A TEACHER - TEACHER COLLABORATIVE INQUIRY

INTO THE TEACHING OF

ELEMENTARY SCIENCE

by Aletha Adell Hay

Faculty of Education

A Thesis submitted in conformity with the requirements

for the Degree of Master of Education in the

University of Manitoba

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A TEACHER-TEACHER COLLABORATIVE INQUIRY INTO THE TEACHING OF ELEMENTARY SCIENCE

BY

ALETHA ADELL HAY

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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Abstract

This case study identified and addressed practical problems in elementary science teaching and studied aspects of teacher development within a collaboratively structured context. The methodology was reflective-constructivist in perspective and fostered classroom-based teacher development.

The meanings and insights constructed by the beginning teacher and the teacher-researcher are written as "vignettes", narrative constructions used to capture the insights and interpretations made based upon transcripts of lessons, reflective conversations, field notes, students' work and letters. The science teaching, which involved "active" learning and student/teacher collaborative inquiry, fostered students' confidence, ownership of learning and achievement in science.

The changes in teacher practise were dramatic due to the "professional collaboration" that featured continuous and supportive inquiry. The teacher-researcher's goal was to facilitate the teacher's growth and transformation by enhancing the theoretical insights and repertoire of strategies through "modelling" and "joint experimentation" in the grade four science classes. By encouraging reflective teaching and negotiating understanding, an emancipatory, yet critical approach to professional development was promoted.

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This thesis came to be because of the desire for professional growth and the commitment to this collaborative venture by my colleague, Diane. Her involvement was generous in time and her contribution sincerely appreciated.

I would also like to express appreciation for the support and encouragement received from my husband and my mother throughout the course of my studies and the writing of this paper.

This thesis is dedicated to my three sons Graeme, Andrew and Alan whose patience allowed me to devote time and energy to the completion of this work.

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Chapter 1

Science and science education have received increased attention over the past decade in Canada. A major stimulus for this attention was concern expressed within Report 36, Science For Every Student (1984) by the Science Council of Canada. This report identified the broad need to develop the awareness, interest and knowledge of students, particularly elementary children, in the sciences and in the related societal and technological interconnections. In short, it pointed out the need for a more scientifically literate generation to insure informed thinking and responsible decision-making in the future of our country.

Following the plea made in the report, Manitoba and the Provincial School Divisions took major steps to up-date the K-9 Science Curriculum Guides (1991), suggest resource materials, and encourage teacher workshops to incorporate a broader, more connected vision of science in the classroom. Interested professional groups, such as the Manitoba Association of Professional Engineers, invested time and financial support to provide resources (For example, World in Motion, 1990) to school boards in the province.

Conversations with teaching colleagues indicated a growing awareness and interest in providing quality science programs. Teachers were asking more questions of themselves and the teaching community. These events stimulated my interest to further investigate science curricular reform and implementation issues.

At the elementary level, science teaching has been identified as an area where many teachers feel a degree of insecurity. The science education community, as MacKinnon and

Grunau (1991) reiterated, has recognized four barriers to successful science teaching: lack of time, lack of equipment and support, lack of confidence in subject matter knowledge, and unfamiliarity with science teaching methodology. These feelings of discomfort with science teaching are not surprising since elementary teachers do not require extensive science educational backgrounds and this may well have led to an avoidance of teaching science studies. In addition, with the increased preference for integrated teaching units, science may have become less focused; being science-related but not science-based. This later point appeared to be supported in a paper by Ebenezer and Achtemichuk (1992) which referred to the experience of a pre-service teacher who found that in her integrated practicum unit, shadows were dealt with as imaginary friends in the poetry lesson. She found the need to clarify shadows as areas of blocked light in her science lesson.

My interest in doing a study of elementary science teaching was to learn about what means would best facilitate quality science teaching and address teacher concerns. The works of Connelly and Clandinin (1988), Elbaz (1988), and Hargreaves et al. (1992) suggested that changes in curriculum, i.e.: better science teaching, is a process of 'curriculum development' as opposed to one merely of curriculum implementation because the former encompasses the role and the responsibility of the teacher within the process. This position incorporated the aspect of teacher development into the issue of curricular reform.

Bell (1993); Cole and Knowles (1993); Loughran (1994); and Madsen and Gallagher (1992) told of structures and contexts which provided coherence and continuity for the classroom teacher who wishes to be involved in a sustained professional development experience in science. Furthermore, they suggested collaborative frameworks which use a

"constructivist" platform or a "critical pedagogy" philosophy would promote teacher development on a social as well as professional level. They emphasized interpretive frameworks and mutually beneficial 'partnership research' as important considerations in successful teacher development programs. Thus an inquiry into improving science teaching must also involve the aspect of teacher development.

Methodological Framework

This research project was designed to study the problems of practice identified by a grade four teacher and to identify mediating factors, including teacher development, that influence science curriculum in an elementary school classroom.

A case study methodology was employed to trace changes in science teaching and to study teacher growth in the normal context of a colleague's daily work. It was conducted on a philosophical premise that teachers are more than transmitters of knowledge. Teachers are believed to be experienced practitioners who bring expertise to the context of their classroom instruction. This expertise, or professional knowledge, is the key component that directs the actual events of teaching. Teachers are also viewed as learners and inquirers, thus they are professionals who are able to study the events of teaching, reflect on them and make changes in their actions based on their assessment of the outcomes.

This study falls within a constructivist-reflective paradigm but is further defined by the "critical pedagogy" position espoused by Bell (1993) as it did not intend to achieve a predetermined level of teacher development or curriculum change but to nurture a classroom

teacher's professional growth in science teaching. This study examined the problems of practise and attempted to track changes and identify important themes. The changes in teacher practice were considered more 'dramatic' due to the collaboration by the teacher with a colleague whose goal was to support the teacher's growth and transformation. This was encouraged by the introduction and modelling of new approaches and strategies within the context of the classroom and the two units of science which made up an important part of the classroom context.

Teacher development in this study addressed personal and social needs since the risk-taking associated with employing new strategies took place within a supportive environment. The reflective conversations considered the practical problems from the position and perspective of the classroom teacher. The interaction and feedback was constructive rather than evaluatory. Pre- and post- conferences facilitated the defining and clarifying of personal beliefs and philosophies about teaching and were critical to teacher learning (Vygotsky in Wells, 1994).

Furthermore, this work was situated in Haabermas' (1972) hermeneutic realm of knowledge where the focus of the collaborating teachers was on experiencing the events of practise, reflecting on them and then interpreting the outcomes and making meaning from the entire activity. This work was also related to a "practical" interest (following Haabermas' categories) as the problem-solving focus encouraged risk-taking, exploring possibilities and self-evaluation within a supportive framework. This feature fostered confidence and was self-actualizing, or emancipatory in intent.

The design of this collaborative work was based on a methodological premise that

for curricular development to be effective, it must be intricately linked with meaningful teacher development. The framework was, broadly speaking, interpretative and based on the empirical data of the events of practice. Narrative constructions were used to capture the essence of the meanings and understandings of the collaborating teachers. The method is outlined in more detail in Chapter 3.

Problem Statement

The following questions were formulated to guide the direction of this inquiry into elementary science teaching:

1. What reconstructions of meaning (professional growth and insights) do the teacher and the teacher-researcher make in the context of their collaborative inquiry into science teaching?

2. What themes (transformations) arise through this collaborative inquiry of the teaching/learning process in science?

3. What experiences, both personal and professional, have influenced the teacher's conception and personal philosophy of science teaching?

Significance

A distinguishing feature of this work was that the research partnership was composed of two teachers, one relatively new to the profession and the other an experienced classroom teacher who was also a graduate student. This work addresses the issue of continued professional growth and views teacher development as an ongoing, lifelong process of renewal and growth in expertise. Also, the collaboration was continuous and classroom-based with both teachers contributing and benefiting mutually from the experience.

Overview of the Thesis

In overview of this document, Chapter 1 introduces the subject matter of the research and sets the philosophical premise and methodology which guided the work. The significance of the research is highlighted. Chapter 2 is a review of related literature. Chapter 3 outlines the design and method of the research from the historical background of the participants through to the final stages of the project. Chapter 4, entitled 'Diane's Metaphors of Science Teaching', contains descriptions of five pertinent themes which were constructed during the course of the collaboration. These themes are organized more or less chronologically in the order that the problems arose and were addressed over time, although there was considerable overlap. The vignettes contain the empirical data of the practical problems and the meaning making which resulted from reflective analysis and the later interpretation of the events. Chapter 5 traces the developmental stages of the collaborative

process. It highlights turning points in the interaction between the teacher and the teacher-researcher and clarifies the shifts in roles and responsibilities as they were negotiated. Chapter 6, the final chapter, contains the conclusions, implications and recommendations which were formed from this work.

Chapter 2

A Review of Related Literature

My interest in learning more about the practice of science teaching led me to examine what the literature said about science, science teaching, how teachers learn about their practice, and what means, if any, are available to help inquiring teachers grow professionally and develop insight into the science teaching that occurs in their classrooms.

I began to read about teacher cognition (thinking and decision making), teacher behaviour, and the role of the teacher in the teaching/learning process. Afterward, I sought readings which discussed teachers' ideas about science and constructivist science teaching. I read literature on the value of reflective processes in teacher development and on how collaboration had been used as a method to enhance teacher growth.

Thus the review of literature related to my study has been organized in the following fashion:

The Nature of Science and Constructivist Science Teaching

Teacher Thinking Processes and Behaviour

Constructivist Teacher Development

-Reflecting on experiences.

-Reflecting on the problems of practice.

Collaborative Contexts

The Nature of Science and Constructivist Science Teaching

The nature of science and what science teaching in schools should involve have been addressed recurrently since the nineteen fifties. Historically, science has been seen as a body of knowledge, defined as facts, principles and theories. Prior to the nineteen sixties, there was a perception that schools were charged with the responsibility of helping children memorize formulas and learn the accepted scientific theories (Cain and Evans,1990). Since that time there has been a movement away from seeing science primarily as content to a more process-oriented endeavour. Science became more active and children were increasingly seen to need many opportunities to experiment, generate ideas and organize information. The nineteen eighties and nineties have seen science curriculum reform promote an approach where science in schools, particularly at the elementary level, is linked to the real world of the children (Shymansky and Kyle, 1992; Science Council of Canada, 1984; Orpwood and Souque, 1985; Education Manitoba, 1991) . Children's understandings and interests have become the focus of current science teaching strategies. Importantly, Cain and Evans (1990) affirmed, science in schools must capitalize on the curiosity of children and foster an attitude of discovery.

Abell and Smith (1994) outlined the Science for All Americans (SFAA) criteria for understanding the nature of science in three categories. The 'scientific world view' category listed four main ideas that students should understand. They are: the world is understandable; scientific ideas are subject to change; scientific knowledge is durable; and science cannot

provide complete answers to all questions. The 'scientific inquiry' category identified five desirable characteristics: science demands evidence; science is a blend of logic and imagination; science explains and predicts; scientists try to identify and avoid bias; and science is not authoritarian. In the last category, 'scientific enterprise', four principles are presented: science is a complex social activity; science is organized into content disciplines and is conducted in various institutions; there are generally accepted ethical principles in the conduct of science; and finally that scientists participate in public affairs as specialists and as citizens. (p. 482-483)

Science, once viewed as an ontological reality, is now more generally looked upon as a guiding set of relationships and theories to help us understand our world. It is constantly being reconstructed as more is learned. These views presented in a current pre-service teacher resource book by Cain and Evans (1990), led me to wonder what beginning teachers, and experienced ones too, make of this changing focus in the definition of the subject. What do teachers interpret it to mean and how will this be expressed in classroom instruction?

Haggerty (1991) discussed a view of science, which is held by many, which she calls "naive realism". This view has science separated from everyday matters and consisting of an organized body of knowledge generally incomprehensible and irrefutable. She expressed a concern about this view of science especially since she reported that studies showed pre-service science teachers held similar views. Abell and Smith (1994) expressed a similar concern about their student teachers' naive realist views which they felt have been constructed over years of formal science instruction and may prove difficult to change (p. 484).

Researchers including MacKinnon (1989), Brauner (in MacKinnon, 1989), Hewson and Hewson (1989) and Aguirre, Haggerty, and Linder (1990) have discussed science teaching and what it should involve. Modern views, according to these authors, are based on conceptual change and 'constructivist' models of knowledge development where the learner constructs his/her own knowledge. Hewson and Hewson (1987), in particular, clarified that students' theories are formed as they "strive to make sense of their experience, and as a result develop relatively stable patterns of belief" (p. 427) which are labeled "conceptions" or notably "alternate conceptions" when they are different from the generally accepted views of the subject. These views were reported to be resistant to change, a position also held by Shapiro (1989).

MacKinnon's (1989) doctoral dissertation outlined a view of science teaching that is based in constructivist philosophy. His view, that individuals possess frameworks or conceptions of how events relate to one another in the real world, is based on two principles. The first principle affirmed that "knowledge is not passively received but is actively built up by the cognizing subject" (p. 88). In other words, the learner thinks about the new experience and attempts to relate to it and understand it based on previously constructed knowledge and experiences. The second principle was that " the function of cognition is adaptive and serves the organization of the experential world, not the discovery of ontological reality" (p. 89). Learners, therefore, try to understand and assimilate new information in such a way as to allow them to better understand the world that they experience. Events can be interpreted differently by different learners based on the fact that each person brings a unique set of past experiences and understandings to any new learning experience (MacKinnon,1989). This

view is supported by other researchers (Bell, 1993; Driver, 1987; O'Loughlin, 1992) who argue that "knowledge is inherently partial and positional because it is grounded in an individual's interpretation of the world" (O'Loughlin, 1992, p. 336).

Within constructivist thinking therefore, the learner is actively involved in the learning and is in control of what he/she learns. The influence of the affective elements such as emotions, beliefs and attitudes do play a role in such a learning process.

Both MacKinnon (1989) and Brauner (in MacKinnon, 1989) commented that since knowledge of the world is "apprehended" by the learner, the teacher must recognize and address: a) the differences between students' explanations for events and those generally accepted explanations; and b) the applicability of students' language (vocabulary) in terms of the most appropriate scientifically correct terminology. Since children will also base their explanations of events upon their own past experiences, it is quite likely that their knowledge of science will consist of "alternate conceptions" to those generally held scientific views (Osborne and Freyburg, 1985; Shapiro, 1989 ; Driver, 1989).

MacKinnon (1989) stated that three pedagogical principles for science teaching must be applied within a constructivist strategy. He outlined:

> The pedagogical principles that have been incorporated in the analytic scheme are: (1) teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts; (2) these ideas must then be taken into account in the instructional program in order to provide a foundation for extending concepts, or constructing new concepts and the meanings derived from them; and (3) as learning is seen to be a purposive activity, students should be actively engaged in the learning situation and should become aware of the purposes that lie behind instruction. (MacKinnon, 1989, p. 88)

MacKinnon (1989) supported a teaching/learning relationship between the teacher and the student in order to enhance awareness of the children's thinking and to foster the children's appreciation for the purposes of learning. However, his views differed somewhat from the conceptual change model outlined by Driver (1987) and Hewson (1981). These researchers also espouse a constructivist framework but there are significant differences. Driver and Hewson both propose instructional models that challenge the "alternate conceptions" of the students with the express purpose of replacing the child's alternate framework with a more powerful and scientifically acceptable one.

In considering Shapiro's (1989) work with children's conceptions of light, there is evidence that children resist accepting explanations that do not fit in with their own experiences and understandings. MacKinnon's (1989) strategy addressed this feature by proposing that the focus of science instruction should be to provide students with a rich experential base of science activities that would promote development of a pupil's "new conception" rather than focus on frequent challenges in order to replace "wrong" conceptualizations (misconceptions). This perspective, he elaborated seems to respect students' ideas more than do advocates (Posner et al, 1982; Hewson, 1981) of the conceptual change model (p. 70).

Aguirre, Haggerty, and Linder (1990) acknowledged the Hewsons' and others' work with conceptual change but felt that pre-service teachers entering the teacher education program also possessed a variety of views about science and science teaching. Just as teachers must respect the alternate conceptions of their students, so must teachers and teacher

educators respect the alternate conceptions of their students, whatever the level, and of their colleagues. The important issue for these researchers was the need to "make these views explicit, to discuss and analyze these views critically, and to provide beginning teachers with other views of science, teaching and learning. Finally it is important to encourage student teachers to reflect on these views and on their implications for science instruction." (p. 389)

Posner (1985) and Taylor (1989) also valued the perception that reflection on one's views about teaching is important and vital to professional growth. They both recognized that it was not how a study of teaching is organized but rather that teaching is examined. I interpreted this to mean that in reflecting on one's teaching, one examines and questions the actions of teaching and assesses the results against personal criteria. Posner described a shift to a constructivist strategy in teaching science as a shift to a more student-centered approach which required teachers to reconceptualize their roles and develop new practices apart from the traditional teaching paradigm. Taylor described a similar shift for the teaching of mathematics.

Constructivist science teaching models (Posner et al, 1982; Osborne and Freyberg, 1985; Needham and Hill, 1987; White, 1993) underwent careful examination and subtle change during the 1980s. These models, which are based on conceptual change philosophy, reflected the position that learning occurs when new understanding is assimilated or accommodated by the student. Ebenezer and Connor (1994) described this conceptual growth as being rooted in "evolutionary" and "revolutionary" terms. The role of the science teacher had become one of focusing on how to help students undergo conceptual change.

These views of constructivism and the associated science teaching models were situated in a view of knowledge construction that O'Loughlin (1992) described as built upon basic assumptions laid out by Piagetian developmental psychology and a view of science that focused only on technical rationality. He argued that:

> Constructivism is problematic because it ignores the subjectivity of the learner and the socially and historically situated nature of knowing; it denies the essentially collaborative and social nature of meaning making; and it privileges only one form of knowledge, namely, the technical rational (O'Loughlin, 1992, p.791).

O'Loughlin (1992) debated the position that students learn only by doing and chose to broaden the explanation of learning (knowing) to include the contextual elements of culture, power and discourse within the classroom. He presented these thoughts as a "sociocultural approach" to teaching and learning.

In developing his sociocultural approach, O'Loughlin (1992) critiqued the underlying assumptions of Piaget's theory on two keys fronts: the 'decentering' of knowledge by an 'objective reality', and the 'personal' construction of knowledge in absence of any consideration of human subjectivity in the process of construction. His view of knowledge construction explained learning as a "dialectical" process that takes place in specific economic, social, cultural and historical contexts. Learning is therefore seen as "a process of examining current reality critically and constructing critical visions of the present reality and the possibility of other realities so that one may become empowered to envision and

enact social change" (p. 799). When students bring their own subjectivities and cultural perspectives to the teaching/learning events, these aspects influence the way in which the children construct understanding. O'Loughlin drew upon the works of Lave (1988) and Wertsch (1991) to articulate his form of constructivism which demands recognition of the influence of power issues and the modes of classroom discourse (speech genres) on learning. In teaching and learning situations, the student's ability to express him/herself with appropriate language influences the value of one's ideas and one's position with peers. O'Loughlin proposed that the school must introduce students to the powerful speech genres of science through a process of negotiation. He advocated the need for students to "negotiate" meaning so that they are able to understand the scientific way of knowing while maintaining a critical eye that will allow them to acknowledge their personal and cultural ways of knowing. He asserted that:

> A truly emergent curriculum would validate the ways of knowing students bring to school by grounding the curriculum in their voices and lives. Then, as Friere (1970/89) notes, through dialogue and the sharing of perspectives, students would gradually come to see their own perspective as one of many socially, culturally, and historically constituted ways of knowing, and through exposure to multiple voices in text and in classroom discussion they could begin to engage other perspectives and other ways of knowing, thus enlarging their epistemological perspectives (O'Loughlin, 1992, p.814).

O'Loughlin's (1992) position appears linked to the work of Kelly, Carlsen, and Cunningham (1993) who outlined how the study of the history, philosophy and sociology of science has contributed to a redefinition of science from "an objective, impartial certification of knowledge to a socially constituted enterprise shaped by human values,

beliefs, and personal commitments" (p. 213). These researchers made note of five possible implications for science education which are summarized here:

> First, scientific knowledge should be understood as contingent upon the social conditions that govern its construction and taught accordingly.... Second, science education will need to balance this new attentiveness to social deliberation with continued insistence on empirical warrant (the latter, of course, defined by prior deliberations within the scientific community).... Third, sociocultural values fundamentally influence the process, content and application of scientific knowledge....Fourth, we advocate the continued erosion of the epistemological separation of the social from the natural sciences.... Fifth, science educators need to retire the idea that by learning science citizens will be automatically equipped to make good public decisions. Richer, more complete public understanding of science requires studying the processes of science (Kelly et al.,1993, p. 215).

From these implications, Kelly et al (1993) concluded that science educators who do teach within a sociocultural context will have three problems to address that are directly related to this perspective. They suggested that it may not be wise to teach a sociologically "accurate" description of science initially since students may develop an incapacitating distrust of science's motivation and findings. In addition, they felt that, at present, there are competing schools of thought in the sociology of science and much elaboration and debate still needs to be resolved. And finally, they cautioned that in incorporating sociological concepts in science teaching, teachers must avoid substituting one form of external authority for another (p. 217).

Linder (1993) and Ebenezer and Gaskel (1995) have attempted to address these social and cultural issues in the development of a perspective of constructivist science teaching that is based upon viewing knowledge construction as "relational" conceptual change. Here, the

position held describes students as possessing a number of conceptions (conceptual dispersion), some which may be considered contradictory to one another unless viewed as context specific. Linder described the role of the teacher as recognizing the range of conceptions, facilitating the enhancement of the students' existing repertoire of conceptualizations, and putting more effort into assisting the students' capabilities to distinguish the most appropriate conception for the context in which it is to be applied. This he referred to as "conceptual fitting". This post-modern view has brought a personal/social constructivist perspective to science teaching.

These research positions provide an indication of the nature of the debate related to constructivist views in science teaching. In the study of elementary science teaching, these post-modern views must be considered when examining the issues and problems that affect children's learning and achievement in science.

As the meanings of "science" and "science teaching" have undergone change, it is to be expected that teacher educators, researchers and teachers themselves would wish to examine teacher practise and the factors that influence it.

Teachers' Thinking Processes and Behaviours

Teacher practise is inextricably linked with teacher beliefs as one informs the other. The following literature examined what researchers have to say about the teacher as a professional and as a person.

Clark and Peterson (1986) reviewed many studies on teacher thought processes. They

designed a heuristic which showed the reciprocal relationship between teacher behavior and teacher thinking, and they found that this relationship was influenced by the context in which the teaching was occurring. But most interestingly, they found that a "teacher's theories and beliefs represent the rich store of knowledge that ... affects their planning and their interactive thoughts and decisions". (p. 258)

Clark and Peterson (1986) offered an heuristic device as an "advance organizer" for their review of research on teacher thinking. Their model depicted two domains: teacher thought process and teachers' actions and their observable effects. The first domain referred to the thinking "inside teachers' heads" which is unobservable and linked it to the phenomena of teacher behaviour and its observable effects. Clark and Peterson cautioned against seeing the relationship between these two domains as linear and unidirectional, instead suggesting that the reciprocal relationship between the two needed to be explored.

Clark and Peterson (1986) defined three categories of teacher thinking:" (a) teacher planning (preactive and postactive thoughts); (b) teachers' interactive thoughts and decisions; and (c) teachers' theories and beliefs" (p. 257). In reviewing the research on interactive thoughts and decisions, these researchers described two models of interactive decision making, their own (Clark and Peterson, 1978) and one designed by Shavelson and Stern (1981). They felt that both models should be revised to reflect "the definition of interactive decision making as a deliberate choice to implement a specific action rather than a choice of actions from several possible alternatives" and "that the majority of teachers' reported interactive decisions are preceded by factors other than judgments made about the student" (p. 277). Furthermore, Clark and Peterson found that studies of teachers' implicit theories

(Munby, 1982; Janesick, 1977; Marland, 1977; Elbaz, 1981; and others) supported the idea that teacher behaviour, cognitive and otherwise, is guided by and made sense of in relation to a personally held system of beliefs, values and principles. In addition, they felt that these researchers concluded that prior to their intervention, these systems had not been clearly articulated by the teachers themselves. (p. 287) In conclusion, Clark and Peterson found that "teaching is complex, demanding, and uniquely human." (p.293)

Scardemalia and Berieter (1989) developed a description of different patterns of teaching behaviors which they said reflected conceptions of teaching. They felt no categorization was absolute and cautioned that teachers should not be labeled by these categories.

The four conceptions Scardemalia and Bereiter (1989) identified were: cultural transmission, skills training, fostering natural development, and promoting conceptual change. These researchers found that as teachers became more expert their teaching reflected all four conceptions. To Scardemalia and Bereiter, professional development should not be viewed as a linear process but as a collective process. It must be based on the understanding that as teachers attained a degree of success with one conception, they shifted focus to other concerns. Usually the shift was found to be toward conceptions which focused on the child, his interests, understandings and conceptual growth. The work of Scardemalia and Bereiter highlighted the importance of continued teacher growth past the pre-service and early in-service years of practice but did not address what factors might influence teacher behaviour and professional growth.

Kennedy's (1991) work described some factors that influence teacher conceptions about teaching. Of the origins and development of teacher conceptions she said:

> One important finding is that teachers develop strong conceptions of the practice of teaching while they are still children. From their experiences as students they form views about the nature of school subjects, about the teacher's role in facilitating learning, and about the pedagogical implications of learner diversity. These views constrain their ability to grasp alternate views...Their experiences are tantamount to an "apprenticeship of observation", and it is one which is invested with emotion, given the students' dependence on the teacher...Teachers' backgrounds are often limited with respect to the kinds of people they have encountered. The persuasiveness of teachers' experiences during their apprenticeship of observation, both across grade levels and across subject areas, coupled with the sheer volume of time spent observing, yields in teachers (and other adults for that matter) a deeply entrenched and tacit set of beliefs about what can and should happen in schools: about the nature of school subjects, about the teacher's role in facilitating learning, and about the pedagogical implications of student diversity (Kennedy, 1991, p.7).

This account of the tremendous influence of an individual teacher's experential background above was an expanded explanation of Lortie's (1975) term "apprenticeship of observation". Loughren (1994) emphasized this influence when, in studying the needs of second year science teachers, he found a regression toward more traditional viewpoints by beginning teachers after they became immersed in their profession. He described the effect of pre-service education as being 'washed out'. Loughren felt this situation in the real world of schools was a dilemma which may well have a restraining influence on employing and assimilating progressive ideas. Churcher (1990) also commented on this when she referred to a "stability factor" in her doctoral dissertation: Teachers often hold steadfastly onto their

existing world views and their present orientations, conceptions and perspectives even after evidence has been identified that another approach might work better. (Churcher,1990, p.29)

The research of Kennedy (1991) and Churcher (1990) suggested two conditions necessary for continued professional growth. Firstly, that teacher growth may require a lengthy process before new ideas or conceptions become a fully assimilated part of one's practice. Secondly, the study of one's practice may require some investigation into previous experiences, both personal and professional.

Shulman (1986) referred to the issue of experience as the 'missing paradigm' in his study of the teaching/learning process in his research program, "Knowledge Growth in Teaching"... His paradigm addressed the following questions:

> What are the sources of teacher knowledge? What does a teacher know and when did he or she come to know it? How is new knowledge acquired, old knowledge retrieved, and both combined to form a new knowledge base? (Shulman,1986, p.8)

In attempting to answer these questions, Shulman (1986) and his colleagues used a perspective which examined teacher 'intellectual biography' as they followed the professional development of pre-service teachers throughout their teaching experience. Shulman focused on defining three categories of content knowledge: subject matter content, pedagogical content knowledge and curricular knowledge. But unlike Churcher (1990) and Kennedy (1991), who alluded to the influence of affective elements like beliefs and feelings, Shulman neglected the influence of knowledge based on one's personal experiences.

Churcher (1990) in her work on "The Nurturance of Professional Growth", acknowledged being initially narrow in her view of knowledge too:

> While I was initially concerned with subject and pedagogical knowledge and to some limited extent, curricular knowledge, I saw the need to expand my horizon to include personal knowledge. (Churcher, 1990, p.39)

In keeping with the idea of previous experience creating implicit beliefs, Brickhouse (1990) tracked the effects of a teacher's beliefs (about the nature of science) on classroom practice. She noted that teacher actions did influence students but that more research was needed on the development of beliefs and the interaction between teacher beliefs and practice. More importantly, she questioned how these beliefs and practice in the classroom affect what the children do in science class and the scientific understandings they develop. She suggested this is justification for study into the understandings that teachers have of science teaching and the formative experiences that have influenced it.

Goodson (1992) in his chapter entitled 'Sponsoring the Teacher's Voice: Teacher's Lives and Teacher Development' posits that a study of curriculum and schooling must involve a study of the teacher's life. His view that "a more valuable and less vulnerable entry point would be to examine teachers' work in the context of the teacher's life" (p.114). He cited strategic and substantive reasons for his position. He found that teachers talk about their own lives as they explain their policy and practise. Their life experiences and background are 'key ingredients...of one's sense of self'. He argued that a teacher's 'lifestyle' and 'life

cycle' also impact on the views held about teaching and on the actual practise. And importantly, Goodson addressed how 'critical incidents in teachers' lives and specifically in their work may crucially affect perception and practise' (p. 118)

In summary, researchers have pointed to the need to learn more about the beliefs and theories that affect teacher behaviors. How can teachers learn about themselves? What means are available for such a task? In order to understand practice, how can teachers examine what they do in their classrooms and reflect on the 'why' of the 'what'? Attempting to answer these questions led me to explore the literature on reflective teaching and teacher development.

Constructivist Teacher Development

Reflecting on experiences.

Dewey (1933) spoke of reflective thinking and how it enabled teachers to "act in a deliberate and intentional fashion" (p.17) to achieve what was needed. His position was that reflection involved breaking habitual ways of recognizing and dealing with situations. Posner (1985) held the view that " we do not actually learn from experience as much as we learn from reflecting on experience" (p.19). These positions support the importance of reflective practise and teacher-initiated professional growth.

Connelly and Clandinin (1986) explained that in writing about one's teaching, teachers reflect on their practise. These researchers felt that teachers can take note of what

is done in the classroom, how they plan, teach and react to the teaching. These actions and the reasons attributed to them by teachers themselves, allow teachers to better understand their own teaching and come to know and define their beliefs and theories about teaching. This strategy would be a starting point, one feasible approach, for any true plan for professional growth.

Connelly and Clandinin (1988) support teacher reflection as a means to understanding curriculum development as well as professional growth. They suggested there is a definite relationship between teachers' thinking, past experiences and images of the future. They clarified that teachers' 'practical knowledge' grows out of experience. They extended the definition of teachers' practical knowledge into the personal realm, including the "moral, emotional and aesthetic dimensions" (p. 22) which contributed to their conception of "personal practical knowledge". These authors defined personal practical knowledge in the following manner:

> It is a particular way of reconstructing the past and the intentions for the future to deal with the exigencies of a present situation. (p. 25)

Connelly and Clandinin (1988) stipulated that to understand how the teacher operates within his/her practise one must recognize that people say and do different things in different circumstances. Different circumstances influence the different aspects of previous experience that are recalled and brought to bear on the present situation. These researchers saw professional growth via a specialized form of reflective process which they called "narrative inquiry", one which incorporates both the cognitive and affective domains of past

experiences, present thinking and images of future teaching events. Beliefs, principles and ideals, together, help to form the "perspective" through which teachers view their teaching. Connelly and Clandinin (1988) used perspective, that is, one's frame of reference, to explain teachers' experience. Perspective was seen to be the link between beliefs and interpretations and intentions and behaviours. If indeed humans make meaning of their experience, by retelling stories and "picturing" what the future will be, based on what they believe it should be, then:

> How a teacher lives out the future may be inspected by observation and participant observation of classroom work. (1988, p. 24)

Knowing that teacher perspective can be observed from actions within the classroom, how can a teacher effect a close examination of his/her teaching? How can teachers identify the actions and the decisions which make up their practise so that as professionals they know where to begin?

Connelly and Clandinin (1988) suggested that there is a role for a narrative technique to collect and record those events and images from a reflection on teaching. Narrative is the means to think of life as a whole. It is the "study of how humans make meaning of experience by endlessly telling and retelling stories about themselves that both refigure the past and create purpose in the future...For any one teacher... clues to the personal are obtained from one's personal history, from how one thinks and feels, and from how one acts. ... One's educational history may... be brought forward for inspection by interview and self-reflection; the same is true for one's present thinking style and concepts" (p. 24). This

"retelling" of stories can be further explained as "reconstructing" of past events and, in this process of reconstruction, the multifaceted components held within one's perspective come into play.

Elliot Eisner, in his introduction to Connelly and Clandinin's (1988) book Teachers as Curriculum Planners, supported the position of integrating the whole person, personal and professional, in understanding teacher practice:

> The metaphors by which teachers live, the way they construe their work, and the stories they recount, tell us more profoundly about what is going on in their lives as professionals than any measured behaviour is likely to reveal. (p. ix)

The work of Connelly and Clandinin (1988) described a personal and integrative form of reflective teaching based on writing and recounting personal descriptions and reasoning to clarify and reconstruct perspectives through the reflective process. In the following section, it will be shown that Donald Schön had a somewhat different approach to reflection, looking at reflection on behaviour, in this case teaching, from a more objective, external, and instrumental position in order to apply a problem-solving element to the study of one's practice.

Reflection on the problems of practice.

Schön's (1983) reflection-in/on-action model provided another strategy for organizing and understanding reflection on practise. His "reflection-in-action" model is

beneficial in framing the problems that are brought to attention in studying practise and in attempting to improve that practise through a reflective format because it is based on an acknowledgment of the knowledge and skills, indeed the art of the practitioner.

In his work, The Reflective Practitioner, Schön (1983) proposed a reflective process which is based on a reflective conversation between a practitioner and client, for example a teacher and student or a researcher and teacher. This conversation involved a more embedded reflective conversation as well, that of dialogue between the practitioner and the context of the emerging problem.

In Schön's (1983) theory, the problem is identified or "framed" by the client, or client working with the practitioner. The practitioner "reframes" the problem by restructuring it in a way that is guided by his own perceptions, knowledge and experience. By reframing the problem, the practitioner suggests a way to re-shape the situation. This could be construed as an implicit criticism, not an open one, to be inferred from the way the problem is restructured. This reframing suggests a different course of action. When the action is carried out, there is a possibility that unintended changes occur within the context. It is important that the practitioner be perceptive and listen to the "back talk". This backtalk could be unforeseen changes, the concerns and comments of the client, or the range of success within the context. This backtalk would permit another reframing and so on, in what might be described as "a process that spirals through stages of appreciation, action and re-appreciation" (p. 276). Schön designated this reflection-in-action as a type of "intuitive knowing". He cautioned against dissecting the linkage of thought and action:

> If we separate thinking from doing, seeing thought as a preparation for action and action only as a implementation for thought, then it is easy to believe that when we step into a separate domain of thought we become lost ... But in actual reflection-in-action, doing and thinking are complementary... When a practitioner keeps inquiry moving, however, he does not abstain from action ... Continuity of inquiry entails a continual interweaving of thinking and doing." (Schön, 1983 p. 278)

MacKinnon (1989) applied Schön's reflection-in-action framework within a pre-service science education practicum. This work with pre-service teachers provided a basis for looking at professional growth in science teaching within a theoretical framework structured to promote continued professional development. He employed a methodology that involved reflection-in-action and constructivism, which he entitled "Schönean-constructivism". MacKinnon's work was located within "a body of theoretical and empirical work that conceived of reflection as the reconstruction of experience in actions situations" (p.43). The following definition of reflection he labeled 'Reflection as Reconstructing Experience':

> Reflection is seen as a means by which teachers attend to features of situations that were previously ignored, or begin to assign new significance to identified features, recasting situations in light of clarifying questions, reconsidering the assumptions on which previous understandings of the situation were based, and rethinking the range of potential responses that are available. In short, these authors [Garman,1986; Noordhoff and Kleinfeld, 1987; Yinger, 1987; Grimmet and Crehan,1987; Labosky and Wilson, 1987] subscribe to a view of reflection as a general means by which the knower appreciates, or apprehends practise situations. (MacKinnon, 1989, p. 34)

MacKinnon also addressed a potential dichotomy in the analysis of Schön's work dealing with theory and practise or in Schönean terms, "technical rationality"

and "reflective practise". He referred to where Schön makes the distinction between 'knowing how' and 'knowing that':

> For Ryle, and for Schön, the existence and importance of "knowing how" is central to the matter of learning practise. This is not to say that "learning by doing' without analysis is a substitute for "learning by doing" with a theory. Rather, it is to say that "learning by doing" mitigates some of the difficulties that arise when a practitioner is unable to articulate and analyze competent performance .... it seems right to say that the meaning of "that" unfolds to the beginning practitioner only gradually, and usually in the context of doing, and then thinking about doing "that"." (MacKinnon, 1989, p. 100)

Like Schön, MacKinnon (1989) agreed that knowledge is shown in the act of "doing" which is guided by the intuitive process called "reflection-in-action". These spontaneous actions within one's practise can be influenced by situations where a practitioner consciously "reconstructs" and "reflects" on experiences and are therefore a result of a deliberate process called "reflection-on-action" (p. 104).

The following passage outlined the orientation that MacKinnon (1989) put forward in his explanation of "professional thinking".

> First, reflection-in/on-action is an account of professional thinking that focuses on problem setting and problem solving. Problem setting involves framing and reframing practise situations -- in short, assigning new significance to particular events or experiences... the central feature of a reflective practicum is reflection itself. It is the act of reconstructing experience and it is accomplished when a practitioner can see a situation in a new light. Thus, for Schön, much of the matter with learning a profession has to do with learning the competence of framing and reframing problems of practise. Of central importance is what might be thought of as the "reconciliation" of reflection-on-action, when the practitioner might overcome the paralysis that may accompany becoming aware of a particular

> representation of his or her current understandings of practise, and achieve a greater level of performance. (MacKinnon, 1989, p.107)

MacKinnon (1989) employed Schön's (1987) three coaching models in his science practicum study. He elaborated, within an educational context, on the characteristics of the three models. The "follow me" model was described as " telling and listening and demonstrating and imitating" (p. 109). Here, the supervising teacher tried to learn what the student teacher understood and could do. Difficulties were identified by early observations of the student-teacher's performances. The supervisor then demonstrated the technique that he wished the student-teacher to employ. The "joint experimentation" model was employed when the supervising teacher joined the student in the practical event. The supervisor would assess the way that the student-teacher framed the problem and behaved in the situation. The "hall of mirrors" model refers to a strategy where the supervisor models the behaviour that he wishes the student-teacher to attempt. This can be the way that the supervisor interacts with the student-teacher, with the express purpose of encouraging the student to use a similar approach with his/her own students.

According to Elbaz (1988), reflecting on one's teaching is not ordinarily part of one's teaching. She proposed that reflective thinking should be an important component of good teaching in order for reform and the improvement of schooling to be realized. Reflecting, she implied, may need to be a skill that is taught and encouraged like any other part of teacher programs because she felt it required a structured setting to maintain it. In MacKinnon's (1989) work such a structured format, the practicum, encouraged the process of on-going reflection.

To address the need for in-service teachers and their professional development, research on collaborative contexts was reviewed.

Collaborative Contexts

Collaboration, in an educational setting, refers to a process that involves two or more people working together to solve a common problem. In the journal Research Forum, Wideen (1989) captured its key features and described its potential and appeal:

> It [collaboration] involves individuals or organizations, that ordinarily function autonomously or in isolation, working jointly on projects of mutual concern. Supporters take the perspective, ' working with, not working on' as a cornerstone to a philosophy which sets teachers, administrators and university people on an equal footing as they work in groups to help solve social problems. The forces behind collaboration find roots in the need for reform and the recognition that such reform requires the collective effort of all stakeholders. Collaboration improves our knowledge of different aspects of the educational system; provides a powerful tool for staff development; creates a framework for reflection; improves knowledge utilization; and empowers people. (p. 4)

Ellis (1990) outlined and enlarged upon benefits attributed to collaborative interaction in educational circles. She listed: professional environments that foster learning; increased productivity and expertise; improvement of teaching practice; increased learning activities; positive effects on students' learning conditions and outcomes; and in a few studies, improved classroom practice as a cycle of reflective decision-making among teachers. Her work indicated that frequent collaboration improved the quality of implementation of non-routine teaching strategies. However, this trend was only evident when the collaborative

meetings were structured.

MacKinnon and Grunau (1991) reported that in their study with pre-service teachers the collaborative setting provided opportunities for interaction and exchange of ideas. It provided:

> The foundation for a number of "forums of action and discourse", in which the knowledge base of teaching gradually and continually developed through supported reflection. (p. 2)

Furthermore, MacKinnon and Grunau articulated that through the sharing of experiences and discourse, prospective teachers came to "see their classroom experiences in new ways" (p. 3) and were able to grow professionally from it.

Erikson (1989), in a paper presented to the Canadian Association for Teacher Education, proposed 'collaborative inquiry' with colleagues and educators as the means by which teachers could develop a repertoire of diagnostic and teaching strategies. This collaborative inquiry could " be based on constructivism and the view that professional knowledge is in a state of continual growth and change" (p. 11)

Allan and Miller (1990) referred to collaboration of this type as cooperative professional development. They visualized action research as the vehicle since it can be fostered by teachers and researchers working in a reciprocal relationship where:

> Teachers as reflective practitioners are focused on their own learning and where the impact of the learning is on real classrooms and on real schools ... (Allan and Miller, 1990, p.196)

Hunt (1987), in Beginning with Ourselves, raised the issue that research into teacher professional development can often be one-sided, benefiting the researcher only. He felt that a study should not be an 'outside-in' approach where the teacher wonders about the purpose and the value of the study to her/him. Collaborative studies, developed with an 'inside-out' approach, benefited both teachers and researchers. He found that participants recognized the 'teacher thinking' brought out was richer because of the trust between colleagues taking the risks together to learn more by an open investigation.

Tripp (1987) supported the concept of 'inside out' research by suggesting that collaboration should be of a symbiotic nature in order for commitment to task by the researcher and by the teacher. He felt that in the past little real collaboration had occurred between teachers and researchers because many researchers stopped "short of the vital step of sharing control of research with teachers" (p.180). He clarified his position by outlining that true collaboration happens when "teachers make their own choices and are active, self-reflective researchers into their own practise and situation" (p. 180). Collaborative research, he stressed, should be the forum where teachers working with researchers "engage with classroom practise at a more theoretical level to answer questions of 'what' and 'why' rather than merely 'how'." (p. 179) The researcher, as the collaborative colleague, becomes a part of the classroom; explores with the teacher her reflections and images of what the teaching/learning should be, examines the goals and plans, and assists the teacher to be engaged in a process of critically examining practise.

Thiessen (1992) developed a model of teacher development that was rooted in the classroom and linked with collaborative interaction. His work with Classroom-Based

Teacher Development (CBTD) examined teacher professional development within the context of the everyday realities of classroom life. He commented on the often limited effectiveness of programs and workshops that deal with the content and structure of teaching apart from the situations that teachers operate in and must address daily. Thiessen indicated that change has often been expected in practise after cursory exposure to new strategies and philosophies with little opportunity for teachers to discuss or debate problems or concerns. He concluded that the context of a teacher's practise has not yet been sufficiently addressed in professional development.

Effective professional development, Thiessen (1992) argued, should be the responsibility of the teacher and be school-based. Strategies such as peer coaching, action research, and teacher centers have been encouraged but not frequently sustained. He felt that CBTD, as an alternative, is an orientation rooted in the classroom and the school, and therefore it is focused on the interaction of the teacher with the students in the teaching/learning event. This focus can provide the motivation for continued interest and growth in teaching practise because the benefits are immediately identified and within the control of the central stakeholders - the teacher and her/his students.

Five conditions are outlined by Thiessen (1992) for teachers involved in CBTD. It must 1) focus on student learning as the 'bottom line' and therefore be classroom based, 2) recognize the importance of all stakeholders in the education process but "refine the power relationship between the teacher and students" (p.218) via control of the choices, 3) visualize the classroom culture as the arena where both the teacher and the students share experiences, make sense of them, and relate them to the web of experience that is their life, 4) encourage

teachers to seek changes in their practise that have personal, educational and social priority, and 5) involve a reflective methodology which fosters interaction and transformation through a collaborative dialogue between teacher and students.

Although three modes of CBTD are possible, this review will focus on the mode that examined how teachers learn from one another (Teachers with Teachers). Here, Thiessen (1992) acknowledged that teachers find other colleagues the most valuable source of professional development. He cautioned that many coaching approaches being currently used differ from CBTD in that they do not address the power, action and reference points of CBTD that were outlined above. He contended that coaching that is neither reflective or transformative is a limited form of inquiry. The direct involvement of the students is important and focuses the action of the professional development on classroom application.

Thiessen's 'Teacher with Teacher' mode is presented in an abbreviated form below:

I. Building Joint Endeavours
    1. Exchanging expertise:
    2. Planning cooperatively:
II. Probing for Meaning
    3. Comparing vignettes:
    4. Learning through participation:
III. Promoting Collaborative Development
    5. Elaborating practical theories:
    6. Enhancing professional development:

(Thiessen, 1992, p. 95)

Hargreaves (1992) elaborated on the influence of colleagues on teacher practise in defining his "cultures of teaching". He contended that strategies and teaching styles are tied to the demands and constraints of the context and are affected by the "beliefs, values, habits and assumed ways of doing things among communities of teachers who have had to deal

with similar demands and constraints over many years" (p. 217). This "culture", Hargreaves asserted, and the relationship between teaching colleagues is a significant aspect in the teacher's life. For change to occur in the practise of teaching, Hargreaves pointed out that a change in the "form" of teaching may be needed. Form being defined as the characteristic patterns of relationship and the forms of association between the members of a particular culture.

Hargreaves (1992) identified four broad categories of teacher culture: individualism, balkanization, collaborative culture, and contrived colleagiality. The first, "Individualism" is used to describe settings where teachers concentrate on short term planning (presentism), avoid discussing, thinking about or committing themselves to change or exploring their practise (conservatism) and avoid collaboration with others because of perceived criticism. Hargreaves referred to Zielinski and Hoy (1983), whose work drew attention to the degree of isolation experienced by elementary teachers. They found that professional dialogue by elementary school teachers was often limited to discussions of materials, discipline, activities and individual student problems rather than the exploration or clarification of curricular goals or teaching behaviour.

Within the "Balkanization" culture, Hargreaves (1992) noted that teachers in this setting tend to form groups based on mutual interest or styles. This separation, most common but not exclusive to high school settings, lead to poor communication and indifference among teaching staff members.

Hargreaves (1992) rated the "Collaborative Culture" defined by Nias et al. (1989) as being supportive of teachers in a full spectrum of ways from the professional to the personal.

In this category, teachers discuss failure and uncertainty with the aim of gaining help and finding support. These cultures require some general agreement on basic educational values but not restrictively so. Collaborative cultures do not arise spontaneously, Hargreaves suggested, but are created and sustained. Leadership and dispersion of that leadership in a respectful, caring context fosters it. His work found that collaborative cultures emerge slowly. They are often impeded by the restrictions of the context of teachers' work-time and curriculum demands.

Hargreaves (1992) cautioned that these two restrictions limit the quality of collaboration and can lead to "bounded collaboration". Bounded collaboration is collaboration marginalized by the lack of depth, scope and frequency of the collaborative events. It may be limited to short units of work or be 'one-shot deals'. Hargreaves cautioned that "contrived collegiality" can occur when the administration retains control of curriculum and binds teachers in time and in space to those purposes and procedures set by their superiors. This form of collaboration is considered a starting point or a way to introduce the thought of professional development linked to curricular development. Ideally, collaboration should be focused on more than immediate concerns and practical needs but extend itself to longer-term planning concerns. Hargreaves (1992) saw teacher development within a collaborative culture as being tied to curriculum development. This reconnection between curriculum and professional development would insure commitment. He saw collaborative cultures as the means to promote professional growth but observed that:

> Attempts at teacher development and educational change [which] will meet with little success unless they engage with the purposes of the teacher, unless they acknowledge the person that the teacher is and unless they adjust to the slow pace of human growth that takes place in the individual and collective lives of teachers. (Hargreaves, 1992, p. 236)

In summary, the following points bear consideration when designing a case study of elementary science education and teacher professional growth. The study of science should recognize the importance of the 'doing' of science and the realization that science, as a changing set of theories, is constantly being reconstructed and enhanced as more is learned. Elementary science teaching which employs a constructivist philosophy is child-centered in the sense that children and teachers must negotiate understandings and appreciate the rich and varied conceptions each holds of how the world is organized. In addition, awareness and respect for the generally accepted views of science knowledge and processes is a valid goal for the elementary classroom. Science teaching should demonstrate respect for different conceptions while providing a program rich in new relevant experiences. These events can foster additions of new concepts and new meanings to the students' understandings. Teacher practice is profoundly influenced by past experiences, contextual influences, beliefs and visions of the future in the same manner. Teachers, like students, are learners and capable of reflective inquiry into their own practice. Through reflection, negotiation with students, and analysis of the backtalk from the science teaching events themselves, teachers can grow as professionals. Teachers commit to collaborative strategies especially when the benefits

are real and relevant to the learning of their students. They commit when there is respect for practical knowledge and experience. Collaborative research when most relevant, places the teacher and the teacher-researcher in a shared power position where both direct the focus of the events being studied.

Chapter 3

Design and Methodology

The rationale for a case study

Early in my program of studies, I knew that my interest in the study of teaching would lead to that area of research involving teacher professional growth, or, as the literature often describes it, teacher development. Being interested and experienced in elementary science education and knowing the concerns of my colleagues in this area, to look at how a teacher teaches science in a meaningful way in the classroom became the focus of my inquiry. I wanted to improve my science teaching and work with other colleagues in this area too.

After reading the literature and talking with colleagues and professors, the nature of my study began to focus on teacher beliefs, knowledge and behaviours and the manner in which these were acted out in the rich context of the classroom. The 'what' and 'why' of science teaching became an interesting puzzle. The idea of a collaborative case study with a teaching colleague, which would explore and extend understandings of science teaching

through interpretations of shared experiences, evolved. The classroom teacher in the study had to be interested in inquiring into her own practice, in reflecting on the teaching events, in employing new strategies, and in modifying previous practise as needed. As a teacher-researcher, my responsibilities were to appreciate the context of the classroom, help identify and frame the critical problems of practise, suggest strategies for instruction, and support changes in practice by guiding, modelling and coaching as needed.

As collaborating partners in research, we would frame the practical problems that arose, address them with strategies appropriate to the situation, assess the success and applicability of these approaches in the unique context of my colleague's classroom. We would reflect on the personal and professional experiences that were brought to the classroom in this study and together try to give meaning to this process. It was my hope that through working as partners, we both would be able to develop a better understanding of science teaching and of ourselves as teachers.

A case study was selected as the most appropriate method to study science teaching because it is based in the rich context of the classroom where the teacher interacts with her students. A collaborative partnership, where both the teacher and the researcher jointly hold responsibility for the decisions and interpretations, was chosen to insure reliability, commitment and mutual benefits to the participants. The roles and responsibilities of the participants were negotiable and, in fact, did change over the course of the study.

The methodology fell within the interpretive and practical realms (Haabermas,1972) because the intent of this work was to study the problems of practice as they were described and clarified in the science class and to develop an appreciation for the teacher perspectives

which directed the teaching. The framework was, broadly speaking, interpretive and meant to portray the sense making of the collaborating partners based on the development of shared meaning and negotiation.

Empirical data included the transcripts of lessons and reflective conversations, journal entries, letters, samples of student work and anecdotal notes. These provided the basis for the interpretive analysis of the events which led to the insights and meaning making which evolved. These forms of data were then written as narrative constructions which took the form of vignettes describing in detail the identified themes and tracing the transformations in practice. The themes, shared as "Diane's Metaphors for Science Teaching", highlight the insights into practise and the process of professional development which came about.

As the intent and focus of my work was formed, the need to identify potential collaborators and then to extend an invitation to a colleague with whom to conduct my case study became important.

The historical background

At the time that this study was being planned, I was a classroom teacher on Sabbatical leave from my school division. As an elementary teacher who possessed an extensive science background, I had been called upon in the past to be involved in various professional development workshops and assessments of school science programs. I had also had the opportunity to be involved as a cooperating teacher in a research study on the

development of an S.T.S. (Science, Technology and Society) teaching model. These experiences with others and continuing questions that I had myself about science and my own science teaching led me to begin a graduate program at the Faculty of Education, University of Manitoba. In reading literature and in participating in an action research project, I felt that more study on the link between teacher development and curriculum reform was needed. Having had the opportunity to join a collaborative research group of professors at the Faculty, I became more confident at appreciating the processes which constituted interpretive research. I felt that a study of science teaching in a colleague's classroom would provide me with insights into the problems many elementary teachers have with science teaching and help me to develop a more enlightened personal philosophy of teaching.

It was quite by chance that I met Diane at a one-day workshop for teachers. We were both interested in considering the use of cooperative learning strategies in our classrooms since our respective schools were presently encouraging professional development in this area. As part of the process of getting to know our fellow teachers and as part of the cooperative structure of the day, the participants were invited to form small groups and share something about themselves as professionals and to comment on why we were attending this particular session. Having shared my interest in science education and the present direction that my studies were following, it was a pleasant surprise to hear from Diane that she was a beginning teacher and was concerned about her science program. As a beginning teacher, Diane was still interested in improving her science teaching and indicated that she would welcome support in this area. At the coffee break, we talked a bit more and exchanged

telephone numbers.

It was two months later, as I was planning out my Sabbatical year and formulating my proposal in a more structured form, that I contacted Diane again. She was still interested in a collaborative study of her science teaching and we met to touch base on what the study would likely involve. I was pleased that after our meeting in her classroom that June day, she was more committed to becoming my teacher collaborator.

The preliminaries

After receiving approval from the Ethics Committee to proceed with my study, I contacted Diane and arranged for a meeting to discuss the beginning of the study and the required permission documentation. At that time, the format we would initiate was elaborated in more detail. We discussed anonymity and I assured Diane of the confidentiality of the data collected. Diane was invited to review the vignettes when they were completed and she was assured of an opportunity to comment on the quotations and interpretations made.

We discussed the collaborative aspect and the fact that the approach would evolve based on the events as they happened and what concerns we decided we would focus on. At this time, there were no specific issues raised related to the science teaching itself, but a beginning understanding we had was that Diane lacked science resources and was concerned about how to approach the planning and development of the science units. We decided that the study should involve the teaching of two science units. In the first unit we would get a

feel for the context and help identify concerns and themes. The second unit was to allow time to concentrate on building strategies and developing a conceptual structure on which to base future science units. The study was to involve the teaching of two units, approximately 10 lessons with additional time for students to work on related projects. As the weekly/monthly timetable of the class varied due to school commitments to in-service days, special events, and parent-teacher interviews, the time frame for the case study was two and one-half months.

Diane had previously spoken with her school principal and received conditional approval to participate in the study. I contacted the principal and arranged to meet him regarding the nature of the study, the possible ramifications to the school, the involvement of the students, and permission to proceed from the administration. I gathered data about the school and its population from the principal.

The context

The case study took place in Parkwood School (a pseudonym) during the spring of 1992. Parkwood was a kindergarten to grade 9 facility and had a population of 435 students arranged into 21 classrooms. The teachers had support from specialists in music, physical education and counseling. There were three resource teacher specialists who worked with teachers and coordinated the fifteen I.A.s (itinerant assistants). In addition, the teacher librarian was supported by a part-time library technician. The principal had a half-time vice-principal who also carried teaching responsibilities at the junior high level.

The school building was located in a residential area of modestly priced homes whose resale values ranged from sixty-five to ninety thousand dollars. This area was an older part of an established suburb outside the city core region. The houses were approximately 50 years old and many of the original owners were now retiring and moving. New families tended to be blue collar workers and young professionals, although the latter were felt to be the exception. The present catchment area of the school extended beyond a major roadway and included apartments and subsidized low income housing. This brought a transient population to the school.

The school profile showed that many children came from homes with both parents working. The principal felt that there were a significant number of single parent families. The proportion of aboriginal students and E.S.L. students in attendance at the school was now stabilized after several years of growth in numbers. Many children were operating below grade level and some exhibited behaviour problems. To address these features, the classroom pupil/teacher ratios were reduced from the division-wide number by 2 to 3 students.

The principal outlined that the staff was being encouraged to participate in in-service training on co-operative learning and the broader school goals included a focus on achieving academic excellence as opposed to crisis management strategies.

Diane's grade 4 class was composed of 12 boys and 9 girls. During the time of the study, one new girl joined the class. She was from an immigrant family and received E.S.L. support. In the class, 5 students received resource help regularly and 2 saw a councilor when needed. Three students had been identified as gifted.

The collaborating teacher

Diane was a beginning teacher who had worked at Parkwood School for three years. The first year she worked 0.5 time in a junior high classroom teaching Language Arts and Health. In her second year, she picked up an additional 0.2 time teaching the Science and Mathematics in a Grade 4 classroom. The year of the study, Diane was teaching her own Grade 4 class full-time.

Diane was in her mid-twenties when we worked together. She was a graduate of the Faculty of Education and had some credits accumulated toward her additional Arts degree. Within the area of science, Diane had taken one university credit, a science course geared for elementary school teachers. In these respects, I felt Diane was a suitable candidate for my study having some experience in the classroom and possessing an educational background common to many elementary teachers.

The teacher-researcher

As the collaborating teacher-researcher, my involvement included teaching some of the science lessons and participating in the related reflective conversations, both roles which involved interventions in the events being studied and which required a commitment to the science teaching and to Diane's professional development. As such, it was important for Diane to know something of me as a teacher and as a person. I shared with Diane my educational background which included a Bachelor of Science degree and a Bachelor of

Education degree. I had had experience as a science research assistant in two separate field studies and had worked with a provincial agriculture department in my early days of employment. I had been an elementary classroom teacher for thirteen years and had facilitated workshops for teachers in the areas of science, social studies and health curriculum materials. I shared with Diane that my teaching responsibilities had involved working in open area settings and in various types of team teaching environments. I was enthusiastic about science clubs, outdoor education and art activities. My interest in S.T.S. issues was a result of being the cooperating teacher in a graduate student's science research study a few years earlier and more recently I had also attended a month long fellowship at the University of Calgary in Energy and Environment Studies (S.E.E.D.S. '88). As a parent, my interest in education spanned from the professional to the personal domain, where I was actively involved in Parent Councils and the University Alumni Association. In addition to sharing my biography, I felt our common interest in co-operative learning allowed Diane and me to have a base from which we could begin our discussions and plan our course of action.

The 'negotiated' framework

Diane and I met to **pre-plan**. We discussed the goals/objectives of the curriculum guides and the resources needed to teach the science units. We considered the various strategies and activities possible since Diane was interested in employing co-operative learning philosophy within a hands-on approach to science teaching. We discussed the science terminology and concepts outlined in the curriculum guide in order to address any

questions Diane had about the content. Diane and I expected to meet before each lesson and confer afterward to determine what the next step or lesson would be. I commented that when concerns or problems arose, we would address them as we went along. At this point, Diane and I certainly expected to have practical problems (the 'how' of teaching) but did not elaborate on the more professional philosophical considerations (the 'what' and the 'why') which arose when reflecting on the science teaching events themselves.

Once the study began, Diane and I met for **pre and post lesson conferences**. Lesson objectives were discussed and any concerns that were noted related to planning or teaching the science program were explored. These conferences were opportunities to discuss problems and student reactions. My anecdotal **field notes** were sources of inquiry and forums for reflection on the events. The **audio tapes** of the lessons and the student work provided a basis for the discussions as well.

Diane and I agreed to keep **journals** of our thoughts and feelings related to the study and how it unfolded. My journal included my anecdotal comments about the lessons as well as observations about our interaction and promising avenues of study. Diane was given no restrictions on what she chose to include/exclude in her journal. As the study proceeded, it became apparent that the demands of teaching her class and the demands of collaborating with me were very time-consuming. Diane found that she was not able to set aside additional time for journal writing. She shared that she felt herself to be an auditory learner and preferred **reflective conversation** as the data gathering technique. Our conferences became more lengthy and the main venue for exchanging ideas, reflecting and meaning making. To facilitate careful records of our reflective discussions, I began to **audio tape** all conversations

and conferences.

During the first three lessons in Diane's class, my role was that of an **observer**. The students were interested in meeting me and expressed enthusiasm in doing some experiments. I learned the students' names and gained an appreciation for how Diane organized her class and interacted with her students. My initial observations were shared with Diane in a first **summary letter** early on.

With the sharing of the summary letter, my role in the classroom changed to a more involved one, that of a **participant-observer**. I began to help organize the equipment, pass out papers, and interact with the students as they carried out activities. Diane and I would conference before and after as well as during the lesson, at convenient points of time while the children were involved with activities. At certain points, I taught part of the lessons including modelling of strategies. These interventions were described by MacKinnon (1989) as "follow me" and "hall of mirrors" coaching models. Diane was exposed to new strategies in this way. She was not expected to imitate them but to consider their value and incorporate what she felt was applicable in her classroom and germane to her teaching style. At a latter point in the collaboration, Diane and I would co-teach lessons working as a team. These opportunities employed the "joint experimentation" model outlined by MacKinnon.

However, these co-teaching sessions developed beyond a mere coaching model format to a point where teacher and teacher-researcher felt their way as a team and as inquirers into practice. This additional step was possible because each member of the team brought her own expertise to the event. Both members were prepared to try new strategies, incorporate suggestions, and rely on the advise of the other. Both took risks and were

immersed in the context. Both teachers interacted with the students in the event being studied and both teachers were committed to promoting a positive educational science experience for the students. The learning about practice was mutual because the control of the lesson event was shared. Critical to this development, which I will term **professional collaboration**, was that sufficient reflective conversation about the science teaching had occurred and had allowed a 'common vision' to be formed. These features are indicative of key conditions raised by Thiessen (1992) in his CBTD orientation.

As the study drew to a close, Diane responded to some general inquires about her background and her feelings/comments about our collaborative research in a **letter** to me. After the conclusion of the formal part of the research, our collaboration extended itself to a broader network of inquiring teachers. Colleagues that we worked with were interested in what we had begun and a loose **network** with infrequent meetings was formed. These meetings were tentatively scheduled by mutual agreement and came about when individuals felt a need to consider the next step. I asked Diane to share in letter format the benefits, if any, of the continued contact.

The collection of data

The data collection for the research was on two levels. The first level involved my original records relating to the science teaching events and teaching dialogue. These included the field notes made in the classroom, transcripts of the audio taped lessons, and samples of

the students' work. These data were later used to stimulate the reflective conversations about the science teaching.

The second level of data collection was the gathering of information related to reflective conversations about teacher practice. Transcripts of audio taped conversations and conferences were the key source, but journal entries and letters were also used.

The analysis of the data

The transcripts, letters, journal entries and field notes were read and analyzed for the problems and concerns addressed in the reflective conversations. In the analysis, the problems which were identified either by Diane or by the two of us together, were noted. It was flagged in which instances Diane broached a concern and where these concerns were "framed" as problems by me based on my experience in science teaching.

The dialogue, where the problems were identified or framed, was flagged by myself and then each successive commentary in the transcripts was pinpointed and the steps of the "reframing" process tied together with contextual details. The actions of recognizing the reframing of the problems was aided via "backtalk" found in the transcript references. This backtalk did allow the concern to be re-addressed. These references were traced throughout the data records until it appeared they were dealt with to the satisfaction of the teacher or left for continued reflection after the conclusion of the formal part of the study.

Problems of practice and concerns raised were of varying degrees of importance but those which I felt were most pertinent to the transformation of Diane's practice were

highlighted. These concerns were the most obvious hindrances to change in Diane's practice and were evidence of the influence of the school culture and Diane's early school experiences which marginalized her view of and her comfort with her science teaching. The themes, which were developed as a result of this process of analytic examination, are shared as vignettes later in Chapter 4. The same process was used to trace the development of our collaborative relationship. In addition, the information gleaned from our correspondence was added to provide a more complete picture of the events. Chapter 5 outlines the professional collaboration.

The themes shared

The vignettes, which describe the points made through a thematic analysis of the events, trace the reflective approach used to address Diane's concerns in the context of her classroom. For this analysis to be viewed with rigour, it was important that Diane be given the opportunity to read the narrative constructions and comment on the interpretations given to the series of events. Diane endorsed the vignettes save for one point. She clarified her initial conception of science teaching regarding note taking. The criticism was valid and the details in this regard were enriched and expanded upon. It was during this process that Diane was given the opportunity to make small changes, edit some of the dialogue for clarity, as conversational communication may be awkward to follow at times. I recall Diane's comment about the titles given to the vignettes, "I like the titles you chose". It was then that I shared that they were really metaphors that she had used in our discussions.

The collaboration traced

The professional collaboration outlined in Chapter 5 is a record of the attempt to employ a constructivist approach to teacher growth using a reflective methodology. This was similar to MacKinnon's (1989) Schönean-constructivist approach in his study of a pre-service science practicum experience. It was important to look at science teaching from Diane's perspective and address those concerns that she had identified, whether they were specific or were feelings of dissatisfaction that needed attention.

The analysis of the data was conducted in the same manner as for the vignettes, except that 'turning points' in the relationship were sought to define the subtle changes that led to a 'common vision'. This was a common vision in the sense that specified ideals were recognized but flexibility in personal style acknowledged. The turning points helped to define the difference stages in the collaborative relationship.

Chapter 4

Diane's Metaphors For Science Teaching

During the four month period Diane and I worked together, several of her concerns related to science teaching would become apparent, be reflected on, and then addressed in the context of her classroom. Although we recognized and gained insight on many of these concerns, this chapter will focus on five predominant themes. These themes, transformations or enhancements in perspective, were the ones I felt were most pertinent to the context of Diane's practice and therefore were most meaningful to her professional growth. The themes will be described as vignettes of related events. The themes shared are entitled: "Remembering What They Have Learned"; "It Doesn't Work"; "A Storehouse of Knowledge"; "Being a Springboard"; and "It's a Good Kind of Mayhem". These titles came from metaphors used by Diane during our reflective conversations.

"Remembering What They Have Learned"

Throughout the time which Diane and I spent teaching science in her classroom, one concern arose and was addressed several times in our conversations. It appeared in a pre-lesson conference the first week of our study when Diane shared her feelings about the importance of students keeping clear, organized notes about important facts and observations. She felt that good sentences and correct spelling were important skills and that

these Language Arts skills should be developed in all subject areas. Diane wanted to extend their application in her science programming. The underlying reasons for this emphasis on recording skills became apparent later (Journal, March 16/92).

Diane shared the importance of writing carefully with her students as the following passage shows:

> Today in your group you will be given a fruit and with your group you will take a look at the fruit and then describe it in words. Write a descriptive paragraph of the fruit. You are going to have to share in the group. Write the words down, certain words that come to mind. For example: rough, bumpy, etc. after it. Ask if you don't know what it is.... you are painting with words what it is, without knowing what it is. Everybody has five to seven minutes to do this in. And you may discuss it in your groups and talk about what you've got in your hand and then you are going to have to do some writing, okay, so I am coming to give you your fruits and you can get started ... I'm going to pick a person to share some of these descriptions ... (Lesson transcript, March 16/92).

Diane had taught this lesson on the description of fruits as an introduction to a unit of study which focused on Structures and Function. She told me after the lesson that she had taught a somewhat related lesson on plants and textures earlier in the year. She had been expecting that some students would transfer previous learning to the present lesson and was surprised and even disappointed when the students didn't make the link and recall some of the words and concepts. She knew that they had class notes about this information in their notebooks and had studied them for the final test.

Diane was troubled about the students not remembering what they had learned. It was at this point, I began to realize that the problem we may need to address wasn't just the

writing down of key concepts that could be used for review. I wondered if the students had not remembered the information because they had not learned it in a personally meaningful way. However, Diane saw the problem in the following way:

> They can look back at their notes, study them for any tests otherwise they may forget everything, or a lot, of what they learned (Journal, March 16/92).

In a second lesson on the structure of fruits, I observed that when Diane gave directions for the assignment, she focused on diagrams as another way to record new information.

> The way that you are going to do your predicting is... You are going to draw what you think you are going to see. Then draw what you did see. Then at the bottom there are a number of questions ... that you are required to answer (Lesson, March 17/92).

These events helped me to understand Diane's dilemma and to reframe the problem. Her goal was to have the students learn and remember the science knowledge taught in class. The notebooks were an important means for keeping track of this knowledge and were used to help the children remember what they had been taught. Time committed to quality notes was justified as a means to provide information and data to all students and to allow for review for tests. Since evaluation was test-based, Diane felt a thorough and careful review of the notes and worksheets was required.

Diane seemed to view science as a body of 'technical' [her term] knowledge with facts and relationships to be learned in a sequenced manner. Haggerty (1991) referred to perceptions of this type as being based on 'naive realism' and found it quite common in pre-

service teachers. In addition, Diane had indicated that her responsibility as a teacher was to organize (transmit) the information into formats that the students could learn, copy down and review. She felt good notes would ensure the facts were available for review and thus her emphasis on recording and copying.

After the first week as an observer in Diane's classroom, I shared a summary letter with her that tried to articulate the important elements she had shared about her science teaching philosophy. The following excerpts refer to the issue of taking notes:

> It is important that all students put forth an equal effort, that is, think about the questions or activity on their own and write down what has happened - not just get answers from others.... They need structure and notes are important for study purposes. If "they know that a test is coming, they think about what they are learning- they are motivated" ... The new information, the content, needs to be presented in an organized sequence. Having students use worksheets and take down notes (teacher prepared) is necessary so that "I know that you (they) have this information down" (Summary letter, April 9/92).

This framework for planning and teaching science was influenced by Diane's early experiences or as Lortie (1975) would say, her 'apprenticeship of observation'. It also reflected the advice she had received from colleagues at the school in her first years of teaching. She had found that the children were accustomed to copying teacher-prepared notes and doing question/answer worksheets in photocopied resource booklets (Example: Milliken's Magnetism and Electricity Duplicating Masters). In the past, lessons that she had observed were often teacher taught with little or no 'hands-on' experiences. Learning science was perceived as an independent experience where each student must learn on her/his own.

The test was used as a motivation for learning and studying. Diane found that her students were used to doing science this way and although she felt that both the students and she needed to look at science in another way, she was uncertain how to effect this change.

Diane was not satisfied with the learning of her students, thus the surprise and disappointment about the structure of fruit lesson. I suggested to Diane that instead of focusing our energies on reviewing terms and concepts, we should start by finding out about what the children already knew about structures. This was a step in reframing the problem in the context of constructivist thinking and conceptual change models. The children were not remembering because they were not 'apprehending' the new knowledge in ways meaningful to them. I chose this point in time to suggest that some hands-on activities which Diane was interested in, would be a good place to begin.

I worked with Diane to plan the next few lessons with a 'hands-on' approach. I became a participant-observer and began to take an active role in teaching parts of the lessons. The class did activities experimenting with shapes, materials and designs of structures such as towers, beams, and bridges. The children were encouraged to talk about their observations and interpretations and more class time was spent 'doing science'. The children were given a few minutes, usually at the end of the lesson, to write down what they learned. We found that they often wrote a few phrases or sentences.

After working collaboratively for a few weeks we decided to try a jigsaw strategy which is normally used to review or brainstorm for facts about a topic. [The information on a topic is collected by small groups, who in turn regroup with representatives from other research groups and mutually share the pooled information. It is a well known co-operative

learning strategy.] The sharing in this case was done orally. We had selected this activity because Diane was interested in assessing what the children had learned as a result of the hands-on approach we had been employing. Afterward, we evaluated the usefulness of this strategy.

> D: The jigsaw, they are not used to working in a structured way. I think that given the opportunity to do it a few more times, or if they had been given more time today [it would have been more successful]. I think that it may be easy for them to forget what happened and what we did. A new strategy like this was too much for that one class.
> [I realized that Diane was still expressing concern about the children forgetting the science knowledge and suggested a form of recording that would bring the focus back to students reflecting on their own learning and writing about it.]
> A: So, we should have them do a bit of personal journaling [after the lesson] about what they learned or felt was going on or thought they learned or some questions that came up. Then we could look at the journals to see what was said. That could give us some leads about what their thinking is and about ideas for other experiments.
> D: And a lot of them are thinking but they don't take the time to write it down, or making predictions as they go along and I would like them to start writing down those predictions. So when its done, they can go back and say, "Hey! I was right on track. I learned something new, I didn't know that. "Let's make up some kind of a science booklet... so as not to say their journal [their L. Arts journal] but maybe a science...
> A: A book?
> D: Yes, a log book for science... even if its little sheets... that's something I'd like to do... some of the kids are not as involved but I think that's because of the large gaps in ability levels of the children (Conference April 20/92).

Diane had recognized the students were thinking about the science and she wanted them to have a record of those ideas. For her class though, she felt some students needed a framework, like a log book worksheet, to guide their thinking back to the events. The aim was actually to guide the children into reflective thinking just as we teachers were attempting

to be reflective practitioners. For the next few lessons, we prepared log book sheets lesson by lesson. The sheets provided an organizational framework and space to jot down notes. After one lesson about eggs and their shell strength, Diane made the following observation.

> D: And I thought his ideas were good [we were looking at students' work]... I was very impressed with his diagram. And Geoff had a very interesting diagram too about the whole outer area and working with the inside. It was very interesting, some of them were able to illustrate very complicated ideas and were not able to write it down (Conference April 21/92).

Diagrams were becoming more than labeled materials. They were becoming venues for expressing understanding and ideas which may be very difficult for the students to express effectively in sentences. As such, they were more than records of what was observed. It was as we continued our discussion about the recording of information and ideas by students, that the underlying reasons for Diane's emphasis on teacher notes resurfaced and was articulated. We were thinking ahead to the upcoming unit on electricity, a unit Diane had taught previously with another teacher when she made this comment:

> D: I know a fair amount about electricity and I had borrowed a book about it from another teacher, Janet, who had taught it using that booklet and it wasn't me. And I found it very restricting and I thought, in my first year, gee, I've got to follow this thing. And it really just turned me off, because it wasn't reflective of my style, it was her style. And I found it really didn't just work for me. And now I guess if I did an electricity unit, I would have to plan it to reflect what I would want done. And not so much pencil-pushing and stuff. The thing that was interesting was, the kids had (have now) been learning with a minimal amount of notes. And that's important because a lot of these kids will look at science as taking notes and that's not what it's meant to be at all. I don't want to be handing out workbooks for everything either. That's part of the reason why I didn't like the electricity unit, that one wasn't me.

> A: Do you mean having the sheet prepared and having to teach to the sheet?
> D: Yeah, and that isn't what I wanted to do. I would rather have taught it to work towards some common knowledge and it (the booklet) was too technical. And that really turns the kids off too. It was too technical for this level, nine year olds... but yeah, but I don't like the books that I got for teaching the science and so I think I'm more comfortable with this approach because it is more of a whole approach. You've got the reading, the writing, the listening, and the 'doing'. The experimenting, the predicting and there's a lot to it. In the other one, you read information and answer the question and then turn the page. You are not really learning about it [electricity] (Conference April 21/92).

This conversation demonstrated to me the changes in Diane's perspective about science teaching. This reflective conversation was a venue for her to consider the 'what' and the 'why' of her teaching behavior and consider the choices available in a collaborative environment described by MacKinnon and Grunau (1991) as a forum of supported reflection. The intent of the collaboration was not to encourage radical changes in Diane's strategies but, as Aguirre et al. (1990) proposed, to respect alternate conceptions of science teaching and use reflective practice as a means to broaden the base of experience to allow the teacher a range of strategies from which to choose. The intent, via a reflective process, was to enrich her conception of science teaching rather than replace features of it.

Again in mid-May, we discussed the approach that we were taking and Diane shared:

> D: I am concerned that they will end up doing booklets or just taking notes all the time. They are used to taking notes and there is a place for taking notes and I do believe they need a certain body of information. This unit has blended itself well because it wasn't certain. It wasn't cut and dried and a mechanical vocabulary... But I think next year it would be a kiss of death [for these students] to not be able to do some experimentation. They have done a lot this year (Conference May 12/92).

Diane was becoming aware that all aspects of the unit did not have to be decided upon in advance- that is, be 'cut and dried'. The planning was based partly on the day to day experiences within the science class - what happened in the experimenting process with the students and what they understood. This feature was very important to her. Therefore the publisher-prepared resource worksheet book was not a strategy she would feel comfortable using restrictively and now felt she could say this and act upon her own belief. She now had another means which better reflected her philosophy. Thus Diane's comment later in one of our teacher conferences:

> D: I've noticed a lot more of the kids are thinking, I can see it. In the literature circles I did at the beginning of the year I was definite on how I wanted the comments done, "don't tell me the story, I want you to think". They emerged from that and they did quite a bit of work with response journaling ... and now that they are doing it (in science) they are really thinking more about their comments ... thinking more. It's very difficult for some to take that idea and record it. But they don't realize that sometimes when you have a good idea you should write it down. That is why next year I would set it up that they write things down in a science journal (Conference May 21/92).

This is an example of the reflection-on-action that allowed Diane to reconsider parts of her practice that were problematic and plan for change based on new images of the future. These images represented a shift from, or rather an enhancement of, the view that notes are a means of keeping track of the facts to which the students have been exposed, to a broader more inclusive use of note taking as being a place for students to write down their ideas and explanations about the science lessons. The science journal became a means to personally reflect on their experiences in science.

I sensed that an outcome of our reflective conversations was a change in Diane's perspective regarding answers, still respecting ones which students came up with individually but also recognizing and valuing answers written after sharing ideas with classmates. This approach seemed to be more satisfying to Diane because the learning was now socially constructed and became integrated with Diane's cooperative learning approach. Teaching with consideration of the thinking children do and the way they understand and hold knowledge influenced the type of recording and note taking that Diane preferred in her classroom.

"It Doesn't Work"

Diane and I had been collaborating for a few weeks when a dilemma arose. We had planned a lesson to show how the type of material affected the strength and design of a structure. The students were building a beam bridge using two blocks of wood as pillars and a variety of paper strips as beams. The students were to determine which type of paper made the strongest beam, based on the number of plastic math cubes the beam would support. The class members were asked to predict the strongest and the weakest beam, carry out the experiment, record their answers on the direction worksheet and be prepared to share their observations and conclusions with the whole class.

The materials had been distributed and the small groups were eager to begin. One group, which included George, had begun the first trial immediately. George, who was a vocal student, quickly discovered that the thin paper beam didn't support even one math

cube. He began to dart from one group to another throughout the classroom and I overheard his comment: "Don't bother doing it, it doesn't work" (Journal April 14, 1992). He became quite loud and the class became distracted. Diane, at this point, encouraged the class to settle down and get back to trying the next beam.

Afterward, during our post-lesson conference, Diane shared, "Can you believe it, that George, he went around to a couple of the other tables and told the others not to do the experiments, that he'd done one and it didn't work" (Journal April 14, 1992). This situation, one in which we both felt an awkwardness because we hadn't foreseen this particular problem, turned out to be a powerful turning point in our science teaching.

Diane had not expected that the thin strip wouldn't support one math cube and she was concerned at the turn of events. I had realized the weakness of the paper but had not foreseen that this would develop into a distraction. One child had viewed this as a failure on the teachers' part and on the 'science' of the activity. It seemed to reflect a view of science as irrefutable, especially in the classroom, and that all events should be totally planned and predictable. This brought to mind Churcher's (1990) comment about her teacher's interest in doing activities that "would work" (p. 92).

Diane and I discussed George's behaviour and our reaction to it. We had been embarrassed because a carefully planned science activity had not worked out exactly as we had intended it to but for different reasons. Had George's response reflected an ingrained assumption held by the students that all science activities were supposed to work out perfectly, exactly as the teacher expected, with no errors? Was there only one set of correct responses acceptable? Did the students think that scientists operated in a perfectly ordered

world? This view represented science as precise and static. If an error occurred then it was not science. I felt that this experience implied that teachers should know exactly what is going to happen and are not supposed to plan activities with unanticipated outcomes. The teachers were supposed to tell the students what would happen before they began the activity. In other words, the activity was a 'trial', a repetition of a set order of events. At the time, I sensed Diane's confusion about this issue as well.

Diane and I discussed our next course of action with two goals in mind (Schön's reconstructing of the situation). The first was to encourage the class to look at an activity that didn't work and to try and figure out what happened and why it happened as it did. We wanted them to apply a problem-solving approach. And the second goal was to address the issue of "failure" in science. After discussing the problem that had occurred, we wanted the students to see failure as an opportunity to learn something new. When planning a project or predicting an experiment outcome, it is acceptable to take a risk and make a guess about what will happen. Through trying and taking a risk, new understanding can be reached. Science was not a precise event but an exploration of the possibilities.

The next day, in agreement with Diane, I began the class by telling the story of Alexander Fleming. I used a library book, The Stories of Scientists, to explain how Fleming, a younger son of a Scottish farmer, became a doctor and researcher trying to discover a way to fight disease. During an experiment where Fleming was growing bacteria on gel plates, several of the experimental plates were spoiled over and over again when mold appeared on them. These plates were discarded. Fleming was concerned because his experiment was not working. In studying the spoiled plates where he was growing bacteria, he noticed that

bacteria was not able to grow in the area around the mold. From this observation, Fleming realized that the mold must produce something which hindered the growth of bacteria. This was what he was looking for! Fleming took a failed experiment and turned it into a scientific success. He had used his ability to observe with a bit of imagination. The use of this story was an example of a situation where Diane and I drew upon "pedagogical content knowledge" (Shulman, 1986) to use an appropriate example to deal with a practical problem.

After sharing this story with the class, I then challenged the class to come up with suggestions about what could be done with the paper strip to enable it to support one plastic cube. I challenged them to see science as an exploration, where all the answers are not known in advance and that it was 'okay' if something doesn't work out. The important point was to explore and try and come up with an explanation for what happened and arrive at possible solutions to the problem.

In the class discussion which followed, one boy, Anton, suggested that if one paper strip alone was not enough to support one cube, then we should put more pieces of the paper together. I supplied the term "layer the paper." I questioned him about where he got his idea, "What is your evidence?" and he shared that he had noticed "paper rolls are made with paper that's wrapped together" (Journal April 20/1992). Afterward Diane and I discussed the lesson, reflecting on the use of the student's idea as part of the lesson. This, I later realized, was a case of a teacher intuitively knowing what was needed at that moment and going with the idea (Schön's reflection-in-action).

> A: Did you notice yesterday when we were talking about that experiment where we redid the part with the different sized beams, one of the students had included in the experiment about layering it and I talked about it and expanded his idea and then I incorporated his idea of layering it into the experiment?
> D: I think it is important to use their ideas. I think that its very important for them to see that somebody is listening to their ideas ... and also thinking that would be an interesting thing to try ... and that they are thinking like a scientist ... And when they saw it work, this person probably thought, Hey, that was a good idea and that would probably work on the bridge (April 20/1992).

Diane was beginning to see science and the 'doing of science' in a broader perspective. It seemed that to her it was now important to encourage the students to think about problems and to attempt to address them. This had been an opportunity to draw attention to my actions regarding failure (MacKinnon's "follow me") and to reinforce student involvement by recognizing their ideas and by using their suggestions for why something didn't work to resolve the situation. This empowered the students and allowed them to begin to appreciate the way in which scientists explore and experiment. It also provided an opportunity for Diane to see how I dealt with an awkward situation based on naive views of science and perceptions of science teaching.

As the following conversation clarifies, this led to a discussion which was influenced by my constructivist philosophy and Diane's sensitivity to the element of risk felt by her students in sharing their ideas.

> A: It just came to mind as we were getting ready and I wondered how we could check that out [use layers of the thin paper]. They had been generating some very interesting ideas... I was just amazed.
> D: I think they are going to find science very boring next year unless they do

> a lot of experimentation because they have had a lot of different and exciting experiences this year...
> A: I'm going to bring in for you an instructional model that tells about using children's ideas
> D: I would like to see more of that... their ideas give it value[relevance], I like the way you incorporate their ideas in. I think that's something I don't see a lot of other people doing. I haven't seen anybody I have worked with in this school use student ideas like that. I don't remember anybody from when I was a student teaching teach and plan, making a focused effort to go back to the ideas of the students. It helps that we have those ideas on tape and can listen to and keep track of them. It would be very difficult to remember through the entire day that one good idea.
> A: I know the chart you made... you were keeping track of a few things up there.
> D: There are a few things I would like to get up there still [notes were made during the discussion with the students] (April 20/1992).

This event turned out to be a turning point in our collaborative study. Diane and I had taken an awkward moment, a teacher's dilemma, and worked through it successfully. The issue of science being precise and with exact answers was addressed with this story and through discussion a broader, more realistic view of the nature of science was shared with Diane and her students. The result was a problem-solving approach to the experiment that "doesn't work" that helped the students and ourselves establish a common vision of science and the sciencing process.

Most importantly for Diane and myself, was the realization that the students had a place, a safe environment, to share ideas, take intellectual risks, and experiment. They needed to tinker with new ideas. Science had been clarified as an exploration where no one has the 'right' answers all the time. Many ideas were seen to enrich the discussion and through trying out ideas, we could all learn.

Diane shared that she had talked about these ideas with the class later in the day,

after I had left the school. Following are her comments:

> D: And I also felt that one of the things that I said that you were doing was generating units from what they think and focusing a lot on how they are thinking and that they are doing it cooperatively. And they [the students] are sharing their ideas and I shared that with the group. I think I need more information on how to take their thinking and develop it more into a unit because it is so easy to take what you are given in the curriculum as opposed to flying with their ideas. That might be more relevant to them as a group. I think that certain structures have to be in place but I think that there is nothing wrong with doing that activity with layering of the bridge... especially because they start thinking that their ideas are important... and that they **are** [her emphasis] creative and that they could discover something important by trying different things and that will make them more accepting of being risk takers and children like these are not risk takers. That's why they have a lot of difficulty in art. So this type of risk taking is a safe environment where you're the one taking the risk for the person is a good approach. Anton is comfortable taking risks, doing that and going back and trying different experiments. And George is doing that now too and some of the other kids will hopefully start taking their ideas now too and trying to experiment with them. And that's how you make a scientist. [my emphasis]
> A: Do you see a lot of difference between what we are doing and what you yourself would have thought science was?
> D: Well, I see this as very different, as opposed to the way I've seen science taught in the schools ... there are other teachers who are slowly getting on board with hands-on ... which I think is going to make science more interesting for the kids and more interesting to teach (April 20/92).

Diane and I had observed that by exploring events with her students and by valuing their ideas, we were reducing the risk that children felt when they shared their understanding. By making it 'okay' to share and by making all responses worthy and acceptable, the students became more involved and more motivated. Diane refers to the science as hands-on at this point but in retrospect, the terminology should have been more inclusive with the minds-on aspect incorporated. "Active" learning would be the most suitable term.

Diane was also recognizing that the curriculum guide was only a guide -- not a prescriptive, outside authority that should dictate the activities and sequence of teaching events. She felt and saw their participation, even by students who normally were quiet and possibly intimidated. Diane's feelings about the attitude of the group were revealed in this discussion where we reflected back to the events of the structure and forces unit, about making mistakes and taking risks:

> D: I think that they are thinking more, period. I think that for a lot of them their logic is improving because they just didn't stop and think before... and they are more interested in building with the blocks and using the Googolplex, and the girls as well...
> A: You've seen improvement in the girls' interest?
> D: Oh yes, oh yes. Haven't you noticed how more of the girls' hands are up? ... as we go along. At the beginning there, they didn't have a clue or think they had a clue ... Now Janice, she thinks before she speaks and she's participating more and understanding more because its hands-on ... [later in conversation]
> A: Why do you think they are doing that in science?
> D: I think that the way its set up they have to think. Its interesting enough they want to think, So, I think that's part of it. And that the activities, like dropping the egg, are something that is kind of a fun thing and the more crazy it is, the more fun the activity, so its not threatening for some of these kids. Because I know art is something that is very threatening for some of these kids. I have had more outbursts from Sean in art class because taking an idea in their heads and getting it down on paper like that is so hard, especially when you've got motor skills that are not the greatest. It's really hard and people don't accept what you've done. They have a set idea of what art should look like. I think that this [science class] is a really good setting for these kids who are afraid to take risks. For Candy and Linda to put up their hands and know that their ideas are okay and that there is no definite right or wrong like in some of the other subject areas because they are exploring things and it is okay because a lot of scientists have explored things and they haven't worked out ... and its okay ... I think they feel more comfortable from that point of view (May 5/1992).

Diane's reference to "a lot of scientists" demonstrated how she has begun to internalize new ideas about science. And this opened new windows on our study as we began to re-examine the importance of children's ideas about science and the teacher's role in nurturing the sciencing process. It provided a forum where insights from the work of Connelly and Clandinin (1986), Haggerty (1991), and Kelly (1978) on gender issues in science were shared and considered within the broader context of learning about science. Diane and I looked at strategies that explored student conceptions about science events. We incorporated 'hands-on' activities and projects to build learning experiences and enhance understanding.

Accepting children's ideas and using their suggestions became a powerful motivator in the classroom to the students and to their collaborating teachers. Diane and I decided to explore children's ideas in a more thorough fashion.

"A Storehouse of Knowledge"

In this vignette, Diane and I learn about the knowledge and understandings brought to the classroom by all the students, not just the ones recognized as talented in science.

When Diane and I began working together, we spent some time discussing her class. She had two students, both boys, who had a strong interest in science topics and were frequent participants in science class discussions. They could be called upon to share their knowledge on topics and because of this were respected by their classmates. However, this recognition did create a problem in science classes as Diane's comment explains:

> D: Some students come from enriched backgrounds and are "a storehouse of knowledge". George and Alex, for example, know a lot, but I wonder how much they do know? Generally, there are gaps in the students' knowledge. They do not have much experiential background with science ideas. It is important that all students put forth equal effort, that is, think about the questions or activity on their own and write down what has happened-not just get answers from others. In forming groups in science class, a homogeneous group might work best 'otherwise Alex might bring the others to his level of understanding in no time'. The other students in his group wait for him to provide the answers and accept his answers without question. They seem content to let him do all the thinking for them (Conference April 9, 1992).

Diane felt that each student needed to think independently and work through the lessons. She wanted them to develop their own understanding of the science concepts, not wait to hear what the 'smart ones' said and then accept it without reservation. Most students were reticent to share ideas and she felt they just didn't have the background to form ideas or explanations.

During our fifth lesson into the unit on Structures and Forces, Diane was encouraging the students to predict and give reasons for their predictions. The lesson focused on an exploration of how structures made from the same material can vary in the amount of weight they can support depending upon the shape of the structure. The class had been given a worksheet, some construction paper and tape. Each group divided the paper into three equal-sized pieces. One was formed into a circular tower, the second a square tower and the third a triangular-shaped tower. Books were stacked one at a time on top of each until the tower was crushed. At the beginning of the activity, the students made a prediction about which tower would be the strongest, weakest, etc. When asked to share their reasoning, comments like the following were given:

*the square because it has the most corners
*this one (triangular), it's only three sides
*the weakest will be the circle cause its got only one side
*the circle covers the most ground, it takes up the most space (strongest)
*its fatter
*I think its stronger, its tighter together (square)
(April 10, 1992 Journal notes).

The students had generated explanations for their predictions. The responses were surprising to us and demonstrated the level of thinking that the students were using. We had been encouraging all students to participate and to be imaginative in their explanations if needed.

Later in our unit, Diane and I presented the class with a discrepant event. We asked the children to try to break a raw egg by pinching it. The students were surprised and perplexed by the strength of the egg. Diane and I reflected on their responses and explanations.

D: When I checked their answers they said, 'When the egg stayed intact it was because it's shaped like a cylinder'. And then I said to them, 'Why did it stay intact because its a cylinder? What do you know about the cylinder?' I was pushing them to try and make that connection... [i.e.: the materials from which a structure is made will affect its strength]. I don't think they were making the connection about the material... I think they understood that [shape was an important property affecting structure] is something important to consider, but I'm not sure if all of them understand how the shape itself works. Like with the corners and sides. Some of them are foggy on that. The other thing with materials, some of them talked about the materials but seldom did I get a response that would maybe incorporate all of these. Anton was more interested in the design. He drew the egg. With looking inside, saying that inside, in fact, there was a cushion of air. And he was thinking that cushion of air was also providing some support. Which I thought was quite advanced.
A: Their thinking is very complex, [if you take a look what we got right at the

> beginning].
> S: And I thought his [Anton's] ideas .. I was very impressed with his diagram. And George had an interesting diagram too about the whole outer area and working with the inside etc. (April 21/1992).

The children were beginning to show application of the previously studied concepts. Diane wasn't fully satisfied with the thoroughness of their answers. I felt they were on the right track and that the encouragement to reason out their answers made them think back to previous experiences to come up with an explanation they themselves had generated and we could see was applied learning. It was interesting to note Diane's initial expectation that the children should give complete explanations and cite evidence related to all the activities where we introduced concepts related to structures and force.

We decided to continue probing the children for explanations. And when we had finished the unit using this strategy, I asked Diane about her thoughts about the constructivist influence on the lesson planning and she commented as follows:

> A: I was wondering if you were seeing positive things from using this approach with your group?
> D: I think this approach has worked well with this group ... because they are all at different points ... that it makes sense to find out where different people are coming from and trying to group them that way and then planning a unit around their needs ... (May 5/1992).

The students possessed differing ideas and understandings [alternate conceptions] about the science concepts. By encouraging them to share these, Diane was finding she could better tune into the level and progress of the students. Her reflect a developmental view of learning based in Piagetian psychology. Her comment at a May meeting reinforced this

opinion:

> D: What they are thinking and what they really understand and how much they know surprises me and how little they know. And then I can get things together for them that will help them ... to fill in any gaps (May 27/1992).

Diane, through this process, was beginning to know her students better and was resolving many of the questions that a teacher must often consider as she plans lessons. Diane now felt she knew where the students were academically and could plan her science classes with more confidence and a more meaningful direction.

When Diane taught a lesson on using several small forces to make one large force, she wanted to give the students an opportunity to be creative and make some predictions based on an in-class warm-up activity. Then she wanted to evaluate what they learned from the demonstration. She had her students use one long piece of string to suspend a brick in the classroom, prior to trying the same experiment suspending a classmate from the playground structure. This conversation is an example of the goals she was beginning to set for herself:

> D: Today, I was interested to see what they were going to do outside. I thought that it would be good for them to do a warm-up activity in the room before they actually went out. I thought their ideas were very creative, things I would never have come up with at the time. For example, the group that used a series of knots and then there was Anthony's which was similar with the looping. It wasn't threatening to them. All they needed was string, a ruler and 'go to it' and 'think of something that's going to hang from it'. And then taking it outside and showing that way, it was more rigid, and they were not actually testing out their ideas because it would take too much rope, but it would be something that they could do.
> A: The activity got them thinking. I liked the way you developed it. They were ready to go out and look at the demonstration.

> D: They were busy pulling on the string themselves and testing its strength. Jesse was busy trying to pull the rope because he wanted to see how strong it was before he started, that thinking-in-advance is an accomplishment (May 5/1992).

Diane recognized the creative element and had encouraged the class to problem-solve. We were both impressed with the ideas that the children came up with as a result of their experience. From this, I shared with Diane Driver's model for teaching conceptually and we decided to explore further the children's conceptions about our next topic, electricity, before we planned and taught the unit on circuits.

I felt the following transcript was important because it demonstrated the 'sense-making' and categorization that Diane made of the elicitation activity she used. In sharing the categories with her students, she showed acknowledgment of their 'alternate conceptions':

> D: What Mrs. Hay and I did was take a good look at some of your ideas. And everyone in this room has some very, very good ideas. And then we took some of the ideas that you had and we wrote them down so that we could share with everybody what you understood or thought to be happening. So the first thing we have on OUR IDEAS ABOUT ELECTRICITY [chart] is - one person wrote that **'energy from the batteries make the light work'** And there were others who had this idea too. The next idea that we had was **'tends to light'** The next idea after that was **'the light works because of the batteries'**. At what point did we learn that happened? Jeff? [because the power is in there... there is energy in power and all the power goes through the wires and up to the light bulb where the light starts]. You probably got that idea when we added the batteries inside the flashlight. The next idea we found was **'the power travels from the batteries to the light bulb'.** This idea about power or as somebody else refers to it as energy, we can see that power and energy are the same thing, traveling from the batteries to the light bulb. So there is that idea of traveling, energy travels. Here is another person's idea, they mention a switch. **'The switch puts the light on and off'**. Where is the switch located? Somebody who had that idea? Bryan? [inside the center] In the center? [closer to the light bulb] Okay. Anybody have

> another idea? Anton? [the circuit is in the center] So the button I was pressing for the on and off was the actual switch? What was it George? [inaudible] Okay, so you have looked inside the flashlight. So the button I was actually pressing was the switch? That was an idea I wanted you to think about [inaudible]... **'Energy from the batteries goes through the wires'**. Again we have that idea that energy travels and then in addition, we have the point that energy travels through the wires. Up to this point we didn't really talk about the wires but we did talk about the idea of the energy traveling. And the next point was **'the flashlight and batteries has only a little power compared to a power plant.'** Now this person had a different way of looking at what was happening and I really appreciate it when people try to look at things a little differently because I wouldn't have looked at it that way and it helped me learn. What that means is the person compared the energy or the power in a battery to the energy in a power plant. There wasn't a lot of power in the flashlight and in the power plant there would be a lot more. There was a very well done diagram with that. **'The switch completes the circuit when the positive wire from the battery touches the bulb.'** This person went into more of a detailed explanation. They understand that wires can be different, that there is a positive and a negative. I don't expect everyone to understand that, but that person had some experience with this and it was a very good idea. This idea of a circuit and that is something you are going to have to learn about a little bit more. There are some people here who know a lot about circuits and there are some who don't know what a circuit is. This will help us all get an understanding about what you people know, and you know quite a lot. I was very impressed... We have a really good picture of where you are at right know and so we can get started (Lesson May 27/92).

The understandings that the children brought to the unit on circuits was varied and impressive. These ideas and explanations were seen to be impressive for many reasons. We discussed the children's creative attempts to logically explain their ideas and the influence of their previous experiences from school and from home. By doing this elicitation, Diane and I working together had built a better awareness of the understandings that each child brought to the lesson. And by acknowledging their efforts to communicate, Diane showed that she valued their thinking. The complexity of the thinking set a fine point from which to

begin the activities of the unit.

Working together, Diane and I explored students' understanding and gained appreciation for the variety of ideas and conceptions. This variety of ideas, the similarities and differences, and the logical development of these ideas gave us insights into the children's conceptual frameworks and experiential base. With the complexity of the children's conceptions and the need to build experiences and enrich them, Diane and I came to the realization that understanding the role of the teacher in this process required closer examination. How we defined and developed that role was another issue on which we reflected.

The children were a 'storehouse of knowledge' and a storehouse of experiences which molded and influenced the way they perceived and organized their world. To teach them and help them look at relationships in the world around them, we would need to work with them at their starting place, their conceptual framework. This led us to ponder the role of the teacher in more depth.

"Being a Springboard"

As Diane and I became more interested in incorporating children's understandings, a reconsideration of the role of the teacher within the teaching/learning dyad became a focus in our conversation. As the students had been given more recognition, they accepted more responsibility for their own learning. The class was eager to try the activities and even carried out experiments at home. The following series of conversations illustrates how we

clarified the teaching approach which was evolving in her classroom:

> A: When we first talked about planning the unit, you mentioned that you'd like it to be short, exciting and punchy... This unit developed in an interesting way... every lesson we took a look at what happened and then we decided what to do next, its not the kind of thing you originally mentioned...
> D: You can't sit and follow that book through. It would be kind of neat if you could go ding, ding, ding, seven lessons and I'm done the whole unit because the kids are really motivated...but, it was necessary to stop and talk to them about what happens when an experiment goes wrong and it was necessary to stop and go back and demonstrate that experiment with the beams again . So that all have that common knowledge and are able to understand what had happened. And I think in that sense it has been very thorough and I respect that. And I think that students like this need that sort of thoroughness. I have felt that there have been no gaps, no loopholes, in this unit whatsoever.
> A: You think we are covering everything?
> D: I wouldn't say that all of them have necessarily made these connections but I think that they have all made some kind of connection (April 21/92).

Diane, at this point, was focusing on meeting the students' needs by covering the activities in a thorough manner and in dealing with any problems that arose in the lessons. The primary strategies used to this point included lectures, demonstrations and guided discovery.

During a later meeting, Diane identified what she saw as the need for the teacher to provide students with basic information to introduce the science unit. This passage shows that she recognized that the potential learning must not be limited by the teacher's knowledge of the content:

> D: I would even say that with this unit, some of them have [learned a lot]... and at the end of it most are understanding it but some do have a deeper understanding about structures and functions than I do. I guess that's going to be the way it is [in the electricity unit]. Yes, I think you can give them some common information, for example when you talked about strength,

> materials, design, shape, [with the students] and I think most of them have an understanding of that. But, I think it is unrealistic to expect them all to have the same depth of understanding. But, I think we should have some common things we want them to learn and should obviously be in the curriculum. And then look at ways to implement this and help some of them achieve this understanding. Maybe with this unit [the electrical circuits] it might mean that we start right at the beginning and walk them through some of it and then lead them to do some experimenting then... see what happens. I really think we need to give them a little information though and help get the ball rolling and them thinking about electricity and then stop and check again the progress. Maybe to decide what projects, who's doing what. The day before they get their projects it will be determined who will be doing what and with whom. That close to it (May 26/1992).

In this next passage, Diane and I reviewed the process we employed. The value of the concrete experience, tied with presentation of information, was addressed and Diane's comment showed her changing 'perspective' which was influenced by the feedback from her students or in Schön's terms, the 'backtalk' from the context:

> D: They are interested and they ask when are we going to have science again. Well, I said that we have some things to prepare before we start. 'Oh, when is that going to be?' ... I would rather have the concrete than the information because these kids are so active and they are very passive at home and don't build things (Conference May 26, 1992).

The initial step of eliciting student ideas was followed by lessons which taught more directly to the curriculum objectives, as Diane had earlier found this necessary for building new knowledge. Although not all students were expected to fully understand or 'apprehend' the concepts, the exposure to new concepts through hands-on experience was important to Diane. The latter part of the unit became a place where the students could apply what they learned. The creative-innovative aspect of the project was fostered in an environment where

the teacher was the facilitator. The following passage elaborates how Diane had come to view the teacher's role:

> A: What kind of role should you and I play while they are doing the bridge project?
> D: I think very removed. Some things should be in place. They should have a project outline instead of a checklist. It should help guide them step by step and it will allow them to progress from stage to stage. We just provide assistance where necessary. Act as a springboard for any ideas but not really in charge of what they do... I would like to see us more removed... like with the egg project. When they were constructing, they came up and explained what they had done. I did not sit there and provide them with too much [guidance or instructions] but asked 'Why are you using that? How do you feel about that? I think that's a good idea! and we'll see how that works'.
> A: And see what they come up with?
> D: Yes, I think that way we see how it really is, we are not placing our values or our ideas on it because we might know more about it than them. And that way we are not influencing because I think some of the kids are going to want that kind of room to create something completely different...
> A: Do I understand you to mean that it is important that they feel their ideas are accepted?
> D: That their ideas are worthy enough to be turned into a bridge or turned into an egg protector. They thought that the sky was the limit.
> [And a bit later...]
> A: When we go into the next unit, I was wondering if you want to take the same approach?
> D: It wouldn't hurt me to walk through this process again. And more formalize it by writing it down so that I could adapt it to other subject areas, because this will work well with a lot of different things (May 5/92).

Diane and the class began to spend the next few afternoons working on the projects. Afterwards I asked her to again articulate the process she used.

> D: Well. what I have been doing is, when they are constructing, I'll come up and ask them what they are doing? and do they need anything from me? And then if they need information and materials.... and a lot of times it is

> materials... I don't think you are teaching them anything directly unless they ask. They often have an idea and they are already in play. They are putting it together. And they don't need any information. Some of them are going through books for information. Ned has a very clear idea what to do...So in a sense I'm assisting but not controlling. Sara was having some problems and we talked about some things that could be done. I think her original idea is good and that is what she wanted to do. So I would like to help her do that. But I think that when they are doing this, they're absorbed with what they are doing. Alex and Jeff over there, just sort of monitor what's happening and make sure that people are on task (May 12/92).

To Diane, the responsibilities of the teacher had become more differentiated - indicative of what Scardemalia and Bereiter (1989) called an 'eclectic' teaching style. The teacher provides some information and arranges some activities which "get the ball rolling". At a certain point, usually in projects, the teacher steps back and plays a facilitating role where the children put their efforts into playing out and testing out their ideas. The students take responsibility to read up on things they need to know related to their projects. The dialogue below illustrates Diane's recognition of the shift in her perspective.

> A: Do you see any parallels between what you are doing with cooperative learning and what we are doing here and what the kids are doing?
> D: Oh, yes. Very much so. I see them learning the same way I'm learning. We talked about that today.
> A: Did you with the kids?
> D: That's why we did that. I said that I'm learning about how to solve problems and I wanted to learn how to work things out and work with other people ... And this hasn't been an easy process for me. I wouldn't say it has been difficult for me but it has made me more aware in a lot of ways about what I am doing and thinking and about changing some of my attitudes too about science (May 26/92).

This comment shows that Diane saw a parallel in development, where the teacher and

the students were both learners. It seems to validate Wells' (1994) ideas on the school as a centre of inquiry for both students and teachers. As well, this demonstrates an expansion in the teaching paradigm used with her class. The shift from the traditional perspective (teacher dominated and directed learning) to a new, more inclusive paradigm was evidenced by this teacher's need to use a variety of strategies to foster learning and motivation for self-directed learning. There was a place for lecture, for guided discovery (demonstrations), discovery (experiments) and for exploration rooted in projects and investigations of discrepant events. The format of the units tended to be based on the students' understandings and learning styles. Indeed, as a teacher Diane was becoming more eclectic in style.

The role of the student had evolved as well. The students learned to share their ideas, expand their reasoning, guide the experimental process with suggestions and tinker with equipment to test out their hypotheses. They enjoyed the creative challenge of the projects where they had opportunities to apply learning in new and creative situations. The children were using higher order thinking skills (Bloom's Taxonomy) moving from recall of information to comprehending new concepts to using the projects as a place to apply what they had learned in new and innovative ways.

Diane's comfort with a project-oriented unit finale, at first surprised me. It was when I recalled Brickhouse's (1990) comment about the influence of formative experiences on teacher beliefs and their practice that the 'why' for this 'what' became clear. Diane's early experiences at home were full of opportunities to tinker with mechano, used a small set of tools to build things and be out in the woods exploring nature (Letter May/92). These 'projects' were now providing a basis for her acceptance of science projects in the classroom

as the next vignette will elaborate.

"It's a Good Kind of Mayhem"

A common concern to teachers is the classroom environment. Aside from the actual physical structure (wall, lighting, furniture), the dynamics are easily identified as an indicator of productivity. Dynamics include activities and the manner in which they are carried out. The latter item often reflects concerns related to behaviour management. Too often a simplistic assessment might be "a quiet classroom is a productive classroom". In Diane's classroom, a broader perspective evolved for the doing of science in a hands-on active learning manner, which generally implies activity, noise, conversation and to some degree flexibility in movement.

Diane's class was organized in small groups of desks, facing the front board. Her focus on the use of cooperative learning strategies to build and reinforce social skills was important to her. She saw a quiet class as a good learning environment and throughout our early collaboration reinforced the positive aspects of the students' behaviours. She used phrases such as "I need you to listen" (March 13/92). Based on comments in class and discussions we had, my first summary letter included the following passage:

> The behaviour of the students in the class is very important. They must listen carefully and stay on task. They should work cooperatively (i.e.: politely and considerately) to allow a quiet and productive atmosphere in the room at all times... (Summary letter April 9/92).

This view of a productive environment in science is appropriate. As the study continued it did not change but rather was enriched. As the type of instruction incorporated new strategies, the parameters of the definition of a productive environment became more inclusive and accommodated the shift.

In the lesson where students were describing fruits using their senses, the need to be cautious about tasting in science experiments was addressed (March 16/92). In a subsequent lesson, Diane showed concern regarding the use of knives by students, as the following quotation shows:

> You won't be cutting into the fruit... because I don't feel comfortable having you use knives at this point... but we will be looking at different views of the fruit and you will be making predictions before I even actually do the cutting (March 17/92).

Diane weighed the safety issue and in light of her previous experience with the students, felt that she should be using the knife. She rotated from group to group. The students waited and made predictions about the fruit structure. Afterward, the students made observations of the actual cross-sections. Allowing the students to cut their own fruit would have expedited the activity but the need for a productive and safe environment came first. Diane intuitively recognized that too much activity at this time might have led to inappropriate behaviour by a few overly excited students who were unaccustomed to hands-on activities.

A group project involving the design and construction of an egg protector was carried out a few weeks later. The students, by this time, had been involved in a number of activities

using manipulatives. They had watched and participated responsibly in demonstrations and small group experiments. Diane felt that they were ready for a project and had enlisted the help of some Grade 9 mentors to work with the students for an hour one afternoon. The week long event proved to be a "carrot for them all week". Diane elaborated on her feelings regarding the way the class handled the activity, the individual responsibility and the hands-on nature of the project:

> D: At this point in the year we need something with a high interest level, that's short and to the point... Not too much pencil pushing, testing... and at this point of the year I want to see them building things and now that they have shown that they can handle the material... I think that they have shown that they can handle everything and doing experiments. At the beginning of the year I wouldn't have felt that they were capable of that. Mind you they haven't had that much experience (May 5/92).

This example of personal, practical knowledge illustrates Diane's bringing knowledge of her class and her teaching to bear upon her planning. Based on the success that we had had with the class in doing the egg project, we discussed the final project related to structures and forces. The students were to plan, design and construct a tower or bridge that would support a standard brick. Diane's comment shows her 'images' of science teaching and her recognition of the expected level of activity:

> D: They're going to go nuts... its going to be mayhem in here but its a good kind of mayhem. I think they are going to respond quite well to that [assignment] and then they have something tangible I've noticed that to them it sort of all accumulates into this... they have a goal to get their bridges done... its their own ideas, and that there's no right or wrong, some parameters have been set but what they do. And I think they like that room...

> I think that kids like George don't like being told that you have to write this and you have to do that ... they are going to wind up learning the same way except they feel that they have some choices...now I'm going to make that bridge, I'm going to do it this way and then he feels control. It gives somebody like Anton a chance to try out some of his more wild ideas ... so ... I think that's worthwhile. With the bridges, I'd kind of like to leave it really open-ended except for a few special needs students like Ruth (May 5/92).

The enthusiasm and goal-oriented behaviour evident in the earlier project was again expected. The open-ended nature would allow freedom to try different ideas. Diane realized that activity and noise levels would be up as a result but she was able to accept this commotion because it would be goal-oriented and represent on-task behaviour.

I pondered the ease with which Diane had incorporated science projects into her science classes. Brickhouse (1991) gave me a plausible explanation. Diane's childhood experiences at home (elaborated in Chapter 5) were very much like the projects she was designing for her students. The open-ended nature of her experiments with the chemistry set and tinkering with the mechano set were positive and influential formative experiences. These were now a part of Diane's 'image' of science teaching.

Diane's trust in her students was fulfilled the following week. One afternoon during the construction phase of the project, a teachers' workshop was held at the school. Diane commented to me afterward:

> D: My kids were hammering in the hallway, making their bridges and towers. All these people were walking down the hall to the meeting, and there they [the students] were, working really well. People were looking at them. They were everywhere. I don't have to be with them now, which is nice, 'you have a goal, you have a target date, you have step by step instructions. I will keep tabs with you' and then they can work together and solve things themselves.

> And that is what some of the people walking down the hall were watching (May 12, 1992).

The students had acted responsibly. They had used tools and materials safely and had been working in a self-directed manner. The visiting teachers had noticed this just as Diane had. She had felt pride and respect for the children's achievement. This is an example of the moral and social dimension brought to play in one's practice.

I noticed that the processes and the learning in science were influencing and being influenced by the lessons in other subject areas. Underlying threads such as using groups, reflecting in journals and valuing children's ideas and project work, contributed to this comment made during a planning conference in May:

> D: I hear comments, its already starting (spring restlessness). I've noticed in my room that its already starting but not in that direction. I'm finding that if anything, they are gearing up, and not out. They are not tuning out. They are very much here and what's happening in the room. So I think that the science has been a great motivator. Even Jeff.. he has been participating in science too. And he had to go home today. 'I (he) forgot my (his) hammer'. He was all upset and he cares. He doesn't have that kind of attachment to regular things. He really cared. He could hear the kids out in the hall hammering. He had things that he had to get done. We have only 45 minutes and I better go home for it. So I see more of that (type of thing) happening with the kids... The behaviour problems are less, let's put it that way and I think if the kids have interesting things to do in school and projects to do that involve them, there isn't much time for disruptions (May 12, 1992).

These reflections on the science program and the way it was received by the students, the contextual backtalk, reinforced the value of the strategies employed in Diane's eyes. A dynamic activity had become representative of a productive learning environment.

Summary

These vignettes trace the changing perspective of Diane, as it evolved throughout the time of the study. My interpretations, which were shared and verified with my colleague, are not only descriptions of 'how' the teaching changed but are intended as interpretations of 'why' we did 'what' we did in the science class. My comments here are based on these interpretations and reflect my own realizations and broadening awareness of the difficulties associated with teaching science and learning about teaching science in a collaborative venue with a teaching colleague.

In the first vignette, 'Remembering What They Learned', the perception of what constituted good note taking underwent change as the whole idea of science and science teaching became enhanced and more inclusive. As Diane began to see science with a broader perspective, many of her strategies for the teaching and learning of science changed. Diane's initial conception of notes as primarily records of facts expanded to notes being records of critical thinking, reflective analysis, observations, predictions and facts. In this instance, the teacher had to be, in my view, directed away from this immediate, retarding feature of her practice until it could be dealt with more fruitfully. The problem was actually addressed from behind, that is, once the teaching became collaboratively and constructivist based, the issue of the type of note taking and the meaning that the students derived from it (learned from it) became resolved. In essence, once the problem was framed and unpacked, it was set aside until more critical underlying concerns could be addressed.

In the second vignette, 'It Doesn't Work', Diane and her students work through

sharing concerns of failure and vulnerability. Addressing this problem directly, by sharing the Fleming experiment, allowed both the teacher and her students to develop a more realistic view of what scientists do, i.e. to explore the possibilities. This freed the students to try new things and be open to take risks and share their ideas and explanations in a 'safe' and accepting environment. This does not mean to suggest that thinking and explanations that were more appropriate than others were not recognized. Instead, the intermediate explanations, or alternate conceptions, were recognized as well.

The third vignette, 'A Storehouse of Knowledge', features an appreciation which developed that all students, not only the bright and scientifically literate ones who possess the recognized genre of the terminology, bring knowledge and experiences to the classroom that can benefit the learning of other students. The conceptual frameworks elicited were varied and complex and demonstrated a range of understandings. In some instances these views varied greatly from those generally recognized and scientifically accepted. Each learner was felt to have developed better understandings of science and more confidence in the socially responsive setting. The strategies used also fostered integrative approaches.

The vignette, 'Being A Springboard', traced the changes that came about in the role that Diane had in her class. With the realization that children bring understanding to instruction, the teacher was not responsible for providing all the knowledge but became a facilitator in accessing what was needed. In Diane's class, the children began to research, find information, share ideas, test out activities in order to learn new things and as such became "self-directed" learners. The teacher saw her role as an initiator for the learning by providing some initial instruction, primarily in the form of formative activities and vocabulary

development. This was followed up by project work which was more independent in nature but directed by a set of guidelines. Students were encouraged to seek the teacher's help with the process and with the materials. The teacher facilitated the learning experiences allowing the students flexibility, creativity and opportunity to develop interest areas. In this instance, evaluation was continuous with the teacher using checklists, projects, reports and presentations as tools. Evaluation became outcomes-based. The students were willing to assume more responsibility for their own learning and the teacher was able to adapt to these changes.

The last vignette, 'A Good Kind of Mayhem', described how, as children took ownership for their learning, productivity became the focus and with that certain characteristics (conversation, interaction, activity) of the science classroom changed. Student-student conversations on science issues were more common and students showed interest in the work and ideas of others. These changes were task oriented and therefore the commotion associated with it was accepted by Diane and her students as well.

These vignettes represented instances where the framing and reframing of practical problems were based on practical knowledge and upon insight from constructivist theory. In other words, as the problem-solving involved both reflection-in-action and reflection-on-action, 'theory' and 'practice' became so intertwined that in many instances they were inseparable. The view that practice is theory-in-action is not new but recognizes that theory is influenced by action and that knowledge is reconstructed in the "fluid conditions of situations" (Beattie, 1989). As teachers and researchers talk and give meaning to their practice, insights which may enrich the study of teaching on many levels is possible. The

classroom via collaboration is a venue where teachers incorporate meaningful changes in their practice, changes that enrich the learning experiences of their students.

In reflecting back on these events, my own vision of science and science teaching was enriched by participating in this study. In the efforts to address the practical problems in Diane's science class and work with her in developing a view of science that she was comfortable with, my own views became clarified and reaffirmed. In employing constructivist strategies within the hands-on and minds-on venue more clearly articulated as active learning, I was able to concentrate on the subtle aspects related to the difficulties and challenges of adding new ideas to teaching practice. The breadth and depth of the students' understanding was a source of inspiration and affirmation for the philosophy which directed our efforts. Keeping in mind the broader constructivist intent of the teacher-teacher interaction provided insights on how to foster professional development without suggesting it be a copy of my own experience. Using Schön's reflection-in/-on action model to address practical problems led to confidence in the process especially when backtalk indicated progress. The themes and insights which were identified in this study allowed me to better appreciate some of the difficulties a beginning elementary science teacher may have to deal with as he/she practices the profession.

Chapter 5

Professional Collaboration: "Light at the End of the Tunnel"

Diane and I used a process in our research which was based on a reflective-constructivist methodology. It required that we identify or frame practical problems which became evident in the science teaching in Diane's class. By working collaboratively through a process of reflection, framing, analysis, and reframing, we addressed the problems and related issues through negotiating meaning and interpretation of the feedback from the situation. Then we chose what we felt was an appropriate course of action , followed through with it and then continued with this process if needed. The collaborative aspect of this process was the mutual commitment to the science teaching and to the students through shared responsibility for the actual teaching and additionally, through the shared responsibility for the decisions and choices made in planning and teaching of the science units.

We each began the study as unique individuals bringing a variety of experiences, ideas and knowledge backgrounds. We brought somewhat different conceptions of science and different expectations as to how the study would evolve within the framework outlined by my proposal. This section will focus on how the collaboration evolved and attempt to trace how we negotiated meaning into our interpretation of science teaching. A few comments regarding the beginning of a colleagial network, which developed as the formal

part of the study drew to a close, will also be shared.

Diane brought an understanding of science and science teaching that was based on her own experiences as a student and a student teacher. These comments, shared in full here, help visualize her 'apprenticeship of observation':

> As a child growing up, science was a part of my life. Now that I am an adult, I am able to see that many of my childhood experiences contained a strong science element. My more meaningful experiences occurred at home. At the time I did not realize that a lot of my childhood activities were science activities. My school activities did not connect with the home activities. I saw no science in what I did at home. As a child I used to play with my older brothers' chemistry set. In the basement there was a work bench for my brothers and I to build things. A mechano set with motors and Lego for building were always around. I had a neighbour who was a geologist and he often talked about his rock collection with me. My brother and I used to explore the riverbanks and the lake shore, collecting rocks and taking casts of animal tracks along the way. These were important and enjoyable experiences for me.
>
> While I was a student in the elementary years I do not recall doing anything outstanding in science. One of my better memories of science was attending the yearly school science fair. I enjoyed looking at all the projects. These projects were done by the students on their own time and seemed to me unrelated to what we did in school. The experiments and projects were hands-on. What we did in school was take notes and watch the occasional film or filmstrip.
>
> Once in junior high the formula of taking notes and memorizing for tests continued. Science to me had nothing to do with the real world. The content that was covered in school was difficult for me to transfer to other areas. As the years were progressing science was becoming boring and difficult for me to relate to.
>
> In high school all my teachers were male. There seemed little encouragement for me to participate in classes and I felt that there was not the same expectation to do as well as the male students. During experiments if my group (consisting of females) were having difficulties there was little interaction. But it always seemed that the teacher was more actively involved with the males. Many of my teachers at this level were very knowledgeable, but seemed unable to explain things clearly. I left high school with the impression that science was beyond my capabilities. I had not enjoyed my

> experiences in high school and had learned little that would help me appreciate and understand science at even a basic level.
>
> In university we were given an opportunity to take a science course geared for elementary school teachers. I was left with the feeling that the regular university science courses were too difficult for the majority of us. Only one of our instructors was a woman. The course was to fill in gaps in our learning about science, but it did not relate to how science could be applicable to our teaching experiences in a meaningful way.
>
> In my final year, I enjoyed the certification course a lot more than anything I had done before. The professor did not talk down to us, but it seemed that science was becoming interesting and fun. I found that I understood the concepts based on my experiences. A valuable connection was made at this time that science is a part of our day to day world and that understanding concepts and relating to it was possible. However, I did feel that we were focusing on projects that did not tie well into our student-teaching experiences at the time (Letter May 21/ 1992).

These early experiences shaped Diane's images of science teaching in schools and were mostly divorced from the meaningful early experiences she had had at home. Diane was motivated by her Curriculum and Instruction course but did not have the pre-service teaching experiences which would allow her to put into play a hands-on approach. Her first years of experience 'washed out' the influence of her pre-service education much in the fashion of Loughran (1994). Therefore, she did have an image of what science teaching could become but no practical experiences to try out her ideas or reinforce the theory she had encountered. The following comments, made by Diane after we had been working together, demonstrated Diane's awareness of differences between her early experiences with science in school and the conceptually based methodology which was being employed in our work together:

> D: I like the way you incorporate their ideas in. I think that's something I don't see a lot of people doing. I never saw anybody when I was a student teacher do that, make a focused effort to start with and plan with student's ideas. Now it helps that we have those ideas on tape and can listen to and then keep track of those ideas. Because with what's said right away, it is very difficult with what's happening throughout the day to remember that one idea that may need further exploration (April 20/1992 Discussion).

> D: Well, I see this approach as very different, as opposed to the way I've seen science taught in the schools by a lot of people [teachers]. But you go into different classrooms and science can be taught very differently depending on who is doing it. I could show some of the books I have gotten from one of the teachers here who teaches science and does go through the books and does experiment too. There are other teachers who are slowly getting on board with hands-on which I think is going to make science more interesting for kids and more interesting to teach (April 21/1992 Discussion).

> D: You sure don't see many people doing this though. People tend to just go into a unit. Sometimes they will brainstorm ideas for Social Studies about what kinds of things do you want to learn and then I'd write them down and in the end, what did we learn about this and about that. And then we'd look at any missing information and ask where could we go to learn that . I've done that, but you don't see many people in science doing that. I haven't seen anybody eliciting their ideas like this at all. In Language Arts we brainstorm and do webbing, sure, but other than that I haven't seen it used in Science (May 5/92).

The inclusion of strategies and methodology which focused on children's thinking about science concepts was recognized and was linked to Diane's experience in other subject areas which were child-focused and integrative in nature. She appreciated the hands-on nature of the science processes we were using and the constructivist based philosophy that guided the teaching. The same characteristics that we as teachers were employing with the students were in many respects paralleled in the relationship between Diane and myself. We were both learners as well as teachers and collaborating colleagues. In the following I will trace this collaborative process as it unfolded between us.

Teachers as Inquirers

The process of collaboration began, I now realize, when Diane and I met at a cooperative learning workshop. We had common concerns regarding children, learning strategies and social development in the classroom. We shared a narrower concern about the quality of science education in the elementary schools. We were both elementary teachers and had worked in somewhat similar school environments in the past. Through a sharing session at the workshop we realized that, potentially, we might be able to work together to learn more about science teaching.

Diane made the following comment thinking back to our meeting:

> D: I don't feel my teacher training was adequate, that there was enough time. I think this (study) was to me more meaningful. And it was sheer luck that we were in that same group at that conference. And I just came out and said that I feel my science program is lacking. And I know it is not meeting their needs and I'll be the first to admit that. But that's because I wanted to do something about it. So it was interesting how it worked out (May 27/1992 meeting).

Diane felt that the approach which she had been using reflected her experiences as a student and as a pre-service teacher. She was dissatisfied with this approach and felt that she was not doing this science justice. At the workshop where we met, the cooperative learning activity gave us a venue to share and elaborate on concerns related to science teaching. I remember Diane telling me that she would be working with a challenging group of Grade 4 students the next school year. In her words it was "not an easy school" (May 27, 1992). I was busy

planning a Sabbatical year where my intention was to explore issues related to science education in the elementary school. Therefore we had common concerns and a willingness to question, explore and take risks exploring our philosophies and behaviours related to this topic. We were inquirers, examining our practice, interested in exploring the teaching/learning process and willing to analyze our approach with a teaching colleague. We felt that we would mutually benefit from a collaborative venture. This feature of genuine collaboration has been identified by Thiessen (1992) and Hunt (1987) as being critical to meaningful research into professional growth.

Teachers as co-planners

When the study began several months later, Diane and I met several times to discuss and negotiate the process. We started as co-planners of the science lessons and units. This step was very much like the process used by many teachers when they work in teams or share ideas with each other. We began with the curriculum guide to determine the goals and objectives, then looked at the available resources and planned a series of lessons based on the limitations of time. Just what 'problems of practice' would arise was not predictable. Diane had felt the same way.

> D: Initially, I was not sure what would result in our work together. I knew you were knowledgeable in the sciences and an experienced teacher. I felt that our actual direction was not one that was clear at this early stage. I felt

> comfortable working with you, but was still uncertain as to how our joint efforts were to unfold. In many respects, I did not fully understand what was to be involved in this collaborative process as this was something I had not experienced on an equal ground. You were conscientious in reassuring me that my honest input was important ... (May/1992).

The following passage is a small portion of a lesson that Diane and I had planned in the manner earlier described. I had helped Diane look at the science vocabulary and concepts which were outlined in the objectives of the curriculum guide (Education Manitoba, Grade 4 Interim Guide, 1991). We had discussed the vocabulary needed to label the parts of the cell. We had reviewed the functions together and collected the overhead transparencies and equipment needed. Diane taught the lesson and I was the observer:

> D: I'm going to put the first overhead back up. I'd like you to start to copy that down and then I'd like you to go back and label the parts on the diagram. Then I'll put that back up again so that you can check... For those of you who are done, and are waiting, edit and make sure that you have corrected all the errors possible. Remain quiet as some of you take more time to copy things down... Don't start packing up yet, then we're going to go through this. We talked about animal cells. We noticed that these cells are similar and have things alike - the nucleus, the cytoplasm. In the plant cell, the function of the nucleus is the same as for the animal cell. It's the brain, the control center for the cell. The cytoplasm, has the same function, and looks similar. (March 13/1992).

This early lesson format continued for a short time. Initially we met to discuss and plan the next lesson. We reviewed the previous lesson only to determine if the materials had met the needs of the situation and how the students behaved. My role was one of careful listener, speaking to those comments and questions raised by Diane. She described our

collaboration as follows:

> D: Working together to plan to meet the needs of my students was beneficial. I felt that you and I were able to work together without one person being in charge. It was after all a team effort. At times I would lead and at other times you would direct our efforts. It seemed to happen spontaneously. For the most part both of us were equal participants (October 1992).

I interpreted this spontaneity as an indication of the trust that was beginning to develop.

Once the first summary letter to Diane was shared, a subtle shift in the intent of the post-lesson conference began. I sensed Diane's discomfort with the description of the science teaching that had been made despite her agreement with what had been written. Our discussion became more reflective. In addition, to once again re-establish a more comfortable rapport between us, I volunteered to teach a lesson and become the teacher so that Diane could take an observing role. In Schön's (1983) terms I modelled a lesson. I recall Diane's surprise in this shift from observer to participant-observer:

> D: I was surprised at the sudden shift when you volunteered to teach a lesson. Up to that point, I felt that I would be doing the lessons. I was pleased that you felt comfortable enough to do this. I appreciate all opportunities to observe colleagues in action. It helps broaden my experiences and ideas on how to approach lessons and concepts. I was also curious to see how you would interact with my students and how they would respond to experiencing you in a more active role... (September 1992).

I felt that Diane would benefit from being the observer for a change for two important reasons. First, she would be watching me and any discomfort she may have had being the one observed would hopefully be lessened by having the opportunity to see me in the more

vulnerable position. Second, her comments had led me to believe that she had had only limited exposure to a variety of science teaching strategies. The decision to exchange roles as we did turned out to be a significant turning point in our collaborative relationship.

Teachers as problem-solvers

The difference between what we were attempting to do and what might be considered team teaching was the reflecting and problem solving process we used to examine the lessons. The approach we used was more holistic and considered the influences of the unique context of this classroom.

We considered the goals of the lesson and how successful we felt the lesson had been at reaching those goals. Parallel to Schön (1983) we extended our reflection to include interesting happenings and situations that puzzled us, to those events that occurred that were unplanned and surprising. These could include an interesting comment, a teachable moment based on a discrepancy or a student's query. It may have been the direction that a lesson went, based on students' responses, which became the focus of our conference together.

We found that children did not always respond in the manner that we had expected when planning the flow of a lesson. We often focused on the students' reactions and learning. They did not always respond as expected.

Diane, as the classroom teacher, evaluated the lessons. She would question, comment, and express concerns. My role was primarily one of careful listener, speaking to those comments and questions raised by Diane, then suggesting another strategy or course of

action. The actions we did take had to fall within Diane's comfort zone (Vygotsky in Wells, 1994) and be representative of her image of science teaching.

Diane and I were both doing teaching and when necessary I was modelling strategies and techniques. The following passage illuminates Diane's sense-making as we developed a solution to introducing and using science-specific terminology:

> D: This unit blended itself well because it wasn't cut and dried and a mechanical vocabulary. That is something I would have done [in the past]. I would have honed in on the vocabulary, giving them words to use, to describe things like force and collapse and whatever else. I think they need those words and that's a really good way to extend it. It would be a 'kiss of death' if the children were not able to do some experimentation...
> A: You mentioned vocabulary, How could we address that?
> D: I think the next unit they do, it would be a good idea to give them a working vocabulary. An engineer uses particular words. If you're going to do a unit on electricity, then there are certain words that you are going to need. And you can't assume that they are all like Alex because most of them are not. They don't have the words to describe things.
> A: They are at a point now where they want to use the words to describe what's happening.
> D: They are getting frustrated I think, too.
> A: Would now be the time to spend a few minutes on different vocabulary words? They have a need for them and they understand the ideas but they don't have a common language to use to describe them [their ideas]. Do you think we should take some time in the next lesson and give them that so when they get to the point where they are trying to explain themselves they have some words to use?
> D: That would be fair.
> A: I wonder when to introduce vocabulary myself. Sometimes when it is introduced before it has meaning, they sit and memorize it but never use it because it hasn't relevance to where they are at conceptually.
> D: Probably half way through. After the last activity we did, then would have been a good time.
> A: As a classroom activity before the project?
> S: Yes, I think that would work.
> A: What kind of vocabulary do we want-force, collapse...
> S: Talk a little bit more about strength, flexibility...

A: I think they know that one, don't you? Maybe we could find out. Beams, supports.
D: Suspension and the bridge types.
A: Good, suspend. you're right. When they are talking about their bridges they should identify them as suspension, beam, arch, cantilever and then in their presentation they might want to use words like durability, design.
D: Again, that is a word that we need to discuss.
A: This one, function. It has a general use but I wonder if they know its meaning. Structure, cells are the basic block to the structure of plants and structure refers to the overall shape. [referring back to an early lesson] They know what shape means but scale. I remember that you wanted to do that but I'm not sure how you wanted to include it.
D: I haven't used it in this context, I have used it in math.
(Conference May 12, 1992).

This was the type of process we used when practical problems were first identified. In this case vocabulary introduction/development was the topic. Another example outlined in detail would be in the "Remembering what they learned" vignette. These themes (the process of addressing problem and enhancing perspective) became turning points in our study of science teaching but they were also turning points in our collaborative study as well. The turning point in our professional collaboration was a problem defined, or framed. It was at these particular points that I became more than the observer and team partner. These points were opportunities that evolved naturally into coaching situations where my suggestions were interventions based on my experience and research into science education and teaching philosophy (Schön's practitioner). It was a point where Diane, with her knowledge of the students and her own experience, would negotiate what she felt would work for her.

The process of identifying or "flagging" an issue was a sensitive time. Flagging was, in a sense, becoming aware of a concern or a feeling of discomfort. In pondering the reason, whether explicit or implicit, our attention would be drawn to it and connections made to

factors which seemed to impact upon it. Taking comments, observing classroom events and bringing them up post-lesson could easily be construed as criticism. The danger of the teacher feeling criticized and exploited for researcher benefit had to be considered. I was guided here by what Schön (1983) had described as reframing of the problem. The criticism was not explicit but implicitly wrapped up in the reframing of the problem. It was important that Diane 'flag' the issue and that I be receptive to clarifying it. To address a meaningful approach to professional growth, I felt the issues must be ones that the classroom teacher identified or brought attention to, for the starting point must be Diane's concerns which reflected her understandings and her philosophy of science teaching. All this was completely consistent with my own underlying constructivist philosophy of teacher education.

In a letter Diane shared the following comment about her feelings regarding feedback:

> D: I found the feedback extremely valuable... I felt comfortable with your suggestions and observations due to the fact that I felt you were non-judgmental and had a good understanding of what my particular situation was. You also worked with my group and had spent a lot of time in my classroom with me. I may not have felt as comfortable with someone who had not invested the time you had spent with my class and me. Accepting suggestions may also have been difficult if you had not been involved at the level you were in the initial stages... (October 1992).

To encourage and protect the trust and confidence that was growing between us, an active role in the lessons was needed. As a collaborator I felt I had to be taking the same risks trying out suggested strategies in the classroom. Indeed when the teaching/observing roles were reversed, it was easy to appreciate how one feels and responds to comments, questions

and observations about the classroom- even the slightest perceived criticism.

The conversation below is an example of the type of communication Diane and I had as we readdressed the vocabulary problem. This dialogue occurred after the first of three planned days when the students would be presenting and discussing their bridge projects with the whole class:

> A: Remember when we did the vocabulary activity, how did you feel it went over? We were concerned because we felt we hadn't addressed some of the words used through the unit.
> D: I liked a lot of the definitions that they [the students] came up with. Some students used those words and some didn't in the explanations but that is okay. The words are still up for them[on a wall chart] and they may use them again. It will be interesting to see the rest of them finish up... to see if some of those people will have picked up on the vocabulary.
> [and later in the same conversation]
> A: I was wondering if there might be a cooperative learning strategy [Diane and I were both interested in employing cooperative learning strategies and had taken workshops in this area] where the students explain things in their own words because that would be more meaningful to them... We did it at the end [of the lessons before the projects] and we talked about not wanting to do it at the beginning and using our meanings for the words [this was a follow-up to a previous discussion about introducing new words].
> D: Midway, probably.
> A: That's something we want to consciously think about as we go into the next unit.
> D: Probably a little bit sooner so that they have a longer block of time to assimilate vocabulary and use it and see it working. ... When we are doing things so that they have the words to describe it.
> A: Perhaps as they come across the concept or idea, then introduce the words.
> D: And keep a running chart.
> A: Let's try that and see if we are more satisfied.
> D: I don't feel that they used a lot of these words. Some of them did. Now today, I was talking about design. I asked if they knew what it meant and some of them were able to tell me. Yes, some of them remember but to keep it going, a running list, every time we introduce a word, stopping, asking do you know what that one means? Write it down and give it a definition as we go along (May 19, 1992).

During this time as problem-solvers, the feature that sustained the process was the role reversal. Each collaborator taking responsibility for a lesson, or part thereof, with the other as the observer. Both the teacher and the researcher were in vulnerable positions, both were seeking, modelling and indeed learning from the other. To clarify my meaning, we were both teachers and both researchers together. My role included bringing ideas from research and strategies from my past experience with children in the classroom to be applied in Diane's classroom. Diane brought a knowledge of her students and her personal practical knowledge of what might possibly work for her.

Another example of the type of problem-solving we were involved in is described in the following discussion. We were examining drawings and writing of the students' conceptions about electrical circuits following an elicitation activity at the beginning of a unit on electrical circuits. We were attempting to categorize the children's understandings about circuits:

> A: Yes, switches allow the power to get from the battery to the light. She wrote 'plastic cap that holds light bulb in place of the generator, which takes power from the batteries from the light bulb and makes light'. Well, do you think at this point there is an understanding of circuit?
> D: I think that the switch [in the drawing] helps her understand it and the generator too.
> A: The generator is another source of power.
> D: Yes, even with this one. Again Ned is on a different tangent I think.
> A: Yes there are some differences, let's put that one aside for now and look at it again later.
> D: Sandi writes 'The battery connects to the bulb and the battery has power to make it go on' and here is Kate 'the energy from the batteries goes through the wires and makes the lights flash. The stick with the flat paddle-like button

> pushes against the batteries'. I think in some ways she has an understanding too, but its not out and out said. I think her diagram is, however, a little more detailed.
> A: She sees the power, like these ones, from the battery to the bulb, but there is not a concept of circuit there (May 26, 1992).

These follow-up conversations where student work was discussed and analyzed helped to enlarge our understanding of the children's entry level knowledge, the growth in knowledge and how they incorporated new learning. As we analyzed the students' work, we noted their participation and ownership of their own learning. Through this pattern we attempted to bring about fruitful changes and appreciate the positive features in the teaching/learning events.

Consider the following passage an example of how Diane and I negotiated meaning through reflection about the process we used in the overall plan of the unit on Structures:

> A: I was working with a pre-service teacher who was using constructivist philosophy. He was teaching a unit on planetary motion. He taught his first lesson and based on what the children shared at the end of that first lesson, he knew what he wanted to cover in the second and so on. Afterward he was reflecting back and he said that he wished that he had done something at the end of the unit, something concrete that they could put their hands on.
> D: I would rather have the concrete than just the information that they need to know because I think these kids are so active ... And its more interesting for them.
> A: Do you not think that we did do the instructing first? The activities where they were experimenting and saying what they thought?
> D: They are at a point now where they could do more things, where you need to know this information first and then give them time to try projects
> A: Then wrap it up with a project where they use their creativity and do it on their own.
> D: Some kids need the room so they can modify certain things and other kids need more support and that is really building enrichment and remediation.
> A: I was thinking back to how we did the latter part of the structures

> experiments with beams and supports and different kinds of shapes. It was very hands-on but they had a lot of experiences to learn from before they had to get into the bridge building.
> D: They had to learn about strength of materials, they had to learn about a lot of things, before they were ready for the project. They were doing hands-on things, experiments.
> A: They were doing experiments within experiments.
> D: They needed to do that. I don't think that should provide them with all the information but you need to give them some information . They also need time to test the information out. And that's where the real learning is, they are not going to remember a lot of the notes that I give them. What they are going to remember is what they learned when they put that brick on that bridge or when they dropped that egg. That's the type of stuff they are going to remember and have learned from. And it reinforces their learning experiences. Like when we started building the towers and continued to reinforce that experience with building bridges (May 26,1992).

This point in the research process was a testing, identifying and back and forth discussion, which Beattie (1990) referred to as 'dialectic', where we worked to develop a mutual understanding of what were we trying to achieve and negotiate a process for science teaching that we could both recognize and support. It was a most powerful step in professional development terms. It encouraged us to clarify the important features of what good science teaching should involve. It allowed us to test and experiment with strategies and get thoughtful feedback in a constructive and meaningful manner. The feedback from the students gave credibility to the whole process, if they liked what they were doing and were excited about their learning and eager to take more responsibility for it, the more encouraged we were.

This led us to a stage in our collaboration where we gained a better understanding of the vision of science teaching we each held. Our discussions nurtured this understanding. This stage seemed to employ more than a consideration of implementing science curriculum

but rather a process of curriculum development in the sense that Hargreaves (1992) described in reference to meaningful teacher development.

Teachers as collaborators

In the latter stages of the study, Diane and I became quite comfortable with our collaboration. We found that on one occasion, we co-taught a lesson together, working as a team in front of the class.

I sensed that this reflected a mutual understanding of the lesson, an awareness of each other's teaching style and to some growing extent, a similarity in approach philosophically (common goals and strategies) but also an appreciation for the differences. We had become collaborators in the fullest sense of the term.

To define the features of collaboration in this sense, I would include: shared experiences, an appreciation for the similarities and differences, the premise that it is okay to accept or reject advice based on a knowledge of what will work for one's self, empowerment for each as each understood better what they wanted from the process, and empowerment in seeing the confidence of the other grow.

Diane and I were still individuals, not one a copy of the other. We could act in a different manner yet appreciate the position and views of the other without prejudice. We each could respect our colleague and her philosophical views and learn from the situation. The feature binding this collaboration was the quest itself and the momentum built by the desire to inquire into our teaching and into the children's learning.

We had enough in common to understand the other's perspective and had negotiated a understanding. The following passage is indicative of our conversations during this collaborative stage. We respect the other's views but end with a different opinion:

> D: We could even do a graffiti for their elicitation.
> A: I don't know what that is.
> D: You pick a topic out of electricity to see what they know about it. You could use 'electricity' as a heading or 'storms'. Write it down and within their groups, the children brainstorm for any ideas that they have on the subject. Each group has a different coloured marker. Then they pass it on. The next group can look at their ideas and then add on their ideas. And that's a graffiti.
> A: I could see that as an excellent ways to evaluate the unit.
> D: It's a neat activity.
> A: This way they could share all their understandings and look at them.
> D: They only have a short block of time though, so someone like Alex can't go off on a tangent. He has to think about the one point he wants down.
> A: Super idea, I see that as an excellent way to wrap up a unit.
> D: It's actually used as a starter too. It's a brainstormer. I've used it for solving problems. like a computer schedule, a fundraising event, ... and they pass it around and write down any of their ideas and it works very well.
> A: I think it would be a great idea for eliciting but what I think we should do now is connect the idea to the child. I would do it another time, but this time I would prefer to look at the particular child and his/her idea.
> D: A Graffiti is one of the structures that I like (May 19,1992).

During one conference close to the end of our study, Diane indicated her interest in continuing our contact. It gave me an opportunity to suggest another venue for teachers like ourselves who were interested in a context for continued professional development:

> D: It would be nice to have somebody like you here next year. I think I will need to actually learn more about the topics before I can look at grouping ideas in this way and plan. [categorizing student conceptions]
> A: It takes time to walk through it.
> D: I don't see anybody doing it this way.

A: Would you be interested in a network group? I am working with a person who would like to get a group together to talk about teaching science using children's ideas.
D: Yes, that would help me. When you gather the kids' ideas, I don't really feel that my inservicing and teacher education have made me feel comfortable with it. How do I meet their needs?...and later... just as I am going through this again, and watching you do this... I think no wonder I have been using those packages Janet gave to me. This is why people don't do this[use ideas] Using their ideas is challenging. It is time consuming to plan activities, organize materials that will meet the diverse needs in my class and to extend existing knowledge... [and later]
D: That's my worry. Consider my own training and how I saw science taught. I mean when we did Curriculum and Instruction, barely even three years ago, we did great things. We did science boxes and then when it came together into a whole vision of where it had to go....experimenting and looking at things in the world, it didn't have that light at the end of the tunnel. It was sort of a series of ideas and activities, none of which knit together at all. And I hope that next year when I'm teaching science, I don't fall back into that trap ... [and even later on] Now I can see that I really do have an ability to use student ideas and really have had a lot of practice. Now I can see where I can use this approach. This hasn't been an easy process for me. I wouldn't say it has been extremely difficult for me, but it has increased my awareness about a lot of things. I have seen my teaching practices changing and some of my attitudes have changed too about science. I hope that in this environment I am able to continue to grow from experiences like these (May 26, 1992).

When the formal part of the study concluded, Diane and I made tentative plans to meet the following school year. In this passage, the value of continued collaboration is articulated by Diane:

D: To network with somebody out in the working [teaching] world. I think that would be very meaningful to me. To actually sit down and work through the units too or work with somebody who is starting an electricity unit the same time as I am and go through the process and compare results. I'm not at the point where I could use this approach without support and yet I see this as an important tool [constructivist science teaching] I would like to continue to use (June 18, 1992).

This collaboration is perhaps a form of Thiessen's (1992) concept of classroom-based teacher development. The classroom teacher building confidence with new strategies and expanding expertise in practice through a new more inclusive teaching paradigm. Importantly, the motivation is characterized by the teacher's commitment to her students. As the children learn in a socially constructed environment, so does the teacher.

Teachers as networkers

The next school year (1992-1993), we met seven times and discussed our plans for science units and possible strategies which we respectively used in our classrooms. We shared students responses to elicitations, reflections of the lessons and discussions of the unique ways in which our students responded to the planned units. We met to reflect on what had happened in our respective groups and discussed similarities, differences, problems and most importantly successes. Other teaching colleagues became curious and later became interested in our collaboration. In Diane's school, it was through cooperative learning project groups. In my own school, my team teaching partner and her student teacher joined our meetings.

It was an informal network, not organized and arranged in a set pattern of meetings but as a more casual group that met, shared ideas and explored activities that could be utilized in our classrooms. We used a strategy which reflected the pattern developed in our formal study (elicit ideas from students, plan lessons based on students' ideas as well as using the curriculum guide for direction, and attempt to employ cooperative formats when

possible).

The process had become one of sharing, reflecting, and of nurturing continued reflection and examination of our science teaching. We had become networkers and had formed a loosely structured colleagial group. It had evolved naturally based on mutual professional interests and needs. It was happening in a non-threatening environment. There was no overt evaluation, but instead self-evaluation was fostered. This nurturing process led to a sense of empowerment.

Following one such session where Diane and I were looking at and categorizing the different conceptions that students had on circuits, she shared:

> D: I think that teachers need time to plan with other teachers, not necessarily with consultants. They're out of touch with what's going on. We need to work with others who are in similar teaching situations. Who have an area of specialty but realize what's going on with some of these kids and what time restraints or what budget restraints we have. To sit down and plan and work with what we've got. I don't see any collaboration going on[in Diane's school area]. I don't see it being encouraged. I think that people are just coping and Resource[the resource teacher] doesn't come in and support what you are doing with this kind of stuff [science]. You can see why science and social studies are on the back burner ... We are supposed to be teaching a balanced curriculum. ... Some may feel that it's boring. I don't think people think it is important. Or, if they do feel it is important, lack training, supplies, planning time to do this area a service. Each unit or concept often seems to be taught as a separate entity and not as part of a continuum (May, 1992).

The following comment made by Diane during a meeting with my advisor and myself reaffirms the value that Diane placed in the collaborative process used in this study. Her implication that this type of process would be valuable for beginning teachers as a next step in professional development after certification highlights the need for personal contact.

> D: It has been a good learning process for me. I wouldn't say that in my training there was enough time to learn any of this.... I wish in other ways that that had been more the approach in my first year. That they had hooked me up with an experienced teacher... I think one of the places to begin is through personal contacts . I've been very lucky to make the connection with Adell and really hope we get to the point where we could share our experiences with some of the people in our school because I think highly of it (May 27,1992).

The key feature mentioned here is the personal contact between teaching colleagues. This aspect, also mentioned by Hargreaves (1992) as a most profound influence within the teaching community, can foster the direction of teacher practice. Scardemalia and Bereiter (1989) spoke of professional development as a continuous process and Hargreaves (1992) talked about it in terms of life cycles. Continued growth and development of teaching practice can be nurtured within collaborative cultures and colleagial networks where the benefits of linking theory with practice in the dynamic context can enrich the education of our students.

In reflecting on the events and outcomes related to the professional collaboration and networking which evolved from it, I became increasingly aware of the confidence that developed not only in Diane but in myself. Working within a collaborative culture encouraged critical pedagogy and fostered confidence in employing changes in my own practice as well as facilitating growth for my colleagues. Seeing the enthusiasm and the learning of the students was a powerful motivation. I also became aware of the many professional, personal and social factors outlined above that contribute to or inhibit positive, permanent changes in practice. A most significant realization was that teachers must continue to inquire into their practice and must continue to consider the ever-changing needs and

conditions of their students. Working with Diane showed me the importance of a collaborative community to achieve these goals.

In Summary

Recent works (Churcher, 1990; Auger and Odell, 1992; Wallace and Louden, 1992; Coles and Knowles, 1993; Bell et al., 1993; Loughran, 1994) discuss teacher education programs designed to function collaboratively at various stages of the teachers' professional life, from pre-service partnerships to post-service tutorial sessions. Each program attempted to address teachers' knowledge growth and reform in classroom curriculum but were not of a sustained supportive nature and did not have as significant enhancement of teacher practice and critical pedagogy.

Auger and Odell (1992) described their contractual school-university partnership which was based on an exchange of services agreement. It permitted an Education Faculty to staff classrooms with university "fellows" at a reduced salary. The regular teachers assumed the role of clinical support teachers. The Auger and Odell partnership was not focused in science nor did it attempt to view the underlying themes or factors which encourage growth in teacher personal and practical knowledge. An important feature which distinguishes this collaborative case study with Diane was its emphasis on a sense-making and emancipatory approach to understanding teacher development in elementary science teaching.

Loughran (1994) conducted a study with the goal of easing the transition of first or

second year teachers into the school system via mentoring processes which began during teacher education programs and immediately upon entering the profession. He found that factors such as time, confidence and support from experienced teachers created dilemmas for beginning teachers who found differences between their expectations from teacher education programs and their experiences in schools. This finding was also supported in Diane's earlier teaching experiences but was addressed with success through the "professional collaboration" and "colleagial networking" which came as a result of this collaborative project. The close support Diane experienced during the study helped to overcome regression toward traditional viewpoints, as discussed in Loughran's work, and led to the risk taking pivotal to exploring and implementing change in teaching practise. The colleagial networking provides a venue for informed reflective inquiry into teaching which could well extend on throughout a teacher's professional career.

Cole and Knowles (1993) have done work within the hermeneutic realm to study the development of new teachers upon entering their own classroom. Their 'partnership' research approach involved researchers exploring the beliefs and practices of beginning teachers once they were teaching full time. They tracked events to note changes in conceptions and practice and made note of any regression to previous or earlier conceptions. Their focus was not intervention but rather on giving 'voice' to teachers' experience. They used established data collection procedures such as interviews, visitations and journaling; and employed an on-going negotiation of the roles and responsibilities of the partners from the data collection stage through to the sense making and documentation stages. These features were also evident in this case study. However, this study was based on a premise of partnership which

is more encompassing than that used by Coles and Knowles. The teacher researcher lives out the same experiences as the teacher and works with a commitment to the students in day to day collaboration. The practical problems are addressed and resolved together with interventions and debate/decision making as an ongoing dialectic interaction. This study with Diane traces changes in perspective as a result of analysis and risk taking on the part of both participants. It required negotiation of meaning related to quality teaching as well as negotiation of process.

Bell's (1993) work described three sequentially conducted teacher development projects for in-service teachers interested in improving their science teaching. These projects involved teacher educators organizing a series of weekly tutorials for experienced elementary and high school teachers. The tutorials were situated at the faculty building or teacher resource center where the teachers were introduced to the 'interactive teaching approach' and were encouraged to follow through with new strategies by meeting regularly to discuss their successes and difficulties. Opportunities for social interaction were also provided in order to address the personal and social development components of adult learning processes as well as the professional component. Bell's research shared common process features with this study in terms of the constructivist/critical pedagogical approach and the importance of the personal, professional and social elements of teacher development. Important differences included the nature of the intervention and the context. In this research study, the interventions were selected and suited to Diane's present conception of science and personal philosophy of teaching. Decisions regarding the use of new strategies and the philosophical direction of the science instruction that the teaching would ultimately follow were in the

hands of the classroom teacher. The risk taking element of employing new approaches was grounded in a supportive environment and feedback was immediate. This study describes teacher development that was classroom based and involved a close professional collaboration throughout the day to day teaching of the science lessons. The reflective discussions were immediate and involved input from two sources in terms of framing the problems, reframing them and considering the affective elements. There was continuous commitment and feedback on the changes employed initially. This study also recognizes that the two teachers have expertise to contribute to the decision making process.

Churcher's (1990) ethnographic case study in elementary science teacher development shares many similarities with this work. The participants were both classroom teachers. There was the important element of studying practice in light of theory. The teacher researcher drew upon theoretical knowledge and current research findings to address the practical problems and provide insights into Ruth's beliefs and actions. Churcher worked closely with Ruth to explore her image of science teaching and the underlying explanations for her perspective. This study of science teaching in Diane's class takes a similar approach as its beginning point but focuses on encouraging teacher growth in knowledge by actively employing intervention strategies and introducing new theory and processes for consideration and reflective evaluation within the context of the classroom. A supportive structure which fosters and sustains risk taking within a constructivist perspective was intentional.

Wallace and Louden (1992) shared research which was based on examining teacher development in the classroom. They conducted two extended ethnographic studies of

Canadian elementary schools which employed participant observation, peer coaching and a hermeneutic interpretation. They explored teachers' knowledge of patterns, of content and of resolutions to common classroom problems which were influenced by teachers' biography and professional experience. They found that: a) teachers' practices are linked to their biographies and experiences, b) teachers search for comfortable patterns of practice, c) teachers' knowledge develops gradually, and d) teachers' work provides little time for experimentation. These four themes were also supported by the findings in this case study. Diane's initial conception of what science teaching involved was strongly influenced by her 'apprenticeship of observation' in the schools she attended and taught in. However, her early childhood experiences with a different kind of science helped her create images of science teaching that were brought to play in her classroom as a result of the collaboration.

As Diane sought changes in her science teaching, those which became a part of her repertoire were ones that she felt comfortable with and could justify in terms of her educational philosophy. Changes and enhancements were accepted when they were educationally productive and fit into the broader more encompassing routines of the classroom. The process of change is time consuming and lengthy if new elements are being incorporated into a teacher's practice. Diane and I worked collaboratively through two units of science. The first unit was to establish initial conceptions and develop a rapport between the participants. The second was to work through and identify a process which Diane could employ in planning and carrying out her teaching units. Diane expressed the need for continued contact with other inquiring teachers and found that an informal colleagial network supported her efforts at on-going professional growth. Critical to her involvement was that

she have the opportunity to interact with other classroom teachers who understand the realities of classroom life.

Wallace and Louden's (1992) point about time for experimentation is recognized in the present study. The teacher researcher plays a key role in reflecting on the events and suggesting various courses of action. The collaboration allows the teacher researcher to participate and model strategies, in other words, lead the way in the experimentation process. Additionally, the colleagial support includes doing the groundwork for unit and lesson materials. This support for the classroom teacher on the up front end of the planning and collection of resources, freed up time for the teacher to be more introspective about her teaching and the new strategies and philosophy being employed. As the study progressed, the interaction between the two teachers and between the teachers and students led to more efficient planning and teaching. As new strategies became comfortable parts of the teaching style and the outcomes assessed in meaningful ways, Diane's energy could be focused onto other aspects of science teaching that required attention. This study with Diane, shares other situation specific themes which arose and are summarized again briefly in Chapter 6. Importantly, this study also addressed the "quick fix" concerns expressed by Hargreaves (1992), as the formation of a network of colleagues to support continued professional growth in science teaching came about as a result of the collaboration.

Chapter 6

Conclusions, Summary, and Implications

This case study documents the experience of two collaborating teachers working in the rich context of one teacher's elementary science classroom. As such, it traces the sense-making and insights of the practitioners as we reflected upon the events that unfolded. The interpretations made give meaning to the experiences we shared. In short, the 'why of the what' in elementary science teaching is addressed. In addition, this study documents the collaborative process which developed as a result of negotiation between us. This research, based within a professional collaboration, addresses the issues of power and control in research relationships and implicitly advocates mutual control and benefit. This study features an emancipatory, yet critical approach to teacher development.

By reading the vignettes in Chapter 4, readers may themselves identify with the perspectives that were implied and the problem solving strategies used, including the images of science teaching which were lived out. Those parts or pieces that are meaningful to readers, as well as the broader perspectives about science which were clarified, may lead to some transferability from this case study to a reader's perspective and/or practice. Thus, it is hoped and anticipated that, the ideas presented may in some form be applicable and useful to other teachers intent on exploring, understanding and enriching their practice and to other

persons who may be interested in teacher development in elementary science.

Professional growth, whether it be process or attitude, represents changes in a teacher's understandings which may be encouraged as a result of overcoming impediments to action or as a result of critical analysis of one's pedagogy at a philosophical, social, and personal level. Practical knowledge is a construct of how the teacher holds knowledge and selectively uses that knowledge in unique contexts which can change in time and place. Whether this knowledge is held in principles of practice or as images or even if it cannot be articulated succinctly in these terms; the value of professional development experiences to individual teachers, in my view, is rooted in sharing the sincere study of teaching and in sharing the reflective analysis and insights which arise as a result. Professional collaboration, which is expanded upon in Chapter 5, may be of interest to others who seek a means to interact with colleagues on the study of teaching.

The unique feature of this work is the nature of the collaboration between the two teachers: the continuous and supportive inquiry which focused on bringing theory and practical knowledge to bear upon the practical problems which were addressed in the teaching of two science units. The strong commitment to consider the social and personal components within the problem solving process may have fostered the trust and respect that led to the quality of commitment and the tremendous changes in perspective that are witnessed in the vignettes. Additionally, the interest in continued contact through an informal colleagial network reflected a 'perceived' need for teacher development programs of this kind. Ones that were long term in nature yet not restrictive in format.

From this collaborative study, certain conclusions were made about science teaching, professional growth and collaborative frameworks. These are conclusions which, strictly speaking, cannot be generalized beyond this study, but may nevertheless represent some of the overall sense that Diane and I made in the course of this work. Furthermore, the entire text we have provided speaks to the questions originally posed. An attempt will be made to respond to the guiding questions here, in a summative fashion. The three original guiding questions, in retrospect, can be simplified to two overarching focus questions. First, "What meaning did a Grade 4 teacher make of science teaching in her classroom?"; and second, "How did the teacher-teacher collaboration influence her understanding of science teaching?"

Conclusions

In response to the first question," What meaning did a Grade 4 teacher make of science teaching in her classroom?", I found that as the focus of the science teaching became more student-centered and "active" in nature, many of the problems of practice that were identified and framed (within the vignettes) were addressed naturally. The answers to the questions about students learning in a meaningful and successful manner seemed to rest within knowing more about the students' thinking and it was the responsibility of the teacher(s) to give their students 'voice', that is, to give their ideas and experiences a chance to be heard. "Active " learning involved a hands-on, minds-on approach which centered on the negotiation of understanding the meaning that children gave to the science events in the classroom. The discussions amongst the students were valued as much as the discussions

with the teachers as these enhanced the experiences upon which learning was based. With the focus of the science teaching being children's understandings, their ideas and their 'ownership' of the responsibility for learning many questions which Diane and I had about their learning were resolved in a fruitful and progressive manner. Students' efforts and learning often exceeded our expectations and we became increasingly aware of the range of conceptions and experiences brought to play in the science activities.

Just as students possess 'alternate conceptions' of science and science teaching, so do teachers. By exploring these conceptions in a supportive and participatory manner, new understandings and insights can be encouraged and experiential background in teaching enriched. We can begin to 'see' the 'old' in new ways through a process of negotiation based on reflection and analysis. This negotiation was context specific and reflects the mutual sense-making of the participants. As teachers study the problems of practice in a reflective mode, feedback from the setting and from each other can foster a positive form of self-examination and self-evaluation. This evaluation can be a profound motivator for seeking increased understanding of one's practice. Deep-seated attitudes and beliefs about teaching which are grounded in memory or in behaviours, can be discovered in the things that are said and the actions which are witnessed. Once brought to light, they are open to examination and enhancement, or reconstruction, as seen fit. As teachers working in a collaborative partnership, Diane and I sought to identify concerns and address them in the classroom context. Furthermore, and perhaps less obviously, we could not help but share perspectives naturally just in the course of our daily work. Changes in one's perspective, whether it be viewed as reaffirmation, enhancements or transformations, are a natural outcome especially

where there is mutual trust and support.

Reflective conversations are a means to promote scrutiny which fosters proactive, constructive critical analysis and may well have benefits not achievable in traditional supervisory professional development valuation models. I feel that teachers in collaborative settings consider their actions from a social and personal level as well as from a professional level. My position is that teachers also need to be given a 'voice' that is heard in the context of their lives where the meanings they attribute to their actions are recognized, valued, and become the vehicle for changes in perspective and in practice.

The vignettes collectively entitled "Diane's Metaphors for Science Teaching" highlight the observations we made, the problems of practice that we framed, the reflections on the practical problems, the actions employed and the changing perspectives which became evident within the context of this study. The following points attempt to summarize briefly the main themes and insights which were identified.

Traditional or habitual classroom routines, instructional strategies and assignments that are changed as a result of a problem solving process must be compatible with teachers' overall educational philosophy. In a constructivist approach to science teaching, this would involve appreciating and employing strategies that foster a dialectic conversation between students and the knowledge of the subject, i.e.: fostering a negotiation between the science events and the students understanding of them. In addition, the importance of establishing a common vision of science was recognized. Teachers and students must be aware that science can be fallible and inexact at the best of times and should consider their classroom activities as explorations of the possibilities. A vast range of experience and understandings

are possessed by students, who do have a role in contributing to the lessons. Their conceptual frameworks present a starting point for any science unit. The role of the teacher in science must evolve from the traditional one as holder of knowledge. In this study, Diane saw her role shift paradigmatically from one of control to one of facilitation. The teacher became a learner along with her students. As science and the definition of good science teaching changes, the awareness that the classroom environment will change must be recognized. A natural outcome of this study was a more participatory interaction by students in the teaching/learning dyad. Conversation, debate and discussion as well as hands-on activity should be the basis for science instruction. "Active" learning may best describe the nature of the learning needed. It should be recognized that the process of negotiating understanding of the science between students and their teacher can be paralleled to the process of negotiation between two teachers intent upon understanding the practice of science teaching. Learning as negotiation is a process which involves additions of new meaning and results in enhanced understanding as relationships are understood in a more complex and personally meaningful way. In some instances, it may result in significant changes in perspective.

The second focusing question which asked, namely "How the teacher-teacher collaboration influenced Diane's understanding of science teaching?", leads to a consideration of the framework used in this work. The collaboration itself was a most significant influence. Since a Schönean-constructivist perspective was most prominent in my approach, concerns and dilemmas that the teacher identified were examined and addressed using this orientation to reflective teaching. The collaboration itself provided an environment where it was natural that the teacher's conception of science teaching was the beginning

the teacher will 'act out' her/his image of teaching. This phase of teacher professional development can balance out the tremendous influence of the 'apprenticeship of observation' and reflect more closely on the needs of today's students. Professional collaboration can become a process of renewal for a teacher-researcher or other experienced teachers for that matter. It can promote tremendous sustained changes in practise and in enhancement of teacher perspective. Professional collaboration can be a critical, powerful and relevant means for curricular reform and implementation through meaningful and emancipatory teacher development.

Summary

The concept of professional collaboration as a means to support and enrich professional growth past the years of pre-service training was meaningful in this context because the resulting relationship was a professional one based in a study of practice. What the participants brought to the relationship on a personal level was respected. Its influence was recognized but was not the focus. The calibre of science teaching, the sharing of images of one's practice and the "reflective" approach to address those concerns reinforced the value of the continued contact even after the close of the study as it was originally conceived. The colleagial network that was built as a result of this study proved to be meaningful because it encouraged reflective science teaching, addressed on-going concerns related to problems of practice, and built a collaborative culture whose focus was science teaching, something not yet evident in many elementary schools.

Continued professional development is vital not only for the benefits to the students who are taught but for the sake of the teacher who struggles to meet the needs of her/his students in an ever-changing world. For schools, the value of collaborative forms of professional support must be recognized and encouraged. And this is so not restrictively for the 'retraining' of teachers, since what they do is much more than going through the motions, but for the larger more inclusive vision of a community of reflective colleagues supporting and growing in knowledge of one's practice. Such a community can address those life cycle concerns and lifestyle issues that affect what a teacher does over the life span of one's career. Programs of this nature could be a most positive vehicle for ensuring curricular reform in that it benefits the teachers and their students, and it is situated in the classroom where the impact is visible and immediate. From this collaborative inquiry in science teaching, a better definition of what constitutes good elementary science teaching was determined for Diane and myself.

Implications

This case study suggests implications for teachers, for schools and for Education faculties. For teachers, the process of teacher education and professional growth doesn't end with graduation from a teacher education program. As it is a continuous, life long process enriched by interaction with students and colleagues, professional development should be classroom-based. It should involve dialogue with colleagues intent upon inquiry into their own teaching and preferably be a form of professional collaboration. Elementary science

teaching should involve 'active' learning with students being encouraged to share responsibility for their own learning. Professional growth that is fruitful and empowering arises in supportive communities of teaching colleagues and is intimately linked with curriculum development. Teacher must recognize that their professional growth should involve a dialectic conversation between theory and practice and be centered in the practical problem-solving milieu. Professional development is critical and means taking risks. Teachers must accept responsibility for their own development and seek colleagial networks. They will need to be assertive in order to arrange time/scheduling flexibility to permit collaborative inquiry.

For schools, teacher development must be considered vital to curricular development and reform. Principals and administrators must recognize that implementing curriculum changes in science, and in integrated S.T.S. programs, is a process that will require more than one-day training sessions and mandated expectations. Changes must be nurtured since permanent change has to be supported for significant periods of time. Learning and learning about teaching can not be done in isolation. Quality science teaching is a process of negotiating meaning and fostering "active" learning. This approach will take teacher commitment, time and access to other stakeholders to be effectively instituted. Since teachers must see for themselves the value and benefit of constructivist science education, schools need to become the place for fostering communication between teachers, students, parents and other stakeholders. The classroom is where the benefits will be visible and student achievement recognized. In encouraging colleagial networks and reflective teaching, principals can nurture meaningful teacher development. Schools must support teacher efforts

by considering scheduling requests and assuring time for teacher collaboration. Elementary principals should allow teaching staff flexibility in determining the most suitable format for their networks and should focus on facilitating the link with resources and resource persons, particularly in the area of science education.

There are implications for Faculties of Education which presently have two responsibilities; one being the education of pre-service teachers and two being research. I feel that Faculties must also commit to encouraging professional development of in-service teachers by promoting reflective practice. Faculties currently offering post-Baccalaureate programs can provide opportunities for discussing theoretical insights into practise and can advocate collaborative relationships and colleagial networks by assisting beginning and experienced teachers to set up networks to foster critical pedagogy. Indeed, there is also a need to further examine approaches to professional development within constructivist philosophy.

Collaborative research projects between teachers and teacher-educators can be the ideal venue for a 'dialectical' examination and debate of what merits quality science teaching. A closer examination of the underlying principles of constructivist science teaching, whether evolutional, revolutional or relational development, is needed. Understanding how students of different age levels and grades hold knowledge and acquire understanding of generally accepted science concepts must be further examined in order to determine the most suitable constructivist approach for primary, elementary and intermediate students. Within constructivist science teaching, the level of background science knowledge needed by elementary classroom teachers should be determined more specifically, as this would address

the comfort level concerns that elementary teachers may have with this approach. In addition, I feel that Faculties must continue to address the issues of power and control in research relationships to ensure rigour and commitment by all participants. Other questions that researchers should consider exploring are: 'What other forums for teacher and faculty collaborative ventures are possible?' and 'Is there a role for teacher organizations in this process?' Science curriculum development is the responsibility of collaborative cultures consisting of all the stakeholders within the teaching profession.

BIBLIOGRAPHY

Abell, S.K. and Smith, D.C. (1994). What is science?: Pre-service elementary teachers' conception of the nature of science. International Journal of Science Education, 16 (4), 475-487.

Aguirre, J., Haggerty, S. and Linder, C. (1990). Student-teachers' conceptions of science, teaching and learning: A case study in pre-service science education. International Journal of Science Education, 12 (2), 381-390.

Allan, K. and Miller, M. (1990). Teacher-researcher collaboratives: Cooperative professional development. Theory Into Practice, XXXIX (3), 196-202.

Auger, F.K. and Odell, S.J. (1992). Three school-university partnerships for teacher development. Journal of Teacher Education, 43 (4), 262-268.

Beattie, M. (1991, April) The making of a music: The construction and reconstruction of a teacher's personal practical knowledge during inquiry. Paper presented at the conference The Narrative and Education: Narratives and Reflection, sponsored by the International Society for Educational Biography, Toronto.

Bell, B. (ed.) (1993). I Know About LISP But How Do I Put It Into Practice? Hamilton, New Zealand, Centre for Science and Mathematics Education Research.

Bell, B. and Gilbert, J. (1994). Teacher development as professional, personal and social development. Teacher and Teacher Education, 10 (5), 483-497.

Biddulph, F. and Osborne, R. (1984). (eds.) Making Sense of Our World. Hamilton, New Zealand, Centre for Science and Mathematics Education Research.

Brauner, C. (1988). Perceptivism: A new philosophy of education. Brief for the British Columbia Royal Commission on Education, University of British Columbia.

Brickhouse, N. (1990). Teacher beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41, 53-62.

Cain, S. and Evans, J. (1990). Sciencing, Merrill Publishing Company.

Carr, C. and Kemmis, S. (1983). Becoming Critical: Knowing through Action Research. Victoria, Australia, Deakin Press.

Churcher, E. (1990). The nurturance of professional growth: A teacher and assistant working together in the classroom. Doctoral thesis submitted in the University of Toronto.

Clark, C. and Peterson, P. (1986). 'Teachers' thought processes'. In Wittrock, M. (ed.) Handbook of Research on Teaching (3rd edn.). MacMillan.

Cole, A.L. and Knowles, J.G. (1993). Teacher development partnership research: A focus on methods and issues. American Educational Research Journal, 30 (3), 473-495.

Connelly, M. and Clandinin, J. (1988). Teachers as Curriculum Planners. Toronto: OISE Press.

Connelly, F., Crocker, R. and Kass, H. (1986). Science Education in Canada* Volume 2, OISE Press.

Dewey, J. (1933). How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process, D.C. Heath.

Driver, R. (1987). Changing conceptions. Paper presented to the International Seminar, Adolescent Development and School Science Students, King's College, London, September, 1987.

Driver, R. (1989). The construction of scientific knowledge in the classroom. In Millar, R. (ed.), Doing Science: Images of Science in Science Education. London: Falmer Press.

Ebenezer, J. and Achtemichuk, L. (1992). What do grade three children really think about shadows?: A pre-service teacher's explorations of her science instruction. The Manitoba Science Teacher, 33(3), 12-15.

Ebenezer, J. and Connor, S. (1994). Exploring Children's Conceptual Worlds in Science. University of Manitoba.

Ebenezer, J, and Hay, A. (in press). International Journal of Science Education.

Ebenezer, J. V., and Gaskell, P.J. (1995). Relational conceptual change in solution chemistry. Science Education, 79 (1), 1-17.

Elbaz, F. (1988). Critical reflection on teaching: Insights from Freire. Journal of Education for Teaching, 14 (2), 171-181.

Ellis, N. (1990). Collaborative interaction for the improvement of teaching, Teaching and Teacher Education, 6 (3), 267-277.

Erikson, G. (1989). Collaborative inquiry and the professional development of science teachers. Paper presented to the Canadian Association of Teacher Educators pre-conference in Quebec City, Quebec.

Goodson, I. (1992). Sponsoring the teacher's voice: Teachers' lives and teacher development. In Understanding Teacher Development, Teachers College Press.

Haggerty, S. (1991). Toward a gender free science in schools. An unpublished paper.

Hargreaves, A. (1992). Cultures of teaching: A focus for change. In Understanding Teacher Development, Teachers College Press.

Hewson, P. W. (1981). A conceptual change approach to learning science. European Journal of Science Education, 3 (4), 383-396.

Hewson, P. and Hewson, M. (1987). Science teachers' concepts of teaching: Implications for teacher education. International Journal for Science Education, 9 (4), 425-440.

Hewson, P. and Hewson, M. (1989). Analysis and use of a task for identifying conceptions of teaching science. Journal of Education for Teaching, 15 (3), 191-209.

Hunt, D. (1987). Beginning with ourselves in Practice, Theory, and Human Affairs. Brookline Books.

Kelly, A. (1978). Girls and Science, Stockholm, Almqvist and Wiksell International.

Kelly, G., Carlsen, W. and Cunningham, C. (1993). Science education in sociocultural context: Perspectives from the sociology of science. Science Education, 77 (2), 207-220.

Kennedy, M. (1991). An Agenda for Research on Teacher Learning. A Special Report. National Centre for Research on Teacher Learning.

Linder, C. (1993). A challenge to conceptual change. Science Education, 77(3), 293-300.

Lortie, D. (1975). School Teacher: A Sociological Study. University of Chicago Press.

Loughran, I. (1994). Bridging the gap: An analysis of the needs of second year science teachers. Science Education, 74 (4), 365-386.

MacKinnon, A. (1989). Conceptualizing a reflective practicum in constructivist science teaching. Doctoral thesis submitted in the University of British Columbia.

MacKinnon, A. and Grunau, H. (1991). Supporting a collaborative culture in science education: Reflection and community. Paper presented at the Annual General Meeting of the Canadian Society for Studies in Education, Kingston.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism

toward a sociocultural model of teaching and learning. Journal of Research in Science Teaching, 29 (8), 791-820.

O'Loughlin, M. (1992). Engaging teachers in emancipatory knowledge construction. Journal of Teacher Education, 43 (5), 336-346.

Orpwood, G.W.F. and Souque, J.P. (1985). Towards the renewal of Canadian science education II. Findings and recommendations. Science Education, 69, 625-636.

Osborne, R. and Freyburg, P. (1985). Learning science and the science of learning. Studies in Science Education, 15, 77-101.

Posner, G. (1985). Field Experience: A Guide to Reflective Teaching, Longman.

Posner, G.J., Strike, K.A., Hewson, P.W., and Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66 (2), 211-227.

Scardemalia, M. and Bereiter, C. (1989). Conceptions of teaching and core problems. In Reynolds, M., Knowledge Base for the Beginning Teacher, Pergammon Press.

Schön, D. (1983). The Reflective Practitioner: How Professionals Think in Action. Basic Books.

Schön, D. (1987). Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions. Jossey-Bass.

Shavelson, R. and Stern, P. (1981). Research on teachers' pedagogical thoughts, judgments, decisions, and behavior. Review of Educational Research, 51 (4), 455-498.

Shapiro, B. (1989). What children bring to light: Giving high status to learners' views and actions in science, Science Education, 73 (6), 711-733.

Shulman, L. (1986). Those who understand: growth in teaching. Educational Researcher, February, 4-14.

Taylor, P. (1989). The influence of teacher beliefs on constructivist teaching practices. Paper presented at the History and Philosophy of Science in Science Teaching First International Conference, Florida State University.

Thiessen, D. (1992). Classroom-based teacher development. In Understanding Teacher Development, Teachers College Press.

Tripp, D. (1987). Teachers, journals and collaborative research. In Smyth, J., Educating Teachers: Changing the Nature of Pedagogical Knowledge. The Falmer Press.

Verstraete, L. (1990). Issue-centered STS (Science-Technology-Society) in the elementary classroom: A case study. Unpublished Master's Thesis, The University of Manitoba, Winnipeg, Manitoba, Canada.

Wallace, J. and Louden, W. (1992). Science teaching and teachers' knowledge: Prospects for reform of elementary classrooms. Science Education, 76 (5), 507-521.

Wells, G. (1994). Creating Schools From Within/ Creating Communities Of Inquiry, OISIE Press.

Wideen, M. (1989). Collaboration: New fad or new possibility? Research Forum, No. 5, B.C. Ministry of Education.

APPENDIX I

Permission Documentation

March 10,1992

Dear Colleague:

With the permission of your principal and the University of Manitoba ethics committee, I would like to document the science instruction and the professional growth that occurs during the two science units that we plan, teach, and investigate together. The title of this proposed study is:

A Teacher-Teacher Collaborative Inquiry into the Teaching of Elementary Science

This study will be a case study of a beginning teacher's professional development in science teaching via a collaborative investigation with an experienced elementary science teacher. It will involve a two to two and a half month time frame. The focus will be to learn about the factors that influence the planned and taught science classes. There will be a mutual exploration into the personal and practical experiences that contribute to the conceptualization of science teaching.

Data collection will be through field notes, journals and audiotapes of the science teaching and of discussions held in the planning and reflecting on of the teaching events. This will allow the teacher and teacher-researcher to share and validate the observations and analyses made throughout the course of the study.

Data obtained from the classroom observations, journals and teacher reflections and responses will be kept confidential. They will be available only to us. The audiotapes made in the classroom , as well as fieldnotes, journals,and transcripts, will be stored safely until the analysis of data is complete and the thesis work with related papers are finished. At that time, all data will be destroyed. Your name and school will not be identified in any

publications. A summary of the results may be obtained after the study is complete.

This proposed study may well contribute to the professional growth of in-service teachers and science education at the elementary level. In particular, it may improve science teaching and facilitate a better awareness of the teacher's role and perception of that role in science teaching. Because this study involves collaboration between two teachers, beginning and experienced, it will help to understand and build upon each other's theoretical and practical knowledge.

Sincerely,

Adell Hay

Your signature below expresses your willingness to be a part of the above described study. A summary of the study results will be available to you upon request. Consent at this time does not preclude your right to withdraw at any time without penalty from this study.

[redacted]

signature of teacher-informant

March 11,1992

Dear [redacted]

With the permission of your School Division, and The University of Manitoba ethics committee, I would like to document the science instruction and the professional growth that occurs during the collaborative study in [redacted] classroom. The title of the proposed study is:

A Teacher-Teacher Collaborative Study into the Teaching of Elementary Science

The proposed study will involve a case study of a beginning teacher's professional development in science teaching via a collaborative investigation with an experienced elementary science teacher. It will involve a two to two and one half month time frame. The focus will be to learn about the factors that influence the planned and taught science classes. There will be a mutual exploration into the personal and practical experiences that contribute to an understanding of science teaching.

Data collection will be through field notes, journals, and audio tapes of the science instruction and of the discussions held in the planning and reflecting on of the teaching.

Data obtained from the classroom observations, journals, and teacher reflections and responses will be kept confidential. They will be available only to me. The audio tapes taken in the classroom will be destroyed at the end of the study. The name of the school will not be identified in any of the publications. A summary of the study results may be obtained after the study is complete.

This proposed study may well contribute to the professional development of in-service teachers and to science education at the elementary level. In particular, it may improve science teaching and facilitate a better awareness of the teacher's role and perception of that role in science

teaching. Because this study involves collaboration between two teachers, beginning and experienced, it will help to build understanding between theoretical and practical knowledge.

I appreciate your consideration of this request. If you have any questions, you may contact me at [redacted] (home phone) or a message may be left at [redacted]

Sincerely,

Adell Hay, BSc., B.Ed
Graduate student

March 10.1992

Dear Parent/Guardian:

With the permission of the School Division, and the University of Manitoba ethics committee, I am documenting the science teaching that occurs during a collaborative study in [redacted] classroom. The title of this study is:

A Teacher-Teacher Collaborative Study into the Teaching of Elementary Science

The study will focus on the factors that influence the planned and taught science classes. This will involve [redacted] and I working closely together, planning and teaching two science units. We will be working cooperatively to better understand the processes that contribute to effective science instruction. The time frame for our study will be approximately two and one half months.

Classroom science lessons will be audiotaped and selected assignments will be discussed by [redacted] and myself. All references to students will be completely anonymous and available data seen only by [redacted] and myself. All audiotapes will be destroyed upon completion of our data analysis. This study will not affect your child's marks, class standing, or regular school program.

If you have any questions, please feel free to contact me at [redacted]

Sincerely,

Adell Hay
(Faculty of Education graduate student)

APPENDIX II

Samples of the Data

SCIENCE SLEUTHS

You will be watching and doing an activity about tower building. Use your **scientific imagination** to help you **predict** and **explain** what happens.

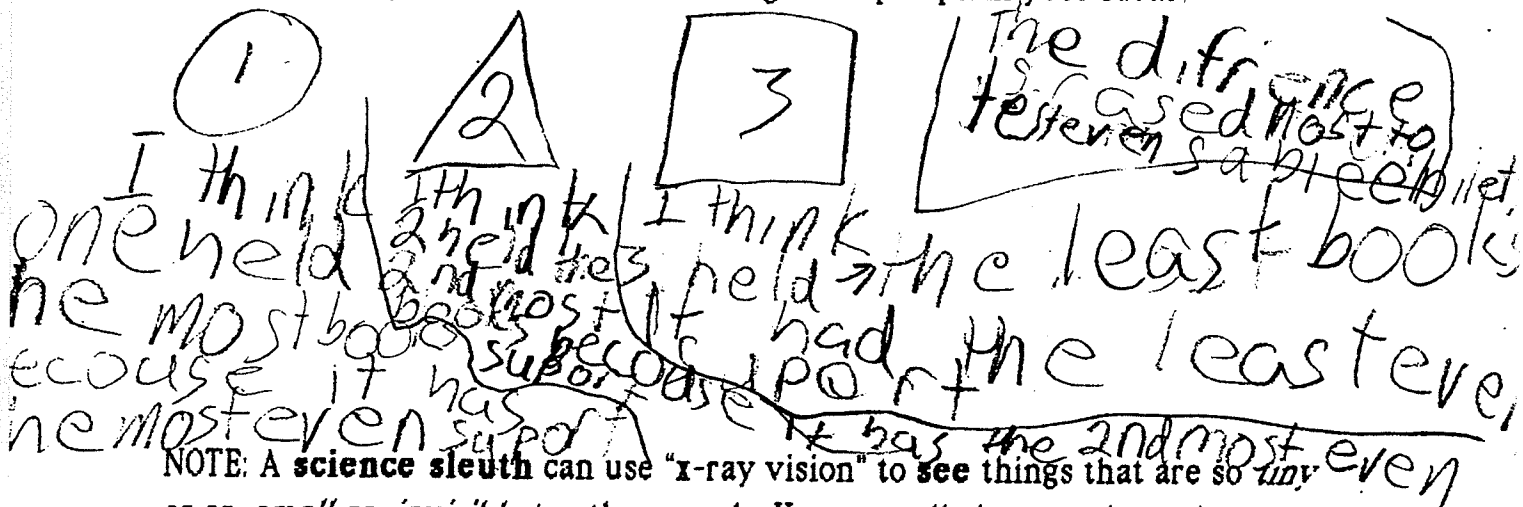
1. Which tower do you think will hold up...the tallest stack of books?

circle ① ...the shortest ? Triangle 2

2. Try the tower building activity in your group. Write down what you found in the space here.

① HHII 2 III 3 I

3. Tell **why** you think the three towers held up different numbers of books. How was that possible? (use a drawing to help explain your ideas)



NOTE: A **science sleuth** can use "x-ray vision" to **see** things that are so *tiny* or so *small* or *invisible* to other people. You can tell about or draw those things in your explanation.....

[redacted]

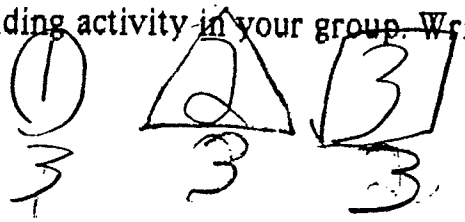
SCIENCE SLEUTHS

You will be watching and doing an activity about tower building. Use your **scientific imagination** to help you **predict** and **explain** what happens.

1. Which tower do you think will hold up...the tallest stack of books?

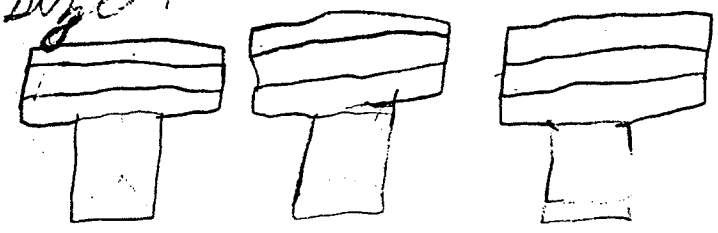
1, 2 and 3 ...the shortest ? none

2. Try the tower building activity in your group. Write down what you found in the space here.



3. Tell **why** you think the three towers held up different numbers of books. How was that possible? (use a drawing to help explain your ideas)

held 3. They were all made out of paper and they were all the same size.



NOTE: A **science sleuth** can use "x-ray vision" to **see** things that are so *tiny* or so *small* or *invisible* to other people. You can tell about or draw those things in your explanation.....

SCIENCE SLEUTH

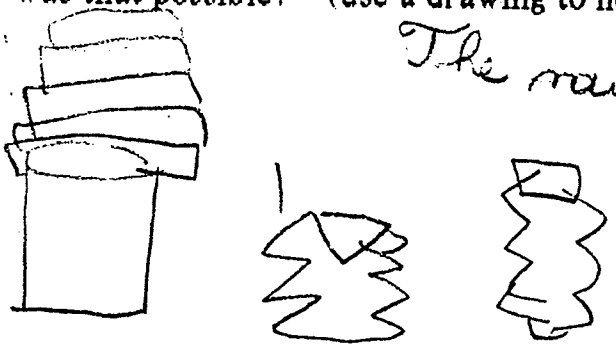
You will be watching and doing an activity about tower building. Use your **scientific imagination** to help you **predict** and **explain** what happens.

1. Which tower do you think will hold up...the tallest stack of books?

1st The circle, ...the shortest ? 3

2. Try the tower building activity in your group. Write down what you found in the space here. We found that the circle holds the most.

3. Tell **why** you think the three towers held up different numbers of books. How was that possible? (use a drawing to help explain your ideas)



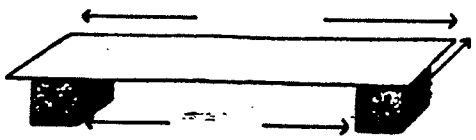
The number of corners.

NOTE: A **science sleuth** can use "x-ray vision" to **see** things that are so *tiny* or so *small* or *invisible* to other people. You can tell about or draw those things in your explanation.....

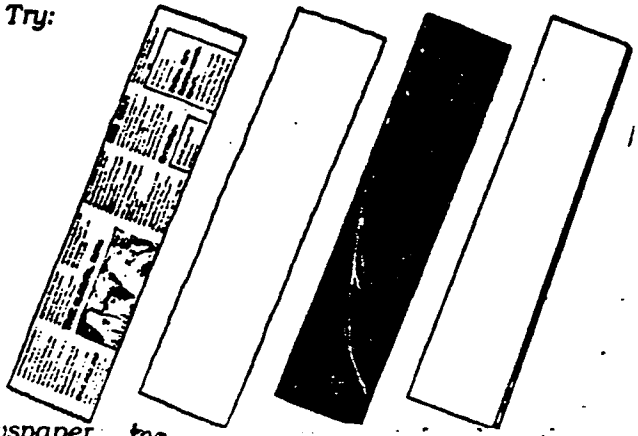
The stability of the base is affected by the sides shape

Does the Material from which a Bridge is Formed Affect its Strength?

Different thicknesses, different materials



Try:



Build a bridge like the one pictured above. Use one type of beam at a time. Carefully add weights until the beam buckles. Record the weight to see how strong the bridge is.

Load held	newspaper	tag paper	mounting board	corrugated cardboard
	held none	held two	held 92	held 96

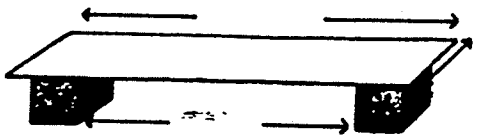
Answer:

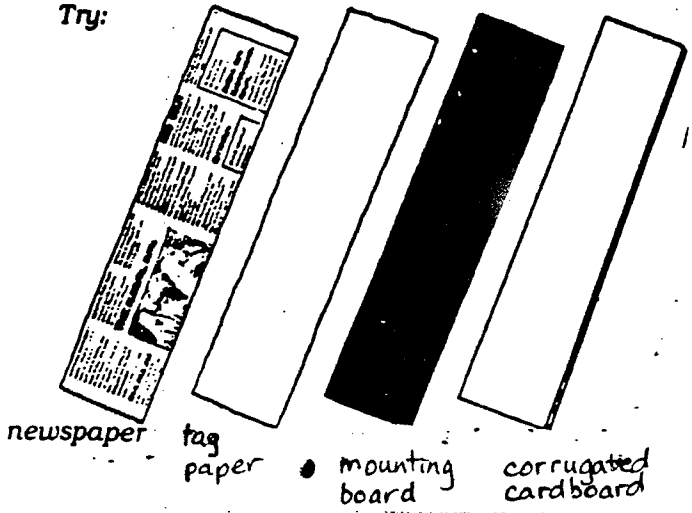
1. Strength is the ability to withstand force. Which material was used to build the strongest bridge?
   Why do you think this material worked best?
   The card board held the most. I think it worke the best because of the lining in the middle.
2. Can you suggest a way that one of the weaker materials could be strengthened (made stronger)?
   you could layer it.

DOES THE MATERIAL FROM WHICH A BRIDGE IS FORMED AFFECT ITS STRENGTH ? "

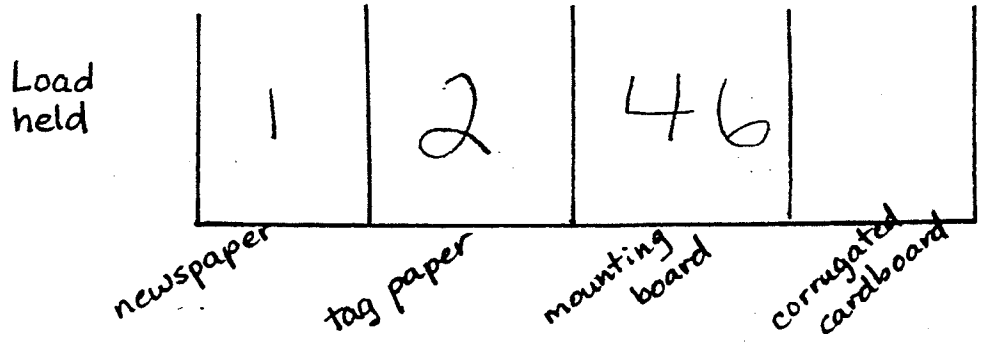
Try:

Different thicknesses, different materials





Build a bridge like the one pictured above. Use one type of beam at a time. Carefully add weights until the beam buckles. Record the weight to see how strong the bridge is.



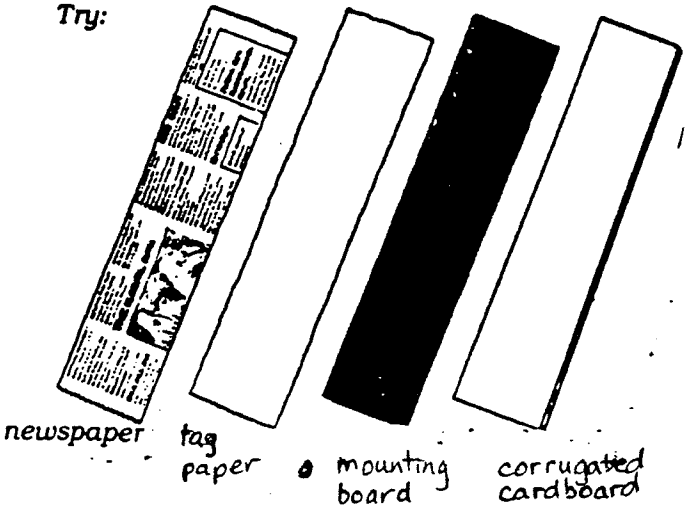
Answer :

1. Strength is the ability to withstand force. Which material was used to build the strongest bridge? It doesn't fall like the Why do you think this material worked best? It was heavy

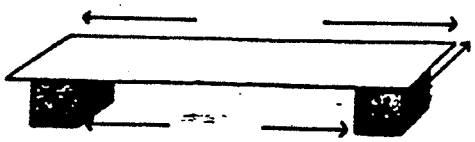
2. Can you suggest a way that one of the weaker materials could be strengthened (made stronger)? With one of the block under it

Does the Material from which a Bridge is Formed Affect its Strength?

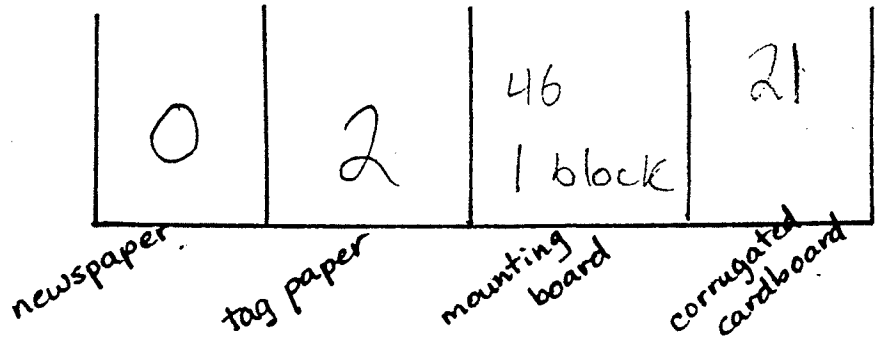
Try:



Different thicknesses, different materials



Build a bridge like the one pictured above. Use one type of beam at a time. Carefully add weights until the beam buckles. Record the weight to see how strong the bridge is.

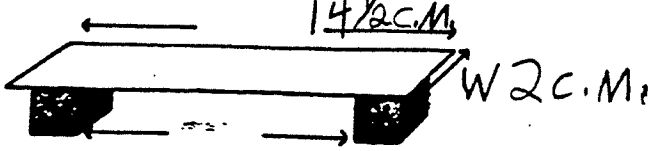


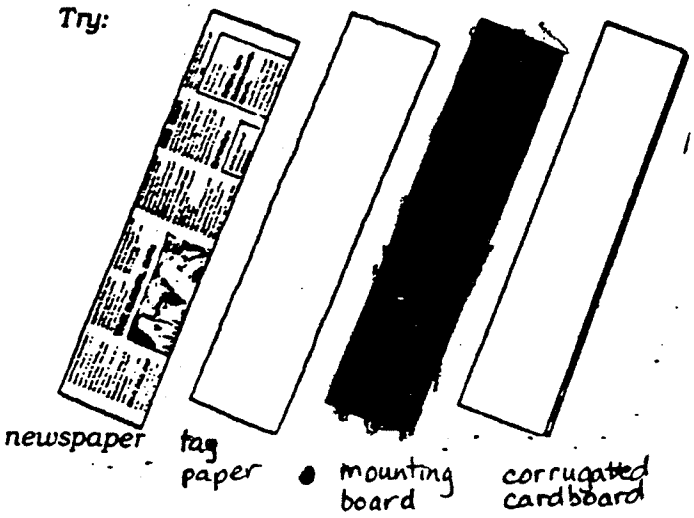
Answer:

1. Strength is the ability to withstand force. Which material was used to build the strongest bridge?
   Why do you think this material worked best?
   The mounting board was the strongest
   It worked good because it was hard & strong.
2. Can you suggest a way that one of the weaker materials could be strengthened (made stronger)?
   You could put lighter thing = on the paper.

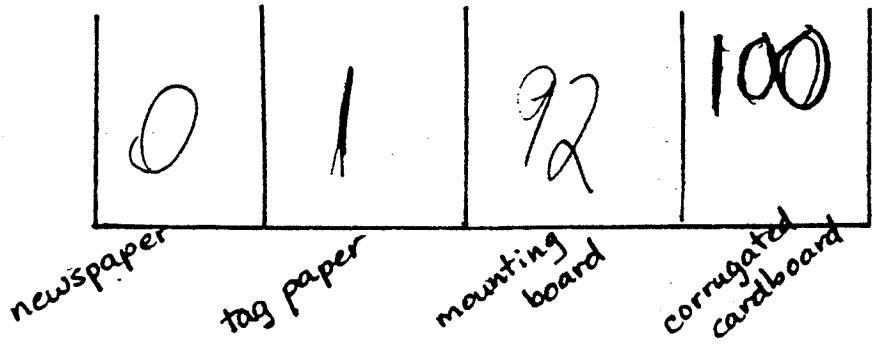
Does the Material from which a Bridge is Formed Affect its Strength?

Try:





Build a bridge like the one pictured above. Use one type of beam at a time. Carefully add weights until the beam buckles. Record the weight to see how strong the bridge is.



Answer:

1. Strength is the ability to withstand force. Which material was used to build the strongest bridge? The cardboa
Why do you think this material worked best? because it was not flexible.

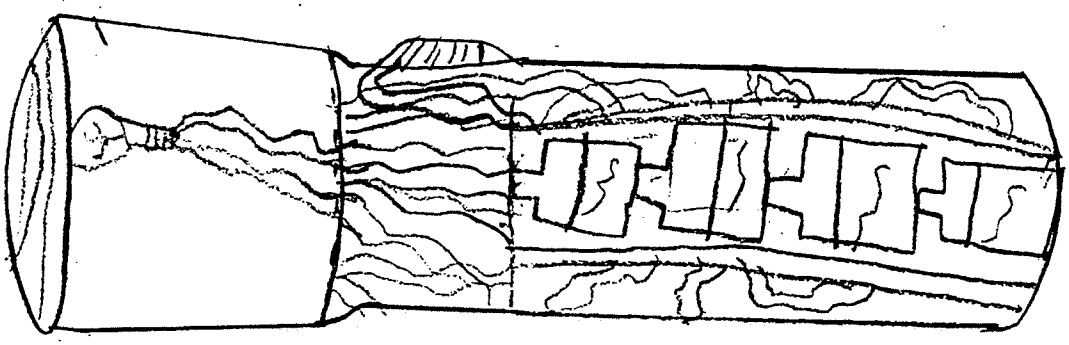
2. Can you suggest a way that one of the weaker materials could be strengthened (made stronger)?
no I could not.

Name: [illegible]

YOUR IDEAS about.....

Watch the two demonstertions performed by your teacher. Use your scientific imagination and your observing skills very carefully. In the spaces below you should start by telling **what** you saw. Then give an explanation **why** it happened that way. Tell **how** it happened. A **drawing** is a very good thing to help share your **ideas**. All answers are good answers...try to be as ***thoughtful*** as you can!

1. Think about what was happening to the lights. Explain how your teacher was able to do what she did. Why does it work this way? I think she was able to do that because she wanted to do that because she felt like it and it work a that way because her brain was telling her and to turn the light witch on and off.

2. Your teacher was showing you somethings about a flashlight. Can you explain why it worked the second time? It didn't work the first time because it did not have any power but it worked the second time because it had power from a battery.

In the outline shape below, **draw** what you ***think*** happens when a flashlight is working. ***Imagine*** that you are able to see things so small, just like using a powerful microscope! What is going on? You may want to explain your drawing too.