on air pressure, providing year 7 students the opportunity to experience sciencing, and to develop curiosity and an interest for science inquiry." In the excerpt below, he describes how his science teaching has changed from short, self-contained units to an ongoing "science is everywhere" approach.

> Science in the classroom – it's something that doesn't just start and end, it's there all the time and it comes into everything, it *does*, and I get the reward out of the kids because they'll see science all over and there's a spinoff from that ... now I've put science in a different bag, it's more exciting, I'm willing to take it, I'm willing to do it. It's given science a place in my classroom rather than just saying "Here's the textbook, I'm running out of time." So it's given my classroom a focus. (Dick, interviewed February 15th, 1993)

<u>Sarah</u>

Sarah has been teaching for about sixteen years and she was a major influence on April during her practicum and first year in the school. She has recently moved to a brand-new school and has a class of thirty grade 7 students with whom she shares her energy and enthusiasm. She did not enjoy science in high school; Biology 12 was just memorisation, and she never considered taking a science course in university where her major was English. Sarah's classroom science was usually a small part of a humanities-based theme, which she was beginning to find unsatisfactory. The summer institute came along at just the right time. Her project for the Comet course was a unit on flight, through which she hoped to foster a positive attitude in her students towards science, and which would require that she "take some risks in the way I present material to my students."

She describes her motivation for attending the summer institute in the excerpt below:

> What really got me thinking, "I've got to change my science program" was when we did a school-wide theme on Space. And my partner and I, and April, devised all these stations and one of these stations was where they did some experiments that I had found in some books – where you make a little rocket out of a match and some foil and you heat it up, and the one where you make a rocket out of a balloon going along a string – and I just watched those kids and how much fun they had, and they would work on it, work on it, we're gonna get it, just change it this way – just the fun that they had and I thought, "This is where it's at," you know, "This kind of science is a lot more fun, getting them to think." (Sarah, interviewed February 24th, 1993)

Ingrid

Ingrid always knew she would be a teacher. When she completed her B.A. in History she took a year of teacher education during which she learned to teach social studies using an inquiry approach. After a miserable high school practicum and a couple of years substituting, she left teaching to work with mentally handicapped people for four years. She joined her present school twelve years ago to work with multiply-handicapped children and, after a year or two, moved back into classroom teaching. At the beginning of the Comet course, she had a class of twenty-five grade 3 and 4 students, and she planned to have them "learn science concepts through a more activity-based approach, rather than through the use of textbooks and lecture format."

An administrator, with whom she had presented district workshops on anecdotal reporting, suggested that she attend the summer institute. She was less than enthusiastic about doing anything concerned with science when she first came to the summer institute. However, as we can see below, her confidence soon started to increase.

> Well, part of my expectation was I wasn't going to enjoy it, I was so apprehensive about doing it. When [the administrator] phoned, I said, "You know I'm not a science person, I couldn't possibly do a science course." He said, "No, it's meant for people like you, people who don't do science." And then when I got there, there were all these people talking science and I thought, "Oh yeah, people who don't know anything about science" and it really scared me, it really scared me, I thought, "Oh no." But after, you know, the first initial time of being there, it was fine. Because to me it was such an eye-opener, that every time I went I felt like I was just feeling more comfortable about doing science. Every time I walked through the door I felt, like, OK I can do it. Like, every time I went there, it was one more step, OK I can do it this year, I can actually do science, and it was just – that's what happened to me, [it] just got

stronger and stronger. (Ingrid, interviewed March 8th, 1993)

Lynne

Lynne came to primary teaching after a career in urban planning and raising a family. She traces her interest in science and nature to childhood summer vacations in the Rocky Mountains but did not take any science courses after high school. She joined her present school in 1989 and, at the time of the summer institute, she was sharing a class of forty-two early primary children with a teaching partner in an open-area classroom. Very little science was going on in their classroom and Lynne was anxious to improve the situation. She identified the goals of her Comet project as follows: "to bring more science into the classroom; to learn about colour, its use and value; to encourage children to develop critical and creative thinking and to explore possible relationships between observations."

> The high point for me during the [Comet] course was when I was actually doing the stuff in my classroom, and seeing it working and just getting it together, right? And seeing that they, the kids, were doing it too and having fun and learning – and talking and coming together and hearing what other people were doing was really good. Also to hear their frustrations and, maybe how they felt about it. And it was nice to meet people when you weren't stressed or had to do something else. It was definitely a time for meeting and that meeting was to be talking about what everybody was doing and that made it really worthwhile. You might not get that kind of discussion in a staff room, that's why I thought it was great. (Lynne, interviewed March 3rd, 1993)

James

James was considered by the others to be the most experienced at teaching science, even though he had no formal training in science or science teaching methods. He spent his years in high school playing sports and just scraped into university where he drifted into majoring in History. He decided to become a teacher because he couldn't think of anything else to do, and spent eleven years in an urban school district teaching grade 7. His interest in science stems from after-dinner puzzles and tricks at a friend's house which he would show to his class. His students' enthusiasm prompted him to develop themes and units which were based on science activities. He moved to his present school, currently being renovated and expanded, in a suburban district in 1989 and teaches thirty-four grade 7 students in one of the fourteen portable classrooms on the site. His project for the Comet course was a science enrichment program for students (not from his own "homeroom" class) which utilised the "science in a bag" concept. As the following extract reveals, James is particularly concerned that students be afforded first-hand experience with science activities.

> ... it was a great logistical thing – we did, in groups of two, popping popcorn in test-tubes – to get the equipment and the stuff and the kids together, it took me a couple of hours to get it all together. The lab went off perfect, seventeen groups all popping popcorn, it was really wonderful, but cutting up the little candles, putting the little piece of sandpaper for the matches in each tube and laying it all out there and having the kids pick it up, it was such a pain but, I mean you *have* to do it. Because otherwise, they never, you know, they're

> watching *me* pop it. So as much as I can I like them to do things, but sometimes it gets pretty tricky. (James, interviewed February 10th, 1993)

Methodology of the Research Process

A comprehensive database for this study has been generated over the past two years. During the Comet course I kept a journal in which I made notes on classroom visits, group meetings, telephone conversations and electronic mail communications with the teachers. I also made field-notes during the monthly meetings, one of which was videotaped and later transcribed. Copies of teachers' journals, monthly progress reports and their written evaluations of the Comet course were all made available.

When the seven participants met at SFU in February, 1993, they were shown short segments of the videotape of their meeting at Science World in November, 1991, where they had discussed their progress in the Comet course and plans for maintaining science in their classes. Their reactions to seeing themselves on tape after more than a year had passed produced some interesting discussion. This meeting in February, 1993 was also videotaped and transcribed.

During February and March, 1993 I visited each teacher in his or her classroom where we conducted an interview after school. Being in the classrooms allowed me to revisit the working environment of the teachers and also contributed to their comfort with the interview process (Mishler, 1986). The interviews, which lasted about an hour and a half, were informal and conversational in style, but the content was directed by a series of open-ended questions on the in-service program and their experiences in teaching science (see Appendix B for the interview outline). The interviews were videotaped for later transcription and analysis, although it could be argued that an important part of the analysis and "selection" process began during the interview itself.

The qualitative nature of the research involved conceptual and analytical stages, with an initial emphasis on conceptualizing the study. During the early stage of the review of the literature, in the fall of 1992, it became clear that the classroom teacher was the key to improving science education at the elementary level. Accordingly, the focus of the study became the experiences of the teachers who had gone through the summer institute and Comet course.

The first interviews took place in February, 1993 following the group meeting at SFU. The teachers' discussion at that meeting, and the contents of the field-notes from the Comet course, were used to develop the topics and questions in the early interviews. These included the teacher's background, reasons for attending the summer institute and for taking the Comet course, views on various aspects of the course, expectations of the course, high and low points, and how the course had influenced the teaching of science. As these early interviews were transcribed and read, I began to see the beginnings of the three themes which eventually framed the final analysis of the database. I also returned to the research literature in order to further conceptualize the study in terms of these themes: scientific literacy, constructivism and teacher development.

At this point the interview topics were expanded to include questions on who or what had influenced their teaching, how the teachers viewed their teaching of science before and after the in-service program, the location of the program at Science World, which specific aspect(s) of the Comet course had been most influential on their science teaching, and how they envisioned themselves as science teachers over the next few years.

The rest of the interviews took place during the first two weeks of March and were transcribed by the end of the month. The month of April was spent reading and re-reading the transcribed interviews, transcriptions of the meetings in November, 1991 and February, 1993, field-notes, teachers' journals and my own Comet journal. This period of immersion in the database strengthened my earlier suppositions and yielded further evidence, which informed the three aspects of the teachers' experiences on which I had chosen to focus.

What constitutes evidence when making claims based on qualitative data? If, in my interpretation of the teacher's words, I am able to crystallize one or more emergent themes which speak to the research questions, then what are the "warrants" for making the step from "data" to "conclusion?" (These are the terms as used by Toulmin (1958) in the layout of arguments, discussed in Chapter One.) In this study, those warrants are grounded in the context of the teachers' experiences, and are based on their own self-reports, through their writings, comments and interview responses. It seems reasonable to claim that confirming evidence would be found in multiple, corroborating examples from different teachers if they gave similar responses to the same line of questions. Also, if a teacher made the same point at different times, perhaps during the Comet course and again during the interview, then the validity of my interpretations would be enhanced.

There is a possible difficulty here, however, which stems from my own relationship with the teachers and their perception of my role at different times. As I indicated in Chapter One, I was initially a participant and presenter at the summer institute, their instructor during the Comet course and now I am appearing in the role of researcher. Although this variety of perspectives has given me a unique insight into the teachers' experiences, which I believe strengthens my interpretations of their responses and writings, it may also have a contaminating effect. Are the teachers telling me what they think I want to hear when I ask them about the Comet course? Am I still "the instructor" with an obvious vested interest in hoping that the program was wonderful and accomplished everything it set out to do?

This was always in the back of my mind as I worked through the database, and, as far as I can tell, it only came to the surface on one occasion. During my interview with Charly, she mentioned how the teachers were more prepared to take risks in their science teaching:

> Charly: I think it's given me a lot of confidence to take those risks ... Knowing that it's O.K. if they fail.
>
> Interviewer: Now, was that part of the Comet as much as the institute, or where was that a major part do you think ...
>
> C: Oh, both parts – yes? ... Hmm, you don't agree? ... What do you want me to say?
>
> I: No, no, I'm just ...
>
> C: Turn [the video camera] it off! What do you want me to say?
>
> I: I don't want you to say anything, I'm just trying to think of where you were doing that and it was actually ... there was a time when you had to stand up and do your science in a bag in the institute there.

During this exchange, the tone was light and I do not think that it was serious enough to jeopardize the views that were expressed during the rest of the interview. It may even have been a result of an unclear, ambiguous question on my part. It serves, however, as a useful reminder to look for corroborating evidence when interpreting the database. In the final analysis, any researcher who engages in interpretative work relies on a sense of the trustworthiness of data and their significance.

Analysis of the Database

The database yields several indications of various aspects of the teachers' experiences. These are presented initially in the form of general findings which seem to be common to most of the participants. Subsequently, the three emergent themes are examined in greater detail.

Support and Collegiality

All of the teachers stressed the value of the monthly meetings where the participants spent the morning together discussing their progress.

> They were really good, the most interesting thing was finding out what other people were doing. That was the best part, getting together with your colleagues. I mean, the appeal of the whole thing was to find out what other teachers were doing [in science]. (April)

The meetings provided a forum for the exchange of ideas and science teaching strategies which were tried and tested by their colleagues, a factor which appears to have been significant in the view of the teachers.

> That, to me, was the greatest value of the course, that you're talking to other practitioners and just getting the actual management, day to day, how did you do it? You see, that's the type of thing we need to get together on, those management things. [Those monthly meetings] were really important because that kind of quality time

> where you get just to sit with other people and discuss something that you're all interested in is very hard to find. I think teachers are so isolated, they never talk to anybody else, and here was this golden opportunity. I mean, you're provided with this opportunity, you come and you sit down, you can chatter away about how you're handling this. It was, it was terrific. (Charly)

> That's what made the course. Because we'd talk about problems we'd been having and I found that to be really stimulating, it made me think about so many things that I was doing – like evaluating, getting other people's ideas and just talking about evaluation technique and process and what is it that is important here. It wouldn't have been a good course at all if we hadn't had those monthly get-togethers. (Sarah)

These practical, day-to-day concerns were an important component of the meetings, but companionship and collegiality were seen as being equally important aspects of the time spent together. Numerous references to teacher isolation and the absence of opportunities to spend professional time discussing common interests indicate the importance of sustained support perceived by the teachers as they worked through the process of implementing science in their classes.

> [The monthly meetings were] something to look forward to, a day with people sharing common interests, people from other districts so you could talk to them. It gives you that whole overall teaching collegiality that's important in your lives. It gives you something more than just your classroom. That's another thing – we as teachers, all in our classrooms, you don't talk with each other. You may go to a meeting or a workshop and then off back to your little cell. So often we're islands, we're cells. (Dick)

> [Comet] people sit around the table and say, "I think this is really important," and they say,"We do too." Whereas in school, when you tell people about an experiment and they say, "Why bother? Why don't you just give them a textbook and have them read it like we do?" It's depressing to hear that. (James)

From my records of the monthly meetings, including the transcript of the November, 1991 meeting which was videotaped, it appears that the discourse between the teachers was primarily on the practical, day-to-day business of classroom strategies and teaching ideas. There is little evidence of discussions of a more philosophical nature, such as why science should be taught, or why a constructivist perspective might be a valuable way of thinking about learning and teaching. It is tempting to speculate on the possible reasons why these questions were not articulated – lack of time, more important things to discuss, or perhaps a feeling that such questions are irrelevant to the classroom – but whatever the reasons, the focus of the teachers was firmly on practical matters.

The Comet course, and particularly the support meetings, were seen as being strong motivators for implementing what was learned in the institute. At the end of the Comet course, Ingrid wrote:

> The additional [Comet] coursework has helped me to implement science throughout the curriculum by giving me the support I need to feel comfortable that I could teach meaningful science. This support has come by giving me a network, both professors and other teachers, with whom I can discuss successes, failures and ideas. Many times, after having attended a conference and having tried a teaching idea, I would have liked the opportunity to gather again with my colleagues to discuss why it worked, if it did, or why it didn't work. This Comet course has given me the forum to do this. (Ingrid)

The summer institute served as the catalyst for change, but for some, it seems that more was needed to implement the change.

> I really wanted to keep motivated, and I felt that if I didn't take [the Comet course] I might just do the workshop and then go, right? And you know how you get involved in what's going on, and you just put it aside, no matter how good it was. At least, that's how I work. I need that extra push, almost, to get it going. (Lynne)

In the interview, Ingrid referred again to her need for motivation to implement what she had learned at the summer institute:

> I learned more and I forced myself to take what I was learning back into the classroom. And that's where we always stop, you know, you take a course all summer and then, (sigh) you come back and you sort of get really busy and there's the stress of this and you mean to do it and then you just never do it. And I really believe that would have happened to me if I wouldn't have taken the Comet course. I would have tried a couple of the experiments, I might have done a little bit of it, but I certainly wouldn't have done the turn around which I've done in the last two years. (Ingrid)

Sarah also talked about the importance of on-going support. When I asked her if she intended taking the Comet course when she first applied for the summer institute, she replied:

> No, I didn't need the credit and life is too busy. But as I took the institute, I saw the value of taking the Comet course. I just thought, "I'm just getting into it here, I want to go farther, I want some more support." I think it was more the idea of support, learning some more and also, the quality of the teachers, the modelling that was done, it was top-notch. I couldn't resist. I think also, because I found out it wasn't going to be reading piles of textbooks, it was going to be really applicable to what I was doing, I was going to get something out of it in return. (Sarah)

Science World

The institute and follow-up meetings were all held at Science World, a location which apparently made an impact on some of the teachers.

> I think it made a difference being at Science World, I really do, because you had different people come in and talk that worked right there and it's a "sciency" place to be – I don't know what it is, maybe just going up and seeing that big silver ball, you feel like you're walking into a scientific place, like you're a scientist, even if you're not. (Ingrid)

Others referred to the atmosphere at Science World, how it made them feel "scientific and special" and helped to foster the group identity.

> I think we could have done it just as well anywhere else but, just the setting and the fact that we were treated so royally, I mean teachers aren't used to being treated so well. And here we were in Science World, we didn't have to pay our seven bucks to get in, and we were always treated as professionals. It was a whole combination of things. (Charly)

These comments would seem to support the views of Salt (1969, cited in Henderson, 1978) in which he suggests that the effectiveness of an in-service program may be enhanced by involving "the course members and staff in a project which requires very intensive interaction in relatively novel circumstances" (p. 79).

Teachers' Perceptions of Change

How effective was the combination of summer institute and Comet course in bringing about real change in the science teaching of the participants? Again, one does not have to look too deeply into the database to find compelling evidence that the teachers themselves perceive a dramatic shift in their attitudes and practice. A few examples include:

> The best one I've taken, it really applied to what I can do in the classroom. This has just had me change my thinking and just my approach to teaching science. It's helped me, I wanted to make that change and this helped me institute that. (Sarah)

> This has been the biggest change I ever had in science, throughout my life. (Dick)

> As you can see I am a chronic student! I mean that [list] is one year's pro-d, I go all the time and I take anything. And I think it had the biggest impact of anything I've ever done in education or any training. Maybe it was a latent interest and it just hit me at the right time in my life, I don't know. It's really had a big impact on my life. (Charly)

> I believe this course has made a permanent change in my science teaching and it has also left a lasting impression with my students that science is everywhere. Science has definitely been the highlight of this term. This course has really been fabulous. (April)

> I cannot believe that I am the same teacher who never wanted to teach science. (Ingrid)

I believe that these findings represent significant changes in the lives of the Comet participants, and provide valuable insights into the experiences of teachers as they work through a meaningful staff development process.

Three Aspects of the Teachers' Experiences

During the early stages of this study, three aspects were chosen to focus the analysis in order to address the research problem.

> Have the participants' views of science, science teaching and "children's science" changed significantly as a result of the program? Does this imply a shift in their "scientific literacy"?
>
> Have the teachers experienced the anxiety and stress which accompanies significant, meaningful change? How influential are their perceptions of science as a difficult and threatening subject in this process of professional growth?
>
> What is the character and quality of the science teaching which is now taking place in their classrooms? Are the Comet teachers using a constructivist view of learning when they talk about their students' learning of science?

In order to examine these questions, a more detailed analysis of the database is required. A useful start might be to select a comment from one of the teachers which seems to characterise some aspects of his or her experiences, and subject it to a more intense scrutiny in order to better understand its significance.

Ingrid's Dilemma

At the end of the Comet course, Ingrid summarized her experiences in a well-articulated paper, in which she described some of the difficulties she had encountered in changing her science teaching. In the following excerpt she discusses the problem of whether to give the students the "correct" outcome or explanation, or whether they should continue to work with an "erroneous" premise. Her dilemma is complicated by her own lack of scientific background.

> I took a poll to find which experiments the students enjoyed the most and found that two of the more favourite experiments were ones which I was not too successful in demonstrating. I think students enjoyed the fact that the experiments did not always work. Therefore, when they try and experiment and it is not successful, they have seen me model what to do.
>
> It's okay to have an experiment not work the way you think it should. I still have a difficult time with this concept, but am working hard at not always having the right answer or having it happen the right way.
>
> Sometimes they make statements which I do not think are correct but I have let them stand because I hope that future experiments will help to change the statement. [My teaching partner] and I have discussed the difficulty we both have had at times in not coming out and telling students what the textbook answer is. At times it is difficult because we ourselves do not quite understand all the so-called "correct" answers. (Ingrid)

What does this tell us about Ingrid's views of science and the teaching of science? I believe it tells us a great deal. If we take the following statements from the quote, and look at them together, we see a pattern begin to take shape.

> *when they try and experiment*
>
> *okay to have an experiment not work the way you think it should*
>
> *not always having the right answer*

These extracts tell us something about what happens in Ingrid's science classes; we see that sometimes the students watch her demonstrating experiments, and that at other times they are doing hands-on experiments themselves. Furthermore, the experiments do not always work as expected or intended but this does not mean that they "failed." Getting the right answer is not the sole objective of doing the experiments, implying that the experimentation process itself has some worth and value.

This way of teaching, and thinking about, science is in marked contrast to Ingrid's previous attitude and practice, where "I would platoon with someone who would teach my science or I would teach a humanities-type approach." She rationalised her reluctance to teach science, citing the usual barriers of equipment and time to set things up, but she also remembered how she had been taught in school, where "no room for error [was] permitted." Given that she was "afraid my knowledge was not vast enough" to teach without error, it is no surprise that she felt inadequate to teach science and, therefore, avoided it.

The view that science is a vast body of knowledge to be taught only by experts is quite common, as we saw in Chapter Two. Ingrid, while still acknowledging that the "textbook answer" embodies some of that knowledge, appears to have made a significant shift in coming to see school science as a process for generating and examining such knowledge; science is a verb as well as a noun. Her view has expanded to include the process of doing science and her emphasis on getting to the "correct" answer seems to have shifted.

These data suggest that Ingrid's scientific literacy, as understood by Roberts (1983) and described in Chapter One, has increased. The "Correct Explanations" emphasis, implicit in the view that science is simply a body of knowledge to be learned, is now accompanied by the "Scientific Skill Development" and "Structure of Science" emphases. Recall that Scientific Skill Development emphasises the means of scientific inquiry by developing the necessary skills such as observing, measuring, hypothesizing and experimenting. Structure of Science, however, is more concerned with the way in which scientific knowledge is developed as an intellectual enterprise, and examines the relationship between evidence and theory and the adequacy of models in explaining phenomena. Further evidence to support this claim of an increase in scientific literacy will be examined later in this chapter.

What other meaning can be taken from Ingrid's words? If she really has undergone a significant change in her scientific literacy, what do these data tell us about the nature of the change?

> *I still have a difficult time with this concept, but am working hard at not always having the right answer or having it happen the right way*

the difficulty we both have had at times in not coming out and telling students what the textbook answer is

At times it is difficult because we ourselves do not quite understand all the so-called "correct" answers (Ingrid)

Apparently, the transformation is neither easy nor complete. There are a number of difficulties, implying that it is not a natural progression in her professional growth but a process which has to be consciously and constantly monitored. It is not easy to break old habits and become comfortable with new strategies, especially when the new methods require a significant philosophical adjustment, such as Ingrid's shift in her views of science and science teaching. Her anxiety is compounded by a lack of scientific background knowledge which inhibits her own understanding of the "correct" explanations. The risk of "not knowing the answer" is often cited as a reason not to teach science, as we saw in the literature reviewed in Chapter Two.

The ongoing nature of the change is indicated by the reference to "working hard" on her difficulty with accepting "failed" experiments, implying that she has yet to complete the required shift in her thinking. It also implies that Ingrid is not giving up in her struggle to make the shift. Perhaps it is unrealistic to expect that teachers will make such a "shift" once and for all. This interpretation of Ingrid's dilemma suggests that her experiences are characteristic of meaningful change, as described by

Fullan (1991) and discussed in Chapter One, in which there is a prolonged period of "loss, anxiety and struggle."

Which other aspects of implementing science in the classroom contribute to these feelings of loss, anxiety and struggle? Is there supporting evidence of meaningful change in the experiences of the other participants? I shall return to these questions shortly.

Ingrid's quotation is also indicatative of a constructivist perspective on the teaching and learning of science. The central premise of constructivism, as we saw in Chapter One, is that all learning is a process of constructing meaning out of new situations by the interaction of the individual's prior knowledge and their observations of the new phenomena. In other words, "the generation and development of knowledge is a matter of putting a construction on reality" (Roberts, 1982, p. 278).

Ingrid clearly demonstrates her awareness of how children might adapt their beliefs when faced with meaningful evidence to the contrary.

> *Sometimes they make statements which I do not think are correct but I have let them stand because I hope that future experiments will help to change the statement.* (Ingrid)

She also refers to *"not coming out and telling students what the textbook answer is,"* indicating the importance of students constructing their own meaning rather than passively accepting the correct information or result.

Three Emergent Themes

These interpretations of Ingrid's dilemma have generated three distinct themes, summarized below, which must now be checked against the experiences of the other participants.

Increased Scientific Literacy. One aspect of an increased scientific literacy is detected by a shift from viewing science as a body of knowledge. School science becomes a process, involving skill development and an emphasis on the structure of science as inquiry.

Not an Easy Transformation. The teachers still have anxiety over knowing the content, even though they may appear to have more confidence and willingness to do science with their students.

A Constructivist Perspective. Teachers demonstrated an awareness of, and sensititivity towards, the beliefs which their students bring to their learning.

Increased Scientific Literacy

Ingrid described the science content of her classes before she took the in-service program as "a humanities-based approach." April used a similar expression as she described the change in her science teaching over the past year and a half. The excerpt below focusses on her teaching of a theme study of "forensic science":

> Science has developed beyond glorified social studies into an accessible discipline, to be taught as such. I like what I did this year, doing a science-based theme and giving credit to the science. We wrote mystery, we read mystery, we watched TV and analysed mystery. But 75% of what we did was science. It was real science, it wasn't phony. So that I'll keep, but the themes will be different. (April)

Sarah made a different, but related, point as she mused over the evaluation of her students in science, an area of concern to which we return shortly.

> What is it that *is* important here? Is it getting the kids to memorise these things or is it important that they're thinking? (Sarah)

This statement indicates a move from the traditional "body of knowledge" view of science to the "science as inquiry" curriculum emphasis.

By reducing the emphasis on content knowledge, the barrier of "inadequate background" to teach science may be viewed from a different perspective, and possibly circumvented. Lynne's experience illustrates this change of viewpoint as she moved from the summer institute back to her classroom and on to presenting workshops to other teachers.

> They were excellent, the demonstrations. Seeing things happen and hearing the comments of the people, realizing that even though you had no science whatsoever perhaps you could come close. And that was the whole idea, that you too can do science and be aware of it, right? You don't have to have a tremendous amount of education but you can still use that kind of thinking. It's really good.
>
> I don't have a great depth of knowledge of water, yet I feel the kids can experience water, or colour, or snow and have fun carrying out observation skills and this kind of thing – they can do that and I don't feel that inadequate, and yet they are learning some of the scientific things that are important. In terms of all the chemistry and everything else that goes into it, My God, I don't know all of that!
>
> I also did district level and pro-d [in school professional development day] workshops. It's really interesting because people – like me, I don't know anything about science – but when you introduce it in a certain way, they really enjoy it. (Lynne)

How far should the emphasis be shifted from content to process? In Chapter One we read Roberts' (1988) argument for a balanced view of science education, in which all the curriculum emphases are acknowledged. Sarah raised a similar concern in one of the monthly Comet meetings:

> What is the balance? To do all hands-on for the entire year? Burn yourself out, burn the kids out from having always to predict and blah, blah, blah. Can you balance it out a little bit? Is it wrong that I'm doing some stuff out of the textbook, or is it wrong that we're doing some research in science – is that not science; is that just language arts? (Sarah)

Determining this balance requires informed choices; the teacher must be aware of the options available and how they can best be employed. Sarah said:

> It was much better than my expectations. I didn't think I'd be coming out of there with so many options as to what I *could* be doing in science. (Sarah)

Some of the options require the teacher to re-think their role in the classroom and may involve a transfer of control from teacher to students, a shift perceived by some as a significant risk.

> But even with the Mystery Powders I pretty well let the kids go with it, I didn't stop very often. And just letting the kids take it where they want to take it. Even the fingerprinting, I thought I'd just do that for a lesson or two, well they got so into it we started fingerprinting people around the school and they'd be analysing it. And maybe I spent too much time on it, but I always felt that the whole time they were doing it they were learning something and as long as I feel like they're learning, they can do it for three weeks. (Ingrid)

> I don't feel worried now about saying to the kids "Go do it" – it's O.K. to set up four or five experiments in the room and let them go hog-wild. This is valid, this is O.K. They don't have to write *everything* in their [science] journals. It was fun, it was productive and they were coming up with the wildest theories – they had really good reasons for negative gravity! It totally became kid-centred after that. From demonstrator and controller I moved to a role of facilitator. (April)

> Does it bother the kids if they ask a question and you have to be honest and say "I'm sorry, I don't know"? (Interviewer)

> Not any more because now they're used to it. You know, they know that I'm the guy on the side, I'm not the guy on the stage because I'll just say, "Well, screwed this one up. So now what do we do?" It's O.K. if it doesn't work, then that's just as well because you just encourage the questioning, "Well, why didn't it work and what did you think was going to happen?" I think it's given me a lot of confidence to take those risks. And that's a big thing with, you know, teachers who don't teach science – "Well, they always fail for me, science experiments always fail." Knowing that it's O.K. if they fail. (Charly)

These extracts from the database – references to a science program rather than glorified social studies, the importance of science knowledge, the role of content in a balanced program, and the changing role of the teacher – are all indicative of a broader perspective on science education. Science is no longer just a body of knowledge to be presented by the expert and passively digested by the student. It should be pointed out, however, that although there is considerable evidence of a shift in the teachers' views of school science and how it can be taught, there is little to suggest that they have made a similar shift in their views of what science actually is. I could find no references in the database to indicate any particular views on the nature of science. Perhaps the wording of the interview questions, which stressed science teaching rather than science itself, precluded any discussion along these lines. Nevertheless, if we accept Roberts' concept of scientific literacy – a balance of various curriculum emphases for the teaching of science – it is apparent that the teachers did undergo a shift in their own scientific literacy.

Not an Easy Transformation

Ingrid's dilemma suggested some anxiety and stress in the implementation of her science program. Doubts about giving the right answer and understanding the concepts were interpreted as signs that the change process was not easy and far from complete, indicating that real, meaningful change was taking place. Do the experiences of the other teachers support these interpretations?

We have just read how April set up four or five experiments and it was O.K. to let the kids go "hog-wild." This was quite a change from her previous science lessons which were strongly teacher-directed. How did she feel when she looked back at this change in her role?

> I was really not comfortable with having it get away from being teacher-controlled. When we did dissections and microscope work it was very controlled, very teacher-centred. It wasn't very active, or very threatening – it was also quite boring. So I was really nervous, feeling that, "Today I'm going to relinquish control and set up the baby bath full of water and let six kids mess everything up." (April)

Earlier we touched on the topic of evaluation when Sarah was wondering what was important in the science learning of her students. Dick also referred to this difficulty in the final assignment of the Comet course:

> My grade 7 students found the written test to be a challenge. Some of the written questions related the principles they had discovered to different circumstances. Transferring that knowledge into another set of circumstances was not an easy task for many students.
> I found that when giving a written test the teacher becomes

> accountable for some form of correct answer. It is a "Catch 22" situation. During the experimentation the emphasis was on predicting, enthusiasm, interest, modifying and trying. The "correct" answer was not as important as the other goals. But historically, students study and prepare for written tests and want to know the right answers in order to prepare themselves. (Dick)

When Dick raised this problem at one of the Comet meetings, it prompted a spirited discussion on what was appropriate to be evaluated and how to go about it. This was clearly an area of concern and anxiety for all the participants.

Another area of concern, raised by Charly, was the difficulty of developing science-based themes which incorporate hands-on activities. The poor facilities in her portable classroom were one factor, but her lack of background was a greater barrier, in her opinion.

> I find it hard to build a curriculum, it's more, "Here's some fun experiments." O.K. we've been doing the Human Body – just did ears and hearing and so we've got all these sound experiments today. I don't know if I could build a whole curriculum unit with hands-on experiments for everybody. It's all very well to have an experiment at the front of the room and demonstrations, but for everybody to do, to be involved – it's also, uhm, made me realise that I don't have enough science background to answer ... well I don't want to answer the questions ... I can't *pose* the right questions because I don't have the right science background, for my own sake. I think, "Boy, I wish I knew more about that." So, you know, for my own self-satisfaction. (Charly)

The barrier of inadequate science knowledge seems to be one of the most prevalent causes of tension and anxiety in the minds of the Comet teachers, always lurking in the background. It does not seem to have prevented them from making what they perceive as dramatic shifts in their science teaching, but it is a factor to which all of them are still coming to terms, as they work through the process of implementing science in their classrooms. Sarah talked about the activities in the summer institute in the context of her not knowing the science background. When I asked her which aspect of the program she considered had had the most influence on her teaching, she replied:

> It was the modelling done by all the instructors, questioning and getting us to think, think, think, [but] I never felt threatened because I didn't know the answer. I never felt, "Oh, I'm so stupid – I *never* felt that. And that was a really positive part of that. Every instructor did that to us, really got us excited about it rather than thinking, "Oh brother, I don't know this, I don't know that." (Sarah)

The distinction between showing students individual experiments and the development of science-based themes mentioned earlier by Charly was also an issue for Ingrid:

> I look at certain experiments and I say, "I really don't understand what's going on here," and I don't now how to explain it to the kids. But last year, when we did those weekly experiments, I just took those books – we just started getting science books – and I was more apt to take them and try the experiments and just say to the kids, "Well, I don't know, you know, like, we just did the experiment, what did you find out?" Well, that's about as much as I know too. But when I'm doing a unit on something, I kind of want to know what's going on. But a lot of it comes from, I think, the fact that I never did any of those things myself. And because, I think, from my schooling, so much was content oriented that I'm always worried that I have to know everything before I teach it. And because I feel so inexperienced with science, I still feel like that when I want to teach it – because I still do feel uncomfortable about the fact that I really don't understand things that happen in science that well. (Ingrid)

As we move into the higher grades we find the teachers in our group tackling the problem of science background in a different way. When I asked Dick, who teaches grade 7, if a weak background limits what he can do in science, this is how he responded:

> No, I think probably at one time I used it as an excuse, and you tend to do it because you're scared, you think, "God, what if they ask me this? I don't really know." But you don't worry about that – still, my biggest concern is, "Give *me* some source of materials which I can fall back on." It might be an excellent science textbook and I can look it up and O.K. read about it – "Oh yes, well O.K., here's the real explanation" – and so I think in that respect, we owe it to the kids and we owe it to ourselves to have some inkling of what the heck's going on. But I don't think you have to let that limit you in not trying things – not doing air pressure or not doing things with water or friction or anything – you just start. (Dick)

James also teaches grade 7:

> The other thing is a background, not university science just "Joe Average" stuff, like, "What air's made of," – really general knowledge stuff. A lot of people don't have that and they get really embarrassed. I mean, I talk to people at pro-d [workshops] and they're worried that they won't know the answer, teachers like to stand up there and know the answer. And knowing the answer means going out there and doing some reading, doing some researching – you've got to find out a little bit.
>
> For me, that's fun and I enjoy it. But if I had to teach, say, music and I had to spend an hour researching a twenty minute music lesson, I might not be real keen on teaching music. And I think that's what happens in science – until it becomes familiar, you spend a lot of time for a short gain. It's not instantaneous. It takes you a while before your class realises what they're supposed to be doing in response. So you spend a lot of time working, like almost a first year teacher, and you don't get instant feedback as being good. And I think it's like anything else – losing weight or whatever – if you don't get instant feedback you've a tendency to drop it. (James)

Doing some reading to find out more about the science may be effective for Dick, and even fun for James. But Ingrid, who teaches grade 4, has a very different opinion:

> Because sometimes you pick up these science books and it'll say – it just gets *so* complicated that you all of a sudden say,"Oh God!" – when all you might want the kids to learn is ... whatever. (Ingrid)

Does the grade level make a difference in the minds of the teachers about knowing the content? Lynne, whose teaching experience has all been at the primary level, has given this issue a lot of thought.

> The knowledge is important. It does make you feel more comfortable, you can stand up there and "yack" about it if you want to. And you can also, perhaps, ask better questions because you know where you end up. The thing is, if you know an awful lot in something, chances are you'll either talk about it too much and the kids won't want to hear, or, if you're really good you'll use it correctly. You won't give them a lot of the knowledge but you'll give them the stuff so that they can find out the knowledge.
>
> But you actually do feel more comfortable if you've got the knowledge. I have no trouble teaching certain things, because I've got the knowledge and I feel I can field and ask questions because I know the answer. Not that I'm going to give them the answer, but I know it.
>
> I do think you have to take one step at a time, you are a little bit worried about doing it if you don't know it. But the only way you're going to know it is if you try it and do it. (Lynne)

Lynne's attitude of taking one step at a time, dealing with the content as you progress, can involve a great deal of doubt and anxiety. Both Ingrid and Sarah addressed these conflicts, wondering if they were teaching "the right stuff" to their students.

> The other day I was saying to another teacher, "What have they really learned from doing Mystery Powders?" And I can't really say that they learned something really scientific. I think they learned some skills that it takes to be a scientist, or the things that you need to observe. So what they were learning there was their observation skills, their recording skills, their reporting back skills. But what did they really learn about science? I don't know. But maybe those are the skills – because I'm a person who believes more about the skills, I don't believe in memorising all the facts and all that stuff, I'm more interested in skills that you need to perform things. Like, do you know what to do? Can you problem solve? And I think they did do that, you know, kids would say, "Well, it's not working."
>
> And I would say, "Well, what are you going to do now?"
>
> "Oh, are we going to add more vinegar? Can I add more vinegar?"
>
> "Well, I'm not the scientist, you are, what do you want to do? Go ahead."
>
> But then I worry, did they learn anything scientific? (Ingrid)

Ingrid seems to be caught in a difficult situation where, on the one hand, she thinks that she should have a better knowledge of the content in order to teach it, but, on the other hand, she is trying to broaden the science for her students to emphasize skills as well as content. The situation is complicated by her own schooling, where content and memorisation were the norm.

Sarah also expresses her doubts quite forcefully:

> I was marking my kids' science binders last night and I have two new girls who've come in from other schools – different schools – but they'd done the same science unit on Sound. They had the same photocopied worksheets, fill in the blanks and all these graphs and

> diagrams and I thought, "Oh my gosh! Am I doing the wrong thing? Maybe the stuff I'm doing with them is too easy or something because look at all this stuff." That really crossed my mind. Then I thought, "Uh-huh, I bet they could never tell me anything about Sound" after I'd looked at all this. I'm getting them to think, to actually think about things, even though they don't have these big, long, fancy lab reports, but I get them to write a lot of stuff down like, "What new thing did you learn?" or, "What makes this a good experiment for teaching cohesion?" Like, they have to think of it in that way, that kind of stuff.
>
> I'm always doubting myself in a way. But I looked at that and I had this moment of panic. "Am I preparing them for High School?" But that's not the big point here, I have to say no, no, no, that's not the important thing, that I'm preparing them for High School. My goal is to get them excited about science and to get them thinking about things rather than taking them for granted. (Sarah)

These data portray doubts about what is being learned, discomfort with the participants' own science knowledge, conflicts between the goals of inquiry and student evaluation, and anxiety about relinquishing control and changing roles. All of these aspects of the shift in scientific literacy of the teachers lend support to the claim that the change process is difficult and on-going, and may be considered as real and meaningful.

A Constructivist Perspective

Does the database support the claim that the Comet teachers are using a constructivist view of learning when they talk about their students' learning of science? We have already seen that Ingrid expects her children to modify their theories as further experiments produce new, and possibly conflicting evidence. Sarah touches on the same idea as she observes her students making sense of an experiment on surface-tension.

> I am noticing that the students are starting to do more and more thinking during the experiments. When I asked, "What do you think makes the needle float on top of the water?" some of them were bringing in knowledge from other experiments we had done. For example, the week before, our student "scientist of the week" did the dancing raisins experiment with the class, and some of the kids thought that maybe there were some bubbles holding the needle up just like they did the raisins. However, when they observed more carefully, they saw that this was not so. (Sarah)

Others also saw their students re-examining their beliefs and theories in the light of new experimental evidence:

> By connecting specific experiments together, building a common theme, I have been able to teach principles by calling upon the experiences of the students during their experimentation times. By developing my questioning strategies, my original goal, I have been able to help the students use their experiences to solve and create hypotheses about the overall concept. For example, "How are these similar?" – "What does this remind you of?" – "Have you seen this result before?" I used air (pressure, movement, volume) to experiment with. By comparing the results of several related experiments, the students began to see the connections between them and they also began to make more intelligent hypotheses. It has been interesting to see how misconceptions were proven wrong. The students were forced to examine the evidence and build new theories, for which they designed other experiments to test these new theories. (April)

> I discovered the students were really getting into predicting, at times using prior knowledge. Discussion and reasoning has been active, leading to a student posing his own question. This question led into another "experiment and prediction" discussion with much interest. (Dick)

Other aspects of the constructivist perspective are also evident in the views expressed by the teachers.

> I think they're learning, but they're learning where they're at. You've got to accept kids for who they are, and you can't force a kid to read who can't read and it's not my fault he can't read. There are other circumstances way beyond what happens just in the classroom. (Ingrid)

Her view that learning can only proceed from the present stage of the student's development is wholly compatible with constructivist principles (MacKinnon, 1990). Similarly, when Ingrid points out that, "kids see things in different ways; they all see different things," she seems to be acknowledging that each person's interpretation of an event is based on their previous experiences and beliefs.

The importance of taking the emotions of the learner into account, discussed in Chapter One, can be illustrated by the following extract from Lynne's transcript, where she shows her awareness of the attachment between the students and their individual conceptualizations of how snow is formed.

> What I've done with the science this term is snow, right? We started off with snow and I had them read David Suzuki's blurb on snow, in that book of his, where he describes how snow is made. And then I had them draw pictures of how snow is made. And it's really interesting to see how they can read and conceptualize ... and some can really get it and they can draw it ... and it becomes really important for them. I'm just still learning, right? (Lynne)

When Ingrid described her difficulty in not giving the students the textbook answer, I interpreted this to mean that she was aware of the importance of her students constructing their own understandings of phenomena, rather than passively accepting the correct explanation or result. A somewhat different, though closely related, example of this is found in Sarah's description of one of her early attempts to involve the class in a discussion about moving air and changing air pressure.

> I had the class hypothesize what would happen if I blew on a small piece of paper that is hanging in front of my mouth. The students came up with a variety of suggestions. After I demonstrated what happens, I had them discuss with each other why this happened. The students did a good job of thinking and articulating their "theories." None came up with the exact reason. However, I did tell them what happened and most of them looked at me glassy-eyed – not really understanding. My goal now – do some more experiments that will help them truly understand what happens. (Sarah)

Sarah soon found that it takes repeated examples of a new concept, in a variety of circumstances, in order for a student to make significant meaning of it.

The last word goes to Ingrid:

> Having the right answer isn't always necessary – students can learn much by posing questions as well as coming up with their own answers. (Ingrid)

We have seen a variety of examples of statements that suggest the presence of a constructivist perspective in the observations and comments of the Comet teachers. These examples may be interpreted as illustrating the parallel experiences shared by the students, in their learning of science, and the teachers, in their learning of the teaching of science. It is not clear from the analysis, however, whether these constructivist views of teaching and learning are due to the teachers' experiences in the summer institute and Comet course, or whether they were present before the course and are now being used in thinking about science education. It is interesting to note that nowhere in the database could I find an explicit mention of constructivism by any of the teachers.

Summary

Despite the wide variation in the background and teaching careers of the Comet teachers, their experiences during the summer institute and Comet course indicate a common appreciation for several aspects of the program. These include the collegiality and support of the monthly meetings, and the location of the program at Science World. All of the participants reported a dramatic shift in their science teaching as a result of their involvement in the program.

In order to address the research problem, three aspects of this shift were analysed and examined. Several "curriculum emphases" were evident in teachers' discussions about their teaching and in the work of their classrooms. This suggests a broadening of the participants' "scientific literacy," according to the definition proposed by Roberts (1983). The teachers came to see school science as more than just a collection of facts to be learned.

The change in scientific literacy was not achieved easily or quickly. The ongoing and difficult nature of the change process served to indicate that the change was meaningful for the teachers and was neither superficial nor complete. There was also evidence of an appreciation of the constructivist perspective on the learning and teaching of science in the classroom. The following, and concluding, chapter presents the conclusions, limitations and implications that emanate from these findings.

Chapter 5

CONCLUSIONS AND IMPLICATIONS

In this last chapter of the thesis, I will present some conclusions of the study and their implications, in the context of the problem of elementary science education. The limitations of the study will then be discussed and some suggestions for further research offered. I will start, however, with a brief summary of the various sections of this document.

Summary of the Study

This thesis set out to examine the effectiveness of an in-service professional development program for teachers which was intended to promote the teaching of activity-based science in elementary classrooms. The program, which consisted of a one-week summer institute and a follow-up implementation course, was designed to assist the participating teachers to become more confident and competent in their science teaching. The need for such programs was discussed in detail in Chapter Two, where the problem of elementary science education was examined through a review of the research literature.

In examining the effectiveness of the program, the thesis focussed on the experiences of the participants during the institute and Comet course, and over the year which had elapsed since the program ended. A comprehensive database was established which contained field-notes, teacher journals and assignments, videotapes and transcripts of group meetings, and my own journal from the Comet course. Videotapes and transcripts of interviews with seven of the participating teachers were also included.

Three key aspects of the teachers' experiences were selected to analyse the database: their perceptions of what constitutes science education, their perspectives on how children learn science, and the nature of their own development as science teachers. Each of these aspects was examined within a specific theoretical framework. The teachers' perceptions of science education were set in the concept of scientific literacy developed by Roberts (1983), in which different curriculum emphases – curricular intentions or purposes for teaching school science – are acknowledged and balanced within a science program. The participants' perspectives on how children learn science were analysed in terms of a constructivist perspective on teaching and learning, which recognizes that learning may involve reorganizing, restructuring or rejecting concepts and conceptions already held by the learner (MacKinnon, 1990). The nature of the participants' development as science teachers was examined in terms of the process of teacher change

(Fullan, 1991). This examination was set against the two models of professional development which were described in Chapter Three – the teacher training model and the teacher development model.

Conclusions of the Study

The results of the study, presented at length in Chapter Four, give rise to the conclusions that are presented below, starting with the specific aspects of the teachers' experiences outlined above.

The results of this study point to a significant change in the teachers' views of what constitutes science education, characterised by a shift in their scientific literacy. The change process is on-going and, for most of the teachers, it is complex and difficult. We have seen earlier, in Chapter Three, that the process of real, meaningful teacher change requires considerable support over an extended period of time. The summer institute contained an element of follow-up activities for the participants, but the process of implementing science in their own classrooms depended on the longer time frame and support mechanism of the Comet course. The doubts and anxieties associated with the teaching and learning of science seemed to be more manageable because the participating teachers' colleagues in the group were expressing the same emotions. What each teacher said about his or her problems and successes was resonant with the experiences of the other teachers. The collegiality and support of the Comet meetings was crucial to the teachers, who often found themselves isolated within their schools in their efforts to implement science. Based on these observations, the following conclusion is offered:

> *The changes in the participants' perceptions of what constitutes science education are due primarily to their involvement in the Comet course.*

This conclusion parallels the work of MacKinnon and Grunau (in press) in which they argue that a major component of a succesful teacher education program is the social structure among the participants. They see a need to enlarge the scope of teacher education from a focus on the individual, to a broader conceptualization of learning to teach in terms of the social interactions of the teachers. MacKinnon and Grunau go on to advocate the "nurturing of appropriate forums in which community and relationship are valued, and reflection and discourse encouraged," much like the monthly meetings of the Comet participants.

Although the results of the study indicated elements of the constructivist perspective in the science teaching of the participants, it was not clear whether this "intellectual empathy" – the capacity to put themselves in the place of their students *intellectually* (MacKinnon, 1989), was attributable to their involvement in the in-service program. The activities at the summer institute were designed to model a constructivist view of learning, as described in Chapter Three, and it is tempting to infer that, since "teachers teach as they were taught" (Goodlad, 1983, p. 469), their learning experiences at the institute were responsible for those aspects of constructivism which were evident in their teaching. This may well be the case, but the results of this study do not warrant such a claim, and this aspect of the analysis remains inconclusive.

The final conclusion of the study is less problematic, and is based on the nature and volume of teachers' comments and responses regarding the monthly meetings of the Comet participants. The section of Chapter Four entitled Support and Collegiality, presented numerous excerpts from the database which strongly emphasised the importance of spending time with colleagues which was devoted to professional discussion around common concerns. The crucial contribution which these meetings had on the effectiveness of the program, as articulated by the participating teachers, was remarkably consistent and emphatic. From my own involvement in the program, I was aware that the meetings were a positive feature in the structure of the course, but I was surprised by their significance in the views of the teachers, as these became apparent during the analysis. These results indicate that:

> *There is a crucial need for collegial, professional interactions in the working lives of elementary classroom teachers which has, so far, been seriously under-estimated.*

Implications of the Study

In light of these conclusions, there are a number of possible implications for the design and structure of teacher development programs, particularly in the area of elementary science education. The need for collegial, professional interaction can perhaps best be addressed in the sustaining structure of a teacher-centred, professional development program which is continuous and on-going. The importance of collegiality and support in the process of teacher development suggests that such programs should be school-based, where this is feasible. The involvement of as many teachers as possible from the same school in the program would help to foster the collegial environment required to enhance the implementation of science in the school.

Where such continuous programming is not possible, consideration should be given to the provision of an extended, follow-up component, such as a Comet style course, in as many science in-service programs as possible. The significance of the collegial interactions structured into such courses in promoting the implementation of science in elementary classrooms cannot be over-emphasised.

Limitations of the Study

The database for this study was established over a period of two years and was quite substantial. However, it was gathered from the experiences of a relatively small group of teachers. Perhaps more important, the teachers who elected to attend the summer institute and complete the Comet course were self-selected and highly motivated, and may not be representative of the larger population of elementary school teachers in the region. The findings and conclusions may not, therefore, be applicable to all in-service science programs.

The study concentrated on the teachers who took the Comet course. No attempt was made to compare their experiences with those of their companions in the summer institute who chose not to take the follow-up part of the in-service program. Neither was it possible to compare the science teaching of the participants before the program with their later achievements, except through their own self-reports. A possibility for further research in this area would be a longitudinal study to compare the science teaching of participants both before and after their involvement in a similar program.

In a study such as this, which relied almost entirely on the comments and responses of the participating teachers, there is always the difficulty of accepting statements at face value. Given the complexities of teaching and the conflicting dynamics of students, parents, administrators and colleagues, it would not be surprising to find inconsistencies between what the teachers said in the research interview, and what was actually going on in their classrooms. Although I had visited the teachers' classrooms on several occasions during the Comet course, I was unable to make further classroom observations at the time of the interviews. A similar problem, whether the teachers were telling me what they thought I wanted to hear, was discussed in the methodology section in Chapter Four. These limitations could be addressed in future studies which involve classroom observations as well as participant interviews.

The content of the interviews was driven mainly by the topics and questions which I had selected to inform the study of the teachers' experiences. The questions were generally open-ended, which allowed the teachers to extend their responses into other areas, but the range of most of the discussions was determined by the interview questions. It is possible, then, that the results of the interviews reflect a bias which is inherent in the phrasing of the questions. The interview outline is presented for the interested reader in Appendix B.

Concluding Remarks

During the past two years of my involvement in this study, I have learned a great deal about a number of aspects of elementary science education. I now have a much greater appreciation for the skills and dedication which most elementary teachers bring to their classes day after day. I know the barriers they face in their efforts to implement the kind of science they know their students deserve. I have shared their frustrations and their successes, and I have been privileged to contribute, in a small way, in helping to bring about some of those successes.

I believe that the teachers who took part in the Comet course, while small in number, will be able to make changes in their own schools which will have positive effects for the science education of a great many students. Unfortunately for my daughter Jean, none of the teachers in her school was involved in the program, and she has yet to enjoy the kind of science teaching of April, Ingrid, Sarah and the rest.

When I visited the classrooms of the Comet teachers during the Fall of 1991, I saw children actively engaged in the process of doing their own science. They were enthusiastic about their science classes, bringing things from home or items from the newspaper and, in one class, signing out a videotape made by the principal of a previous science lesson in which they dissected owl pellets, to show at home. It seemed that science was an important part of their lives, and not just another subject to be studied in school.

I saw instances of science teaching where a variety of strategies and approaches fostered a "hands-on, minds-on" learning environment in which students were encouraged to explore their own ideas and develop their own explanations for what was going on. The explanations which the students proposed were often different to the conventional views of the science textbook. The teacher did not, however, discount the explanations as wrong, but acknowledged and valued them as indicators of the students' current understanding of the phenomenon. This then became a starting point for further discussion, experimentation or investigation.

By acknowledging the value of the child's own beliefs, the teachers demonstrated the intellectual empathy which characterizes a constructivist perspective on the teaching and learning of science. The correlation between a constructivist view of science education and competence in science teaching, suggested in Chapter One, was clearly visible in these classroom observations.

It may not be possible to credit the summer institute and Comet course for the constructivist perspective which the teachers demonstrated in their classrooms; some of them may have been teaching other subjects in this way for many years. However, I am confident that the effective combination of constructivism and science content which I observed may be directly attributed to the teachers' experiences in the in-service program.

All of the participants reported dramatic changes in their science teaching as a result of their involvement in the program. I also am convinced that a training event, such as the summer institute at Science World, followed by a self-directed, teacher development process like the Comet course, is a powerful combination for the implementation of exemplary science teaching in our elementary schools.

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November 1992

Dear - - - - -

I am presently formulating plans for my thesis research around the experiences and perceptions of the group of teachers who were involved in the Comet E7 course during the fall of 1991.

This letter constitutes a formal invitation for your participation in the research, and I ask you to read it carefully before signifying your written consent.

Your involvement in the project may include some or all of the following:

- attendance at one or more meetings of the Comet group, to be scheduled at a time and location which is convenient to as many of the participants as possible. (Approx. 2 hours)

- a classroom visit and follow-up interview. (Approx. 1 hour)

- providing access to journals and other relevant records made during the Comet course.

(Meetings, interviews and classroom visits may be recorded on audio or video tape.)

In considering this invitation, please take the following safeguards into account.

1. All the data collected will be treated in strict confidence.
2. At any stage of the project, you may request clarification of any procedures or motives.
3. At no time during the analysis or presentation of the research data will individuals be identified.
4. You may refuse to participate or withdraw your involvement at any time, without prejudice, even if you have signed this letter of consent.

Further clarification on any issue regarding this project may be obtained from myself or my supervisor, Dr Allan MacKinnon. Please feel free to contact us if there is anything you would like to know. Thank you for your consideration of this request. I look forward to working with as many of you as possible over the coming months.

Peter Hopkinson: Office: 871-7285 Home: 430-3556
Allan MacKinnon: Office: 291-3432 Home: 420-0919

I, ______________________________, have read the above and have had the opportunity to discuss in full the nature of this project, and to question Peter Hopkinson about the specific nature of my potential involvement in the study. I understand that the information gathered during the study is to be kept strictly confidential and to be used only for the purpose of Peter Hopkinson's research as described above.

Further, I understand that any documentation resulting from this study will guarantee my anonymity and that my name will not appear in any publication; unless I specifically request that I am identified by name.

Finally, I understand that I may withhold any data which concerns me and that I may withdraw my consent at any time during the study.

I hereby give my consent to participate in this project, and acknowledge receipt of this document.

Signature:____________________________ Date:_________________

INTERVIEW SCHEDULE

What name would you like to be called in the thesis?

Can you tell me something about your personal history?

– science in elementary school, high school, university?

– science methods in teacher training?

Why (how?) did you become a teacher?

Tell me some of the significant events, people which influenced your teaching.

What was your science teaching like before you took the summer institute?

How/why did you get into the institute?

What made you decide to take the Comet course?

Opinion of aspects of Institute and Comet.

-Credit important?

-Keeping the Journal, was it useful?

-Writing monthly updates, was it useful?

-Attending monthly meetings.

-Classroom visit by instructor

-Registration/Housekeeping stuff/Evaluation

-Science World facilities

-What were your expectations of the course?

-Low point(s) in the program? - Ever feel like quitting?

-High point(s)

-Choose one aspect of the program which was most valuable to you and your teaching.

Have you been involved in other Science pro-d activities? How did the summer institute and Comet compare?

Influence of Institute/Comet on your teaching, relative to other pro-d and major influences mentioned earlier.

How would you characterise your science teaching now?

If you were asked to help plan a future institute/comet program, what changes would you make or suggest?

Any contact with comet colleagues since course ended?

Where do you see yourself/your teaching in a year? 5 years?