Science and Mathematics Education Centre

TEACHERS' PERCEPTIONS OF STUDENT UNDERSTANDING IN THE SCIENCE CLASSROOM

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DECLARATION

I declare that this thesis is my own account of my research and contains work that has not previously been submitted for a degree at any other university or educational institution

Adrienne T. Gibson

Name Signature

DEDICATION

This work is dedicated to science teachers across the nation who share the vision of teaching for understanding.

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and hopes for their students.

"The students had memorised everything but
they didn't know what anything meant"
(Feynman, 1985, p. 192)

ABSTRACT

In the USA, science teachers are challenged by the National Science Education Standards (NSES) to "select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners" (NRC, 1996, p. 30). While standards do not explicitly refer to constructivist learning theory, they are entirely consistent with the view that knowledge is a human construction, learning is based on prior knowledge, and students respond to their environment to build new understandings. Paralleling the NSES reforms, with their constructivist underpinnings, there is also a strong and often contradictory pressure on teachers to prepare students for national and state standardised tests. The need for teachers to balance these competing demands while trying to teach for understanding sets the context for this research.

The purpose of this research has been to focus on "how" teachers determine students' understanding and "why" they employ the instructional and assessment strategies that they do. Interpretive case studies of five teacher participants from one school district are used to describe how these teachers teach for understanding in the face of the competing pressures of conforming to the NSES and preparing students for success on standardised multiple-choice achievement tests. These case studies are analysed to identify common themes and propositions about teaching for understanding

The teachers in this study used a variety of instructional and assessment strategies. Their choices of strategies made a difference in the degree of understanding that their students achieved. Frequently, the teachers' decisions were affected by their grasp of science concepts and ideas about how students learned. When teaching for understanding, these teachers preferred informal knowledge of student understanding to that obtained from

standardised tests. Although subjected to conflicting pressures regarding how to assess for understanding, the teachers were able to disregard assessments that did not provide evidence of student understanding. This research has implications for the five teacher participants, myself as a researcher, the district as a whole and educators with an interest in implementing assessment strategies that foster student achievement for understanding.

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CHAPTER 1 - INTRODUCTION

"The students had memorised everything but
they didn't know what anything meant"
(Feynman, 1985, p. 192)

When Richard Feynman expressed his frustration over the manner in which his students in Brazil approached learning, he was also bemoaning the manner in which they had been instructed. Their memorized knowledge was the result of what has been identified as a transmissionist view of teaching and an absorptionist view of learning. During the last two decades, science education reformers have espoused an alternative theory about the importance of teaching for understanding, consistent with a constructivist view of learning.

Educators and psychologists have shifted their views of how students learn and many teachers have found themselves in the position of having to shift their personal paradigms regarding what constitutes student understanding. They also have begun to develop effective ways of assessing the levels of student achievement that have been defined as district, state and national science learning goals. Additional influences on the direction teachers have chosen to follow, as they developed their skills in instruction for and assessment of student understanding, were the development of national standards in science education as well as other content areas and the concurrent national concern with standardised test scores. My study is an attempt to identify what science teachers in one school district, receiving direction from different sources, are saying about their students' level of understanding and how those same teachers assess student achievement to inform themselves of that understanding. I have an additional interest in how they have come to terms with the seemingly contradictory expectations that they are directed to meet. My interest in this topic has been generated by my many years of work in the district which is the location of this study. I have a personal investment of many hundreds of hours spent trying to improve the

science curriculum offered by the district and to support teachers that begin their careers in elementary classrooms with only a minimum of science education in their own backgrounds. My initiation of this research was an outgrowth of an ongoing district project to bring the kindergarten through twelfth grade science program into alignment with the National Science Education Standards (NSES), (NRC, 1996).

This first chapter presents an overview of the theoretical underpinnings on which my research has been based, a description of the setting, and an explanation of the dynamics of the district in which the study was conducted. A statement of the objective of the research is followed by a description of the process that led me to be interested in it. In addition I discuss the basis for my decision to use a qualitative research method, and briefly identify the procedures I followed in collecting and analysing data, the use of narrative analysis, case study story and connoisseurship. The chapter concludes with a discussion of the significance this study might have for those interested in what teachers are thinking and doing including those interested in educational reform, those who are teachers of teachers and, on a local level, the school district and teachers involved, as well as for myself.

Theoretical Context

Ideas promoted in the literature on teaching for understanding call for a change in science classes from teaching practices that focus on facts and procedures to practices that focus on the understanding of concepts. The NSES take the position that if teachers are to be prepared to teach for understanding, they will need to be prepared with greater knowledge of content and content specific pedagogical knowledge. They will also need a clear understanding of how students learn (NRC, 1996).

Constructivist learning theory asserts that all learning is an active process of constructing meaning and that knowledge is a human construction that cannot be transferred as a complete assemblage from one individual to

another. From a constructivist perspective, students are understood to use prior knowledge and understandings to build new knowledge and understandings. Constructivism, as a theory of how learning is achieved, does not delineate a blueprint for action on the part of teachers. However science teachers, using a constructivist referent, provide opportunities that challenge students' existing knowledge and help them develop new understandings of the world around them. Much has been written about strategies that teachers might use if they are teaching for understanding and using constructivism as a referent. (Brooks & Brooks, 1999; Prawat, 1989; Tobin & Tippins, 1993; Windschitl, 1999; Yager, 1991). If instruction is designed using the tenets of constructivism there must be a concurrent shift in strategies of assessing student understanding to those which are consistent with the student achievement outcomes of a constructivist environment (Holmes & Leitzel, 1993).

While the National Science Education Standards (NSES) do not specifically espouse any one model for instruction many of the teaching standards proposed in the NSES are paralleled in strategies included in discussions of the constructivist model of learning. The authors of the NSES (NRC, 1996) consider the standards for teaching paramount to the standards for professional development, assessment, content, programs and systems. The standards for teaching are placed before the others in the NSES document as a means of highlighting the importance of teachers in science education (NRC, 1996). Introduction of NSES in 1996 as well as the many state standards for science education that followed initiated a national concern for "what" is being taught in kindergarten through twelfth grade science classrooms. Within the same time frame of the adoption of state standards for science curriculum, there has been a concurrent increase in national concern for the degree to which students are demonstrating achievement on national standardised tests.

The Sonoran Foothills School District (SFSD), the setting of this research, has made a commitment to use national education content standards,

produced as a basis for revising their kindergarten through twelfth grade science curriculum. At the same time, in response to the community's perceived interest in standardised test scores, the district school board and administration adopted a set of goals that would elevate the status of the school district to that of number 1 in the southwest region and then number 1 in the nation based on standardised test scores along with other criteria. In order to achieve those goals, the SFSD also invested a considerable amount of money aligning its science (along with other content areas) curriculum and assessment instruments (i.e. criterion reference measures or CRM's) to National Science Education (content) Standards and the objectives of the Stanford 9 achievement tests. The district invested additional resources in the supplies and materials needed to support the new curriculum with hands-on labs and activities. The NSES (NRC, 1996) place standards for teaching before any of the other standards discussed in the document. However, there has not been a concern in the SFSD for the "who" that is teaching science or "how" and "why" specific instructional strategies are being used equal to the concern expressed for curriculum and assessment.

The ideas promulgated by the teaching for understanding literature require a shift in paradigm for teachers who have practiced a transmissionist form of instruction. Constructivist theory tells us that students build new knowledge on prior knowledge and understanding. Teachers seeking to teach effectively for understanding will need to develop an understanding themselves of how students learn as well as to develop content specific knowledge and strategies designed to facilitate student learning (NRC, 1996). Teacher behaviour, as suggested by the literature on teaching for understanding, including constructivist learning theory and the NSES, is one of the critical factors in student understanding of science content. In Chapter Two I have used literature on teaching for understanding, constructivist learning theory and the NSES to provide a conceptual framework for my research. I have also reviewed literature regarding assessment trends and the national concern for standardised test scores as a measure of student achievement. I have attempted, with this review to establish a description of the environment of

what appear at times to be contradictory directions in which science teachers find themselves working.

Research Setting

I conducted this research in the SFSD that, although still a relatively small district in numbers, has one of the most rapidly growing populations of any district in the state. The district has experienced an average 10%-12% growth in student population yearly for the past several years. The prediction is that the rapid rate of growth will continue with a five-fold increase in student population over the next ten years. The district plan is to open at least one new school each year in order to avoid overcrowding of the existing facilities and maintain a low class size in all grade levels. One implication of this rapid growth is the number of new teachers who will be hired during the next ten years. During the year that this study was completed, 40% of the teachers in the district were non-tenured with less than three years experience. Many of the new elementary level teachers have had only minimal training in science education. In several cases, teachers assigned to the middle grade (grades 6 - 8) science program did not have a science education background.

While planning for rapid expansion, the SFSD administration has also defined a set of academic goals for all students enrolled in the district schools. The first goal, entitled the "May 2000 Initiative," proposed that "by May 2000, Sonoran Foothills School District will be the No. 1 school district in academic achievement in the south-west region of the United States as demonstrated by the following: a) All students scoring in the 80th percentile on the Stanford 9 achievement test; and b) All students scoring at the 90th percent level or above on the district developed mastery tests - Criterion Reference Measurement (CRM) tests" (SFSD, 1997, p. 1). An extension of this first goal is the statement that:

> The primary goal of the Sonoran Foothills School District is to become the No. 1 school district in the United States by May 2003. Student performance on standardised tests, district Criterion Reference Measurement (CRM) testing assessments and student

> participation in extracurricular and co-curricular activities will be used to confirm this result" (SFSD, 1997, p. 1).

These goals were proposed by the SFSD superintendent of schools and agreed to by the governing board of the school district after a lengthy meeting, which included much public input. All district teachers were then expected to define and implement specific actions to increase their students' test scores and enable the district as a whole to meet the stated goals. Science teachers would not only be held responsible for student test scores on science CRM's but also considered equally responsible for their students' scores on the language arts and math tests as the teachers of those specific disciplines.

At the time of this study, the State of Arizona, the location of the SFSD, required that the Stanford 9 Achievement Tests be administered to all Arizona students in grades three to eleven. However, the SFSD chose to administer this test to all students in grades one to twelve and the Stanford 9 science test to students in grades nine to twelve. These tests consisted of multiple-choice questions covering reading, language arts and math in addition to the ninth through twelfth grade science. Results from the 1998-1999 state-wide norm referenced testing program showed that the SFSD students were scoring above county, state and national standards. The majority of the math and language arts average scores for grades one through twelve were in the 60th and 70th percentile ranges. None of the average scores for the grade levels was below the 50th percentile range.

Criterion reference measurement (CRM) testing of all students was mandated by the State of Arizona, in addition to the norm referenced Stanford 9 achievement tests (ARS, 1998). The SFSD began development of its Language Arts, Mathematics, Science and Social Studies CRM's during the 1997-98 school year. Each CRM test consisted of two parts. Part I, for each content area, was a multiple choice test of 50 items that tested 10 essential curriculum objectives, with five multiple-choice questions testing each objective. The essential objectives were taken from the district curriculum

and were identified as essential in that document. Objectives were designated as being essential because achievement of them was understood to be critical to student understanding of basic concepts (science in this study) at each grade level. Part II of each test was designated as a "teacher observable" test. Teacher observable referred to projects, lab activities, performances and authentic assessments. In most cases the Part II tests for each content area and each grade level had not been developed at the time this thesis was submitted.

Prior to and during the time that the SFSD district and the state were refining mandated tests, the district made a commitment to its teachers to extensively reorganise and rewrite the curriculum for the kindergarten through twelfth grade language arts, mathematics, science and social studies programs. In the case of the science curriculum, the NSES were used to align the content material designated for each grade level. Several in-service days were scheduled and teachers from all grade levels in the district worked together to bring the district grade level content goals and objectives into alignment with those proposed by the NSES. The goals and objectives, established during these sessions, became the adopted science curriculum for the district in 1998. Once the curriculum was adopted, the district focus shifted from writing curriculum to developing CRM tests which would be aligned to the new curriculum goals and addressing the need to meet the district goals by raising Stanford 9 test scores.

As the SFSD began the process of rewriting its kindergarten through twelfth grade curriculum, the State of Arizona also began developing mandated goals and objectives for each curricular area. In order to assure that each district in the state was implementing the state education standards, the state Department of Education developed a battery of multiple choice tests based on the state curricula. In September 1998, the state piloted its Arizona Instructional Measures (AIMS) tests with the understanding that that test would become mandated for 3rd, 5th, 8th, and 10th grade students and would serve as an exit exam for graduating seniors. At the time this study was

conducted, Arizona students and students in the SFSD were pre-tested in CRM's each fall and given Stanford 9, CRM and AIMS tests each spring. Tenth grade students that failed to pass the AIMS test were required to try again each succeeding year until they successfully passed each subtest. Success on each segment of the AIMS test was proposed to be a twelfth grade graduation requirement in the State of Arizona.

The SFSD put a clear emphasis on the importance of student achievement as evidenced by test scores. In order to reward teachers for their efforts to specifically address those scores, the district implemented an incentive pay plan that provided cash bonuses for teachers whose students achieved certain test score goals. The district also offered teachers an option of participating in a career ladder pay program that provided compensation additional to the teacher's contracted salary. Test scores again were used as one criterion for earning a career ladder stipend.

Many of the SFSD teachers took advantage of available district funding to participate in professional development opportunities in order to increase their instructional skills and thus increase student achievement. Some spent time on learning how to develop performance-based and authentic type assessments as well as how to implement portfolio assessments. Several of the district science teachers met in district funded workshops to discuss the changes in assessment practices suggested by the NSES. It is suggested in that document that assessment practices begin to emphasise:

1) assessing what is most highly valued;
2) assessing rich, well structured knowledge;
3) assessing scientific understanding and reasoning;
4) assessing to learn what students do understand;
5) students engage in ongoing self assessment and; teachers be involved in the development of assessments(NRC, 1996, p. 100). .

The document suggests that less emphasis be placed on:

1) assessing what is easily measured;
2) assessing discrete knowledge;
3) assessing scientific knowledge;
4) assessing to learn what students do not know;

5) assessing only achievement and
6) development of external assessments by measurement experts alone (NRC, 1996, p. 100).

Due to the rapid growth in student population many new teachers were hired in the SFSD just prior to the initiation of this study. Several of them were first year teachers with little or no experience teaching science. They began their first year teaching and were immediately placed in a position of responsibility for enabling their students to achieve high test scores on standardised tests. Science teachers were faced with a range of different messages about the importance of and the desired type of assessments they were to use when determining the effectiveness of their teaching as evidenced by student achievement. These teachers knew that the district goal involved specific effort to raise student scores on the state mandated standardised achievement tests. However, they are learning in workshops, professional conferences and from research based literature that there were more effective ways than standardized, multiple choice tests to assess student achievement when teaching for understanding.

Objective of Study

There appeared to be very different factors influencing science teachers in the Sonoran Foothills School District as they chose instruction and assessment strategies for determining the level of understanding students are achieving in their classrooms. National, state and local standardized tests were mandated and consisted primarily of multiple-choice, true false and matching questions that assess factual information at the lower levels of Bloom's Taxonomy (1971). Strategies suggested by advocates of teaching for understanding, constructivist learning theory and the NSES encouraged the use of assessment processes which addressed the outcomes of higher level thinking including the learning of major conceptual themes rather than factual information (NRC, 1996). In addition, NSES, which had been used in the development of the district science curriculum, provided guidelines for instructional and assessment practices.

My purpose in conducting this study was to focus on science teachers; "how" they developed perceptions of student understanding in their classrooms and "why" they employed the instructional and assessment strategies that they did. In a sense, each teacher in this study served several masters as he or she implemented strategies designed both to bring their students closer to the district goals and to enable them to develop conceptual understandings as emphasised in the NSES. My interest was in the teachers' own reflections on and perceptions of their students' success in making sense of what was taught and the actual strategies they used to develop those perceptions. I sought insight into dilemmas that teachers may experience as they make sense of science learning and assessment practices in their classrooms.

Research Story

My interest in teacher perceptions of student understanding was generated from the many discussions I have had over the years with teachers in my science department, my school and the entire school district. I had worked in the Sonoran Foothills Unified School District for the past twenty-six years in several capacities prior to initiating this study. My assignments included the roles of science teacher for grades four through twelve, science department chair at the high school level, science resource person for all grade levels, staff development resource person providing help with instruction and classroom management techniques, and interim principal of the high school. I am, currently, principal of a new middle school that includes grades sixth through eighth. I have worked with many colleagues over the past several years, trying to develop the structure for a coherent K–12 science program. My interest in the guidelines set by the NSES came from my own frustrations with the task of developing a program without research based guidelines on which to plan programs or enlist administrative support for program implementation. District science teachers welcomed the arrival of Benchmarks (AAAS, 1993) but the document did not address issues outside of curriculum content. The arrival of the NSES provided not only content

standards but also a delineation of expectations and responsibilities for teachers as well as local educational systems. This allowed us to garner the help we needed from our district administration for the provision of necessary supplies, materials and opportunities for the improvement of the science instructional and assessment strategies used by our teachers.

As I sought to improve my own instructional skills and then was placed in a position of responsibility for helping others to do the same, I became more and more interested in the ideas embodied in the teaching for understanding literature, constructivist learning theory and how an understanding of these ideas and the use of them to inform teaching would help our students become more successful. I began to see a relationship between constructivist learning theory, the teaching standards proposed by the NSES and, on a more practical level, the principles of learning identified in the Essential Elements of Instruction (Hunter, 1979). Madeline Hunter's ideas for effective instruction are taught to all teachers coming into our district and teachers are expected to use them as the basis for structuring all lessons. Each of these areas of research and thought presented guidelines for teachers that might be used to increase student achievement of conceptual understanding.

I changed my position in the district from that of a classroom teacher to that of an administrator and became very aware of the contradiction in direction that science teachers were receiving regarding effective instructional and assessment strategies. As an administrator I needed to support the district goal of increasing standardised test scores while, at the same time, needing to encourage the teachers that I worked with to develop strategies aligned with constructivist beliefs. I began to observe that the combination of influences on what teachers were doing in our district caused some confusion in expectations for how they were to accurately assess the level of understanding that their students were achieving.

The Research Process

I began this research with a general focus on the perceptions that five teachers had of student understanding and how those perceptions are developed. My interest was in what teachers were saying about their students' success. As the research continued, a process of "responsive focusing" (Guba and Lincoln, 1989) directed the focus to more specific claims, concerns and issues that the teachers themselves began to identify. It soon became clear that there were several topics of common interest among them relating to instruction and assessment of student understanding. Guba and Lincoln (1989) point out that the emergence of issues and concerns may occur as a result of the process rather be a predetermined focus of the evaluation process. As I began to analyse the data I collected during observations of and interviews with the teachers, I identified some of those claims as elements characteristic of each individual's practice. I discuss other concerns and issues that arose during my analysis of data, in individual chapters and then, again, in chapters nine and ten when I bring the five teacher participants together and discuss the outcomes of my research.

I chose to conduct this research in the form of qualitative and interpretive case study research, as that format seemed a comfortable extension of the discussions I had already held with many of the teachers involved. In addition, I had prior experience in collecting data through a somewhat open-ended, semi-structured interview process (Cobern, Gibson & Underwood, 1995) and found that, by allowing people to explore their own ideas in a conversational setting, they frequently revealed more personal insight that they did when asked to provide answers to a prepared set of questions.

After identifying five teachers who were interested in working with me for an extended period of time, I began to visit their classrooms. During that time, I alternated my observations between five different classrooms,

spending approximately 50 hours in each room over a twenty-week period of time. Data were collected by classroom observation, dialogue journaling with the teachers, individual semi-structured interviews and informal conversations with the teachers, review of sample student work and available standardised test scores and a final discussion of the NSES teaching standards and issues of concern that included all five participating teachers.

Once I had accumulated a substantial amount of data I started to develop case studies. Each case study includes a story centred on one unit of instruction in each teacher's classroom. The stories are constructed from the words of both the teachers and the students as well as from my own classroom observations. Each was designed to illustrate specific elements of instruction and assessment that I found to be characteristic of the individual teacher's instructional style. In addition, I prepared a self-reflective essay in each teacher's voice. These essays are commentaries on their personal perceptions of their own instruction and assessment practices. I have followed these pieces with a discussion of the elements I found to be characteristic of each teacher's practice and my observations and reactions to the teachers' practices and comments. Preparation of the case studies was an iterative process. Each teacher had opportunities to discuss their individual pieces and I made frequent returns to each classroom to check on the accuracy of my own observations.

I continued conversations with the teacher participants after the formal data collection phase of my research. Their own personal reflections during the process generated the desire to continue discussing several topics of common interest. I have included material from some of those discussions in both the data analysis section of individual chapters and in the final chapter of discussion and implications of my research. Each teacher is presented in individual chapters, Chapters Four through Eight. Chapter Nine brings the teachers together, provides an overview of the information gathered from each teacher and a discussion of what can be learned from the combination

of case studies. I report my findings in Chapter Ten and discuss their implications.

Significance

Organising a constructivist classroom based on the principles of teaching for understanding and then recognising student understanding is a challenging task for teachers who are concerned that their students achieve a conceptual level of understanding in their classes. The primary purpose of this study was to explore the beliefs and actions of teachers regarding their instructional and assessment strategies and to gain insight into how they developed their own perceptions of the level of understanding that their students were achieving. The five case studies should be of interest to scholars as they provide a rich description of what teachers are thinking and doing in the context of receiving contradictory directions about the appropriate strategies to use in the assessment of student achievement. The study should contribute to both theory and practice as it explores the many variables that affect the complex decision making responsibilities of classroom teachers. Constructivist theorists have offered varying descriptions of how classrooms can be transformed from traditional approaches to instruction. In order to approach the goals set by these theorists, educators must engage in dialogue about real classroom experiences and concerns about those experiences. An important part of that dialogue should be the logistical challenges that teachers face as they attempt to meet both the political and pedagogical goals that are presented to them.

The Sonoran Foothills School District has challenged its students and staff with the task of achieving very high academic goals as measured by external, multiple-choice standardised achievement tests. This study should be of direct benefit to the participants in the research and their students, the district as a whole and to me personally as I changed my role from teacher to principal within the district. The district benefited initially by having five teachers become more aware of their students' needs as they participated in

my research. It is my belief that, by identifying teachers' levels of understanding of effective science instruction as well as their background, experiences and goals, strategies can be developed that would enable both the teachers and the district as a whole to meet their goals.

In their discussion of "guiding principles" for improving teaching and learning, Baird and White (1996) emphasise the importance of purposeful inquiry, reflection and meta-cognition for learning with understanding. Each of the teachers who participated in this study benefited from reflective activities focusing on what they were doing, why they were doing it and what their students were understanding as a result of their instructional behaviours. As teachers develop an awareness of their students' understandings it would seem a logical next step that their students would ultimately benefit as well.

The district has defined the role of a principal primarily as an "instructional leader." As a new principal charged with setting up a new middle school, I have benefited by my participation in a variety of different classrooms with students of different ages and the exposure to different aspects of the district's curriculum that that experience has afforded me. My experience as a high school science teacher (the last 15 of 26 years of teaching) limited my working relationship with science teachers primarily to those that were heavily trained in their content areas. By observing and participating in classes at the middle and elementary school levels, I continued to gain an understanding of the needs of teachers with different levels of experience and training. By participating in reflective activities and being informed of the challenges facing teachers, I have begun to identify ways that I could support and encourage teachers who are willing to integrate constuctivist practices into their classrooms.

The district administration, as well as the teachers involved, need to determine the path they should follow in order to meet the district goals. By focusing on individual teacher's practices and identifying characteristic

elements of each practice that generate information for the teacher to use in assessing student understanding, I have provided an analytical framework that might be implemented in developing an understanding of where the starting point of that path might be. It is my hope that the information gained from my research will be useful in determining the appropriate path for both the district as a whole, individual teachers and students. I also hope that it will generate a dialogue among all interest groups within the school community.

Chapter Summary

In this chapter, I have identified the purpose of this research as my intent to focus on science teachers, "how" they come to an understanding of the level of student understanding in their classrooms and "why" they employ the instruction and assessment strategies that they do. Science teachers have received direction from contradictory sources in terms of how to determine the level of understanding that their students have achieved. I have been concerned with what the teachers were actually thinking and doing in light of the position of contradiction in which they had been placed. What were their reflections on and perceptions of their students' success in making sense of what was taught and how did they develop those perceptions.

The chapter includes an overview of the theoretical context in which my interest in teacher perceptions was generated. Teaching for understanding literature and constructivist learning theory informs us that science teachers should provide opportunities that challenge students' existing knowledge and help them develop new understandings of the world around them. Many concepts described by constructivist learning theory are also identified as important by the NSES (NRC, 1996). Constructivist learning theory and the ideas embedded in the NSES have been identified as the underlying causes for my interest in teachers and what they are thinking about student understanding. Chapter Two includes a discussion of the theoretical context of my interest in teacher perception of student understanding including a

review of literature on teaching for understanding, constructivism and a constructivist learning model, a discussion of the development of the NSES and the current national concern for standardized tests.

In this first chapter, I have also described the setting in which this research was pursued and the manner in which I conducted it. I have included a description of the Sonoran Foothills School District goals and the national, state and local trend to place strong emphasis on the results of standardized tests as an indicator of student achievement. The process of aligning the science curriculum with the NSES and developing state mandated district tests has resulted in teachers receiving direction from different sources about how to best assess student understanding. It was within this context of somewhat contradictory messages that I began to question what teachers themselves were doing. What were their perceptions of student understanding within their own classrooms and how did they develop those perceptions. I followed a process of qualitative and interpretive case study research. There were five teacher participants that worked with me. My collected data consisted of classroom observations, teacher journal entries, interviews and a taped discussion among all the teacher participants regarding the NSES. A detailed description of these methods will be developed in Chapter Three. Individual teacher's stories are presented in Chapters Four through Eight.

The rich description of teachers' beliefs about their own assessment practices provided by the case studies should provide material for dialogue between scholars as well as practising educators as to how classroom structures can shift to a constructivist environment in spite of the political challenges that teachers face. I hope that the significance of this research will be recognised by the impact it will have on science instruction and assessment practices within the SFSD as a whole, on the teacher participants and on me personally as a result of the many, thought provoking conversations I have had with them. I also hope that this research will have the effect of continuing to generate discussions among all the stakeholders in the district regarding

appropriate science instruction and assessment strategies. Teachers as a whole should have opportunities to share their insights, explore the tensions associated with their professions and draw on the richness of their colleagues experiences. The teachers involved in this research have benefited by reflecting on the effectiveness of their own instruction and assessment strategies and I have benefited as an administrator by listening to what the teachers had to say about their own practice. In the end it should be students who continue to benefit by the implementation of improved science instructional and assessment strategies.

CHAPTER 2 - LITERATURE REVIEW AND BACKGROUND INFORMATION

Overview

Different and sometimes contradictory political and pedagogical forces have influenced Sonoran Foothills School District science teachers, as well as science teachers across the nation. While teachers sought opportunities to develop strategies identified as effective for both instruction and assessment of student understanding, the SFSD administration and governing board challenged them to choose strategies that would increase student ability to achieve high scores on the state mandated standardized tests. The purpose of this chapter is, first, to provide a review of literature relating to the theoretical context for my research, teaching for understanding and constructivist learning theory. I briefly summarize the history of the development of national education standards and specifically the NSES and discuss the relationship between constructivist learning theory and the standards. Then I describe the current emphasis on standardised test scores in both the national and local political and educational arenas. These topics are included in this chapter because each has been either a direct or indirect source of direction given to teachers in the district. My intent in this literature review has been to develop a context that explains the position in which science teachers find themselves as they work in the SFSD. It is a position that is shared to some degree by science teachers across the nation. It also has been my intent in this chapter to provide a conceptual framework for my research. The literature that I review will serve as a referent for analysis and discussion of the data I collected during my observations of and conversations with the teacher participants in my research.

My interest in teacher perceptions of their students' understanding developed as I became familiar with the teaching for understanding literature and constructivist theories and began to see how this research provided a theoretical foundation for the NSES. I wanted to know how teachers were

resolving the contradictory needs of teaching for understanding and teaching for student achievement of high standardised test scores. The goals set by the district school board members would have little effect on teacher behaviour and, consequently, student achievement of understanding if the teachers did not accept the goal as their own. It was my belief that both the teachers and the district administration would be able to reach their goals more quickly if an understanding could be developed of what the teachers were thinking and doing about student achievement and assessment. The value of any form of assessment depends on its effective implementation, the purpose for which it is used, and the skills of the people using it. It was also my belief that by understanding what teachers were thinking and doing, educators in a variety of positions could begin to provide the support teachers needed to effectively teach for understanding.

Teaching for Understanding

Teaching for understanding dramatically differs from the traditional view of teaching as an act of transmission and learning as an act of absorption. As part of the Science as a Way of Knowing project, Peter Volpe (1984) discussed the shame of science education as being the inability of science students to appreciate the scope and meaning of science partly because of the traditional passive role students play as note takers and regurgitators of information. In agreement, Roth (1989) described the traditional method of teaching science as being focused on textbook instruction and didactic teaching. The instructional pattern typically consisted of reading the text and answering factual questions posed by text or teacher. Demonstrations and hands-on activities were added to provide interest and foster motivation but did little to develop conceptual understanding or higher level thinking. Science and scientific thinking was viewed as the acquisition of facts (Roth, 1989).

Many science reform initiatives have centred on the need to teach science for the understanding of concepts rather than for simple recall of facts without

meaning. A conceptually oriented view of teaching might include three attributes that have been identified by Prawat (1989) including focus and coherence, negotiation, and analysis and diagnosis. He sees a direct relationship between a teacher's content and pedagogical knowledge and the ability of a teacher to focus instruction on a limited set of major ideas and to provide coherence in the way ideas are integrated in discussions that link different segments within lessons and across different lessons. Prawat uses the term negotiation to mean, "overcome obstacles skilfully" and views a teacher's role in part as one of developing a negotiation of meaning within the classroom interactions between teacher and students. That negotiation of meaning should involve moving students in a certain direction by pointing out obstacles and working with them to overcome those obstacles. Prawat (1989) sees a direct link between the ability of a teacher to provide focus and coherence with instruction and the ability to structure classroom discussions that would enable students to negotiate successfully to deeper understandings. The third attribute that Prawat uses to characterise teaching for understanding is analysis and diagnosis of student understanding throughout lessons. Analysis of student learning should serve as the basis of instructional planning. Ongoing assessment of student understanding by the teacher provides information as to the obstacles students are encountering while negotiating their way toward concept understanding. Each of Prawat's attributes of teaching for understanding is entwined with the others and each describes a dramatically different mode of teaching than traditional transmissionist practices (Prawat, 1989).

Talbert and McLaughlin (1993) identify three characteristics of teaching for understanding that extend those posed by Prawat:

1) A conception of knowledge as constructed by the learner and therefore situated in the context of prior knowledge, skills, values and beliefs;
2) A conception of teachers as guide, as co-constructor of students' knowledge; and
3) A conception of the classroom as a community of learners, in which shared goals and standards, an atmosphere of mutual trust and norms for behaviour support students in taking risks

> and making sustained efforts needed in serious learning. (p.169)

These authors see the "vision of teaching for understanding, of students and teachers engaged in constructing new knowledge" as promising "the kind of learning for both teachers and students that many educators and researchers judge most valuable to individuals and society" (McLaughlin & Talbert, 1993, p. 7). In short, the aim of teaching for understanding is to enhance higher order thinking skills in students. McLaughlin and Talbert (1993) go on to explain that teaching for understanding requires new learning for teachers, comprehensive in-depth knowledge for teachers, pedagogical content knowledge, knowledge of the learner, an understanding of when the use of constructivist forms of teaching are appropriate and new strategies of assessment of student work.

A question at the heart of teaching for understanding is "what is understanding." Members of the Teaching for Understanding Project, a 5-year collaborative effort between researchers at the Harvard Graduate School of Education and Boston area teachers, investigated the nature of understanding and developed and tested an approach to teaching for understanding. This group defined understanding as the "ability to carry out a variety of performances that show one's understanding of a topic and, at the same time, advance it" (Perkins & Blythe, 1994, p. 6). The framework suggested by the Teaching for Understanding Project as an approach to developing the ability to teach for understanding includes: identifying generative topics that are central to the discipline, accessible to students and connectable to diverse topics inside and outside the discipline; understanding goals in order to create a focus for the learning; expecting student performances that demonstrate understanding both embedded in and as culminating activities of an extended unit of learning; and conducting ongoing assessment in order to provide students with criteria for learning, feedback and opportunities for learning from the beginning and throughout a sequence of learning (Perkins & Blythe, 1994)

Good science teachers have been defined as those that teach for "deep understanding", using "students' ideas about science to guide lessons, providing experiences to test and challenge those ideas to help students arrive at more sophisticated understandings" (Wildy & Wallace, 1995, p. 143). Teachers involved in reforming their teaching strategies must be reflective in questioning how their behaviours and actions will negatively and positively affect the learning of their students. Those good science teachers will need to exemplify constructivist teaching practices as they undertake the task of teaching for understanding (Yager, 1996).

Constructivist Learning Theory

Yager (1991) calls for teachers to adopt constructivist teaching practices if they are to teach for understanding. McLaughlin and Talbert (1993) concur with Yager. Von Glasersfeld defines the foundational principles on which constructivist theory is based as being:

1) Knowledge is not passively received through the senses or by way of communication. Knowledge is actively built up by the cognising subject.
2) The function of cognition is adaptive, in the biological sense of the term, tending towards fit or viability;
3) Cognition serves the subject's organisation of the experiential world, not the discovery of an objective ontological reality. (1990, p. 22)

Referring to von Glasersfeld's ideas, Yager (1991) describes constructivists as those who "do not consider knowledge to be an objective representation of the world. For them, knowledge refers to conceptual structures considered viable by epistemic agents. Modern science offers a way for us to interpret events of nature and to cope with the world" (p 54). Teachers of science need to "understand that knowledge cannot be simply transferred by means of words without first an agreement about meaning and some experiential base. Knowledge is not acquired passively. Learning is the product of "self-organisation and reorganisation" Yager, 1991).

Constructivism is not a method or instructional strategy. It is a theory about how learners come to know something. Constructivists reject the view that knowledge is fixed and independent of the knower. They favour the idea that knowledge is produced by the knower from existing beliefs, new experiences and ideas encountered. Knowledge is tentative and can never by viewed as absolute (Airasian & Walsh, 1997).

Constructivism, as a set of beliefs about knowing and knowledge, can be used as a referent for teachers to determine the learning potential of a given classroom situation. A constructivist view of learning has consequences not only for how one views an understanding of science content but also for how the role of a teacher is perceived. Von Glasersfeld (1992) differentiates between training and teaching with a constructivist orientation. "The teacher is viewed as a facilitator of knowledge and not as a person that transfers knowledge to the brains of students" (Duit & Treagust, 1995, p. 52). Teachers need to decide what experiences should be provided in order to facilitate learning and how the learner can represent what is already known to give meaning to the new experiences. In the role of facilitator the teacher needs to ensure that students are "provided with opportunities for quality learning experiences that provide a solid base for learning with understanding" (Tobin & Tippins, 1993, p. 10).

If teachers are to mediate the learning process they also must have ways of determining the extent to which students are understanding what they are learning (Tobin & Tippins, 1993). Tobin and Tippins (1993) define the most significant role of a teacher, from a constructivist point of view, as that of evaluating student learning. Teaching in its new role aims at determining the student's conceptual fit with the consensual domain of a particular field, a fit which, from the teacher's perspective would constitute understanding. Understanding cannot be demonstrated by the presentation of results that may have been acquired by rote learning. It would seem that thinking, conceptual development, understanding, and meanings are located in someone's head and not directly observable. Teachers using constructivism

as a referent will have to confront the need for establishing criteria or standards for determining understanding on the part of their students. The development of standards and criteria for evaluation that are clear but allow variance is paramount for teachers who are teaching for understanding and implementing a constructivist learning model in their practices (Tobin & Tippins, 1993).

National Education Standards

Education standards have been widely embraced as a key to school improvement and increased student achievement. Forty-nine out of fifty states (Iowa is the exception) have produced their own standards documents. At the national level documents have been produced for the opportunity to raise student achievement and improve education equity across the races and social classes. Darling-Hammond and Falk (1997) argue that content and performance standards can be a basis for high quality performance assessments that provide information about how students and schools are doing. That data could then be used to inform teaching strategies, to trigger support for student learning and to evaluate school practices. The premise of standards based reform is intuitively sound if school communities can agree on what students should know and be able to do; if on-going assessment can be used to measure progress toward the standards; if assessment results used to guide teaching and learning; and if educators and students are held accountable for learning. Given these conditions all students would have opportunities to excel (Kennedy, 1997).

The development of standards has not been without some controversy. Standards driven reforms offer threats to students, teachers and administrators that pose obstacles to standards driven success for student achievement (Cross & Joftus, 1997). Some educators have suggested that data gathered from performance assessments might simply be used to allocate mechanically determined rewards and sanctions and to determine automatic grade retention (Darling-Hammond & Falk, 1997). Others caution

that standards promise easy, quick but superficial solutions to the very complicated process of reforming education. Too little mention is made in many of the content standards documents of minority groups and at-risk students. Cost issues are not addressed and there seems to be a trend in the content standards to emphasise rote memorisation rather than critical thinking (Berube, 1996). Should a school or district decide to use standards as the framework on which to build or revise its curricula, many other related activities must change. Teaching to the test, for example, will become teaching to the standards, teacher in-service will need to be focused on appropriate teaching techniques for implementing the standards, student assessment tools will need to be created that reflect the values espoused by the various standards. Schools will need to plan on a long-term investment in their personnel if student achievement is to be the end result of shifting to standard based goals (Lewis, 1997).

Many educators see the publication of *A Nation at Risk* as the beginning of the movement towards the development of content standards (National Commission on Excellence in Education, 1983). After this negative review of the American education system, educators began to examine the existing policies and programs in place with the intent of increasing the rigor of the education provided for American young people. Those in favour of reform also saw a link between the financial security and economic competitiveness of the nation and our educational system (Marzano & Kendall, 1997). Publications, conferences and initiatives such as *A Nation at Risk* (1983), *Project 2061* (1985), *To Secure Our Future* (1989), *Goals 2000: Educate America Act* (1989), *Science for All Americans* (1993), *Benchmarks for Scientific Literacy* (1993), *National Education Standards Improvement Council* (1995), and *National Science Education Standards* (1996) have preceded and lead to the current movement towards the use of national science content standards, and others, as a tool for improving student achievement.

At the time of this study, various groups and professional organisations had generated standards documents for all the major curricular areas. These groups have produced one or more documents identifying content standards in their respective content areas. The content areas now supplied with a resource of content standards include: Science, Foreign Language, Language Arts, History, Arts, Health, Civics, Economics, Geography, Physical Education, Mathematics, and Social Studies.

The National Council of Teachers of Mathematics (NCTM) led the way in using national standards as a tool to generate widespread educational reform. The NCTM standards created a coherent plan for mathematics education from kindergarten through grade twelve. The result of 40 states accepting this document has been instructional reform, which encouraged movement away from rote memorisation and repetition and towards an increasing emphasis on problem solving, math applications and the use of hands-on approaches to math. In 1992, Ravitch observed that math assessment was changing, textbooks were changing and teachers were being retrained (Ravitch, 1992).

The *National Science Education Standards* (NSES), published by the National Research Council, were made available to the public in 1996. This document includes standards for science teaching, professional development of teachers, assessment in science education, science content, science education programs and, science education systems. For the vision of science education to be attained, according to the document, the standards in all six sections need to be implemented.

The NSES Professional Development Standards call for the integration of knowledge about science with knowledge about learning, pedagogy and students (NRC, 1996). In Prawat's discussion of the attributes of teaching for understanding, he emphasises the importance of having teachers with both knowledge of their field as well as pedagogical knowledge specific to their field (Prawat, 1989). Teachers of science according to the NSES must have

a strong foundation in learning theory. Effective teaching requires that teachers need to know what students at different ages are likely to know, understand and be able to do, predict typical misunderstandings as well as understand themselves how students of different backgrounds, experiences and motivations, learning styles, abilities and interests learn science. Inquiry into practice is considered to be essential for effective teaching (NRC, 1996). These ideas mirror Prawat's definition of the importance of having focus and coherence when teaching for understanding.

The NSES do not specifically espouse any one instructional model as being most appropriate for implementing the ideas described in the NSES document. They do, however, state that:

> Effective teaching requires that teachers know what students of certain ages are likely to know, understand and be able to do; what they would learn quickly; and what will be a struggle. Teachers of science need to anticipate typical misunderstandings and to judge the appropriateness of concepts for the developmental level of their students. (NRC, 1996, p. 62)

With reference to statements such as this found within the NSES, Rodriquez (1997) identifies constructivism as the "driving theory of teaching and learning throughout the document" (1997, p. 30). Although the term "constructivism" does not appear in the standards, there are many additional references in the NSES document that are consistent with this theory, such as "to teach science as portrayed in the Standards, teachers must have theoretical and practical knowledge and abilities about science, learning and science teaching" (p. 28), "in addition to solid knowledge of science, teachers of science must have a firm grounding in learning theory - understanding how learning occurs and is facilitated" (p. 62), and "effective teachers design many activities for group learning, not simply as an exercise but as collaboration essential to inquiry"(p. 50). These statements support constructivism as the theoretical framework for the teaching and learning of science in schools (Rodriquez, 1997, p. 30).

National Concern for Standardized Test Scores

Concurrent with the national movement to promote the development of standards of education in each of the curricular areas commonly taught in public schools, there has been an increase of interest in the use of standardised tests as a measure of student achievement. While the federal government provided funding for the development of national standards in education it has been left to the states to manage the development of assessments that would be aimed at individual achievement (Ravitch, 1993). Reports about the demise of traditional approaches to assessment are unfounded. Ryan and Miyasaka (1995) report that norm-referenced and criterion referenced multiple-choice tests of student achievement are still the most common form of large-scale student assessment. The use of alternative assessment practices is increasing but the objective format standardised tests still have many useful functions and will continue to be used for some time. The most common purposes of state testing are accountability for the schools and school districts, instructional improvement, and program evaluation. Less common purposes are student diagnosis, placement and high school graduation. All but one state tests students in mathematics and language arts, primarily in grades four and eight, with many states developing high school exit exams as well. Many states also test students in science and social studies. Multiple-choice tests are still the most common format (70%); performance assessment (28%) and portfolios (18%) are used as well (Ryan & Miyasaka, 1995). In contrast to the pattern of assessment external to the classroom, a questionnaire given as part of the National Assessment of Educational Progress (NAEP) 1992 mathematics assessment found that at the classroom level the nonmultiple-choice testing formats were predominant (Barton & Coley, 1994).

During the past several years there has been much national, state and local discussion about how to shift reliance on tests that are multiple choice, requiring standardised answers, to tests that gauge student achievement by assessment of performance. In the past, the phrase "teaching to the test" was

an anathema to educators. It put to much emphasis on standardised tests that, in some minds, were poorly constructed, irrelevant to the curriculum and the process encouraged cheating. A new perspective is emerging today and the phrase "curriculum alignment" has crept into the education vernacular. It means teaching knowledge and skills that are assessed by tests designed largely around academic standards set by states (Bushweller, 1997).

The State of Arizona, the location of the district where this research was conducted, had developed a series of "high stakes" tests that were to be administered during the fifth, eighth and tenth years of a student's education. It was intended that all portions of the tenth grade test would have to be passed prior to a student's graduation from the twelfth grade. The tests were an offshoot of the national push for states to adopt clear academic standards. The Arizona State Superintendent of Public Instruction, Lisa Graham Keegan believed that "if you don't test it, it doesn't get taught." Countering an argument from an Arizona State University professor that standardised testing is a political not an educational issue resulting in instruction that becomes "test coaching and test preparation," Keegan replied that, "You can't teach to a test without imparting knowledge" (Ingley, 1998).

The knowledge and skills that are tested on standardised tests should be aligned with the curriculum taught if the classroom time taken to give the tests is not to be considered a waste by teachers. Standardised test publishers try to approximate the curricula of as many states as possible and share the list of objectives measured by their tests (Powell, 1999). If state and local educational organisations have established curricula with goals that overlap those of a standardised test then teaching to the test becomes inevitable. "There is a big difference between teaching to the test and teaching the test" (Bushweller, 1997).

If "teaching to the test" is to mean doing a better job of teaching for understanding of science concepts, procedures and problem solving strategies then, according to Shavelson, Carey and Webb (1990), we need to

develop new kinds of achievement indicators. The multiple choice format of most standardised tests prevents us from measuring some of the things that science teachers think are important. An educator might be interested in, for example, how well a student develops an answer to a question, rather than simply knowing whether a student selects a correct alternative from four choices. In order to provide educationally useful indicators of science achievement, tests scores should reflect students' conceptual understanding and problem solving skills as well as their ability to apply their knowledge and understanding to a new situation (Shavelson, Carey & Webb, 1990).

Chapter Summary

The focus of this chapter has been the issues that science teachers in the Sonoran Foothills School District have had to consider when planning instructional strategies for and assessment of student's understanding. Those issues include the ideas embedded in the teaching for understanding literature, constructivist learning theory, NSES and the current national and local trend to emphasise the importance of standardised test scores as indicators of student achievement. My own increasing awareness and understanding of each of these topics generated my interest in teacher perceptions of student understanding.

Both educators and researchers have held the vision of teaching for understanding as the goal of education. This vision involves teachers moving away from a transmission of knowledge instructional model and adopting newer instructional strategies that encourage student to become active participants in the learning process. Constructivism provides the theoretical basis for developing teaching for understanding instructional strategies. While not an instructional model itself, constructivist theory has led to a constructivist model of learning. Much of the philosophy of learning, espoused by the NSES, finds support in constructivist learning theory.

The NSES were produced in concert with other educational standards documents over the past several years. These documents were used as the basis of an extended curriculum development project in the SFSD A review of the NSES has been included in this chapter because many of the district's science teachers used them specifically when writing the district science curriculum. The teachers in this study did not express having any more than a passing knowledge of the NSES document. However, other science teachers in the district continued to use them as a guide to their own classroom practice.

Although advocates of teaching for understanding, the constructivist learning model and the NSES support a variety of performance based assessments of student achievement, the current trend in both the political and educational arenas is to emphasise standardised test scores. At the time of this research the SFSD students were mandated by the state to participate in three different standardised testing programs annually. Each of these programs involved multiple choice style tests. This was a consideration that each of the teachers in the study had to take into account when planning for instruction and assessment. It was the direction of the district administration that any instruction and assessment strategies implemented in the classroom ultimately result in an increase in standardised state and national test scores. It was within the context of each of these contradictory sources of direction that the teachers in the district operated. Teachers in the district were placed in the position of having to resolve the contradictions as they chose strategies to inform themselves of their students' achievement.

I have used this literature review to develop a context that explains the position in which SFSD science teachers found themselves at the time of this study and to provide a conceptual framework for my research. The literature reviewed in this chapter has served as a referent for analysis and discussion of the data I collected during my observations of and conversations with the teacher participants in my research.

CHAPTER 3 - METHODOLOGY AND METHODS

Overview

I began this research with a general focus on the perceptions that five teachers have of student understanding. This chapter includes a description of the processes I chose to use in seeking to understand how science teachers develop perceptions of student understanding. My interest was in what those teachers were saying about their own students' success as they were attempting to both teach for understanding, a professional goal, and teach for high scores on standardized tests, the district and state goal. Within this chapter I discuss the basis for my decision to use a qualitative case study research method, narrative analysis and case study story, connoisseurship, and the specific procedures I followed in collecting and analysing my data. I also identify issues of my own concern relating to the research process and explain how I resolved them.

Qualitative Case Study Research

I have chosen to use a qualitative and interpretive case study research approach for my research because that format seemed a comfortable extension of the discussions I had already held with many of the teachers involved. Within the context of case study research I selected an approach that was exploratory and descriptive in nature (Marshall and Rossman, 1995). My intent was to investigate little known phenomena relating to teacher understandings and to describe those phenomena. Such an approach lends itself to gaining insight, discovery and interpretation rather than hypothesis testing (Merriam, 1998). Merriam characterises case study research as being "particularistic, descriptive and heuristic" (p. 29). This research project is particularistic, meaning that the case "focuses on one phenomena or concentrates attention on the way that particular groups confront specific problems" (Merriam, 1998, p.29), because the focus is centred on the one phenomena or problem of each teacher's developing perceptions of student understandings while balancing contradictory

pressures. The research is descriptive because the end product attempts to provide a rich illustration of the phenomena under study in each case (Merriam, 1998). It also is descriptive because it has attempted to identify the sources of teacher perceptions and explain how they interact (Marshall & Rossman, 1995). The research is heuristic as it attempts to illuminate the reader's understanding of the phenomena under study (Merriam, 1998).

Yin defines a case study as "an empirical inquiry that investigates a contemporary phenomena within its real life context" (1994, p. 13). In this study, the contemporary phenomenon is teacher perceptions of student understanding within the real-life context of the science classroom. The study falls into the category of a collective case study as I have studied several cases jointly in order to inquire into the phenomena of teacher perceptions. Individual cases were chosen because I believed that understanding them might lead to a better understanding of a larger collection of cases (Stake, 1994). When I selected the cases I did not know if they would manifest any common characteristics that might be used to understand a broader set of cases. Firestone (1993), in his description of case-to-case studies, suggests that while the transfer of understandings from one case to another should be done by the reader, it remains the researchers responsibility to provide a description of each case that is rich enough in detail to enable the transfer to occur. It was not my intent to use these case studies to make "grand generalizations" (Stake, 1994) but to see the results as a small step toward understanding on a general level the strategies teachers use to assess student understanding and their success in doing so.

Yin (1994) recommends that when case study research is done, multiple sources of evidence should be used in order to allow an investigator to address a broader range of attitudinal and behavioural issues as well as allow for the development of "converging lines of inquiry" by providing several different sources of information and "multiple measures of the same phenomena" (Yin, 1994, p. 92). I have used multiple methods of data collection in this study including participant observations, dialogue

journaling, semi-structured interviews and a final group discussion by all participants.

Participants

Teacher participants were chosen from a group of approximately twenty-six volunteers. I wanted to work with a group that represented several different age levels as well as varying years of experience. I also hoped for a balance of males and females but in the end was not able to achieve this in the selection process. In fact, I had only two male volunteers and chose both because they had different amounts of experience and taught different grade levels. One of these teachers withdrew his participation at the beginning of the project due to other commitments. It was important to me that the selected teachers not be ones with classroom management problems or other classroom issues that might interfere with the focus of my study. Consequently, I worked with the different district principals to identify the final five teachers chosen. These teachers were not necessarily identified by their principals as being skilled in teaching science. Rather they were recommended because of their reliability and consistency in the classroom and their interests in continuing to grow in instructional skills.

Once the teachers were chosen I informed them that the district would be awarding them a small stipend for participation in my project. It was the opinion of the assistant superintendent that they would be improving their instructional skills by the acts of self-reflection involved in the research process. She felt it to be appropriate to support them in their efforts as well as mine (I did not receive any stipend). Participating teachers signed a release form allowing me to use the data I collected and giving them the right to remove themselves from the project if they chose. They were told that I would be using pseudonyms in the final report in an attempt to disguise their identity. I, also, would be changing the name of the school district. We discussed the fact that, in spite of my efforts to maintain some anonymity for them, it was still possible that they could be easily identified if someone

chose to do so. In order to be awarded the stipend the teachers would have to complete a minimum of 25 hours of observation with me, participate in a dialogue journaling process on their instruction and assessment strategies, complete two semi-structured interviews and participate in a full day workshop on science instructional strategies and the NSES (1996).

Data Collection

Yin (1994) proposes three principles of data collection as overriding considerations when conducting case study research. They are as follows:

1) use multiple sources of evidence in order to develop converging lines of evidence or triangulation;
2) create a case study database as a way of organising and documenting the data and;
3) maintain a chain of evidence to increase the degree of reliability of a case (1994, p. 79).

I have used several different data collection techniques as I have conducted this research. I began as a participant observer in the classrooms of each of the teachers involved, scripting as much of the classroom dialogue as possible. The teachers kept journal notes of the classes that I observed and sent their notes to me soon after the observations. I would send them back with my own questions about their lessons. In this manner we maintained an ongoing dialogue about the classroom proceedings. The teachers frequently included notes in their journals about lessons leading up to and immediately following the ones that I observed. I had frequent opportunities to discuss particulars of several lessons with the teachers immediately following the lessons themselves. We attempted to schedule observations in order to allow for this immediate follow-up conversation but it wasn't always practical.

The teachers and I engaged in regular conversations throughout the data collection process, discussing a wide range of topics relating to particular lesson content, instruction and assessment strategies and other relevant issues. I also conducted two informal interviews and two semi-structured interviews with each teacher. Teachers provided me with samples of student work, class assignment sheets, quizzes and teacher generated test scores as

they came available. In addition, the district allowed me access to any of the standardised test scores that might be helpful. In the end these test scores proved to be of little value due to the format, but they served as support for some of the concerns that the teachers voiced. My collected data consisted of observation notes, journal entries, interview transcripts, discussion transcripts, and artefacts such as student papers, class-handouts, and test scores (Yin, 1994). All of this material was put in the category of field text, a body of information created by researcher and participant to represent selective aspects of the field experience (Clandinin & Connelly, 1994). As I gathered the various pieces of data, I continued to follow Yin's guidelines by organising my growing collection and making notations that would serve to aid me in the development of a line of evidence during the process of data analysis.

Classroom Observations

Much of my data came from the time spent in the classroom as participant observer. I balanced the two roles of participant and observer by choosing the appropriate role according to the lesson I was invited to join. In most cases I tried to observe several consecutive lessons so that my observations would include a broad spectrum of a teacher's actions. I took copious notes during "lecture" phases of instruction and, when invited to participate, put down my notebook and worked with the students in the classroom. I both listened to what the students were saying as they worked on the assigned activity and engaged them in conversation about the topic under study. My participation was generally limited to helping students get supplies, organize their activities, look up information in the library, spell and write words correctly and, in the case of the younger ones, provide assistance to the teacher as asked. My notes were always within reach during the times that I was participating in lessons and I frequently recorded relevant comments that the students made. Immediately upon the conclusion of a lesson I would record my recollections of everything that I could remember having happened. Shortly after each lesson I would send the teacher any questions

that I might want them to address as part of their journaling process. I would also send responses to questions that they raised in their journals. The teachers recorded their reactions to each lesson in a journal as soon after the lesson as they were able. We tried to schedule lesson observations so that they would occur just prior to a free period of time for the teachers but this was not often possible. Both the teachers and I chose which lessons I would observe. Our choices were made as a result of matching our schedules and trying to arrange for observation times that would include a series of related lessons. During the course of the data collection phase, I spent approximately 50 hours of time in each of five teachers' classrooms. I also returned to each classroom several times during the writing phase of this study when seeking to confirm some of the elements that I was attributing to each teacher's practice.

The role of participant observer has been described by Adler and Adler (1994) as depicting those who enter settings for the purpose of data gathering yet interact casually with subjects while engaged in their observational pursuits. When I first entered each classroom, I was introduced to the students and my reason for being there and my role as participant observer was described. The younger students were told that I was a friend of the teacher, I had had a lot of science teaching experience and I would be helping the teacher with the lessons. The older students were told that I was working on a research project on science education with the purpose of improving the programs we were offering them. Students were also told that I would be writing down everything that I could about the classroom. I would also be available to help them with their activities based on my experience as a science teacher. Generally, the older students had passing interest in the research process and were happy to enlist my aid in setting up some of their lab activities. Frequently they would bring me an extra class handout for my notes. The younger students accepted me readily as another source of help when they needed it and invited me to sit with them while I was taking notes but expressed little interest in what I was actually doing. Our goal was to have the students accept me as a part of the classroom, to

become accustomed to my presence and to ignore me unless I was actually helping them. Again, my familiarity with many of the students and the procedures of the school allowed us to accomplish that goal quickly. In most cases, after I was initially introduced, the students would greet me and then go about their own business as I would go about mine. There was occasional interaction between the teacher, students and me during lecture phases of instruction when someone asked a question that the teacher could not answer or when there was a discussion and an opinion from my quasi-administrative perspective was sought. The older students, particularly, knew that I was serving as a district staff developer as well as a planning principal during the period of time that I was collecting data. I also had taught a few of them in previous years and had served as interim principal of their high school the year before.

Interviews

Fontana and Frey discuss the goal of unstructured interviewing as being to establish rapport, allowing the researcher to see a situation from the point of view of the respondents to the interview "rather than impose the world of academia and preconceptions on them" (1994, p. 367). By rejecting an interview protocol of maintaining friendly objectivity I intended to implement the guidelines posed by Fontana and Frey by conducting rather loosely structured (semi-structured) interviews and, in so doing, generate the interest of the interviewees and engage in real conversation. Fontana and Frey suggest that the nature of this more relaxed interview style makes the interview more reliable and allows the respondent to express personal feelings. A more realistic picture is presented than that resulting from using traditional objective interview methods.

In addition to the many casual conversations that I had with the teachers about both the lessons I observed and their understanding of what had happened in those lessons, I conducted two semi-structured interviews. Each teacher participated in these interviews during the time period that I was

observing in their classrooms, one being held at an approximate midpoint of the classroom observation period and the second held at the completion of the observations. The length of the interviews ranged from one to two hours. Their interviews were all tape recorded and transcribed later. The teacher reflections reported in each individual case study chapter were compiled almost entirely from these transcriptions.

My purpose in doing this research was not to merely collect data but also to make inferences about what the teachers were saying and to understand how they informed themselves of student understanding in light of the contradictory directions they were receiving. I wanted to listen and be taught by the interviewees about their vision and understanding of what they do. Merriam (1998) supports the use of less formal or semi-structured interviews for qualitative research. These interviews may include a mix of more or less structured questions. The format allows the researcher to respond to the situation at hand and to issues emerging from the interviewee's concerns. Although I came to those interviews with questions that I had prepared in order to focus our conversation on the teachers' thoughts about instruction and assessment strategies, most of the questions were open ended. Some questions were generated from the previous, more casual conversations we had had. Each of these interviews had some aspects of a completely unstructured format, as I allowed the conversation that we engaged in to go in directions that the teachers wanted to pursue. My intent was to focus but not to restrict our interview conversations to the topics of instruction and assessment practices. I wanted each teacher participant to have an opportunity to continue exploring and sharing any of their thoughts on the ideas we had touched on during the interviews or during other conversations. I also included questions in the interview that would provide me some consistency of information as I began to compare the ideas of each participant to the others. An example would be the attempt of two teachers to define "understanding". As a result of their thoughts I asked the other three to share their definitions of the word as well.

Workshop and Discussion

At the end of the time in which I collected data, I hosted a workshop focused on the NSES (NRC, 1996) and what our district needed to do to bring us closer to the visions described in them. The teachers who participated in my research and several other district teachers attended that workshop and participated in a discussion of the NSES teaching standards. Marshall and Rossman (1995) advocate the use of focus group interviewing as part of a set of data collection techniques because it acknowledges that an individual's attitudes and beliefs do not form in a vacuum. People often need to listen to other people's opinions and understandings in order to form their own. An advantage to such a group is that new issues and topics of concern to the participants may emerge from the dialogue in which all are engaged. Although there were members of the workshop group that had not participated in my research process, the group as a whole served as a focus group by sharing new ideas and reiterating some of those previously expressed by the teachers who had participated.

The specific focus of our workshop discussion was the criteria posed in the NSES teaching standards. However, as the teachers addressed these criteria, they also added their own understandings and concerns to the dialogue. Each teacher presented a portion of the teaching standards, identifying the main points and talking about them in reference to our district and their individual classrooms. The other members of the group added their own ideas and reactions throughout the discussion. For many of these teachers, including three participants in my research, this was the first time they had either seen or read any portion of the NSES. The discussion was tape recorded and later transcribed. I added the transcript of this discussion to the bank of data that I collected and used many of the comments of the teacher participants in my project in their individual chapters.

Narrative Analysis and the Use of Case Study Story

Once I had accumulated a substantial amount of data from different sources, I began to seek an appropriate way to represent what the teachers were saying about their own instructional strategies and their perceptions of student understanding as well as about what I actually had observed in their classrooms. I chose to include a case study story for each teacher, using story in the sense defined by Polkinghorne (1995). The word "story" is used by Polkinghorne to signify narratives that combine a succession of incidents into a unified whole. Story is a way of knowing and thinking that is particularly suited to clarifying and interpreting the issues with which we deal in education (Carter, 1993). "A storied narrative is a linguistic form that preserves the complexity of human action with its interrelationship of temporal sequence, human motivation, chance happenings and changing interpersonal and environmental contexts. Stories are concerned with human attempts to progress to a solution, clarification, or unravelling of an incomplete situation" (Polkinghorne, 1995, p. 7). Stories have three basic elements:

1) a situation involving some predicament or conflict;
2) a protagonist that engages in the situation for a purpose;
3) a sequence with implied causality or plot (Carter, 1993).

When people relate something from their experience they do so, not by recording of that experience, but in storied form (Clandinin & Connelly, 1994). Clandinin and Connelly go on to say that people lead storied lives and researchers describe those lives by collecting and writing stories about them and narratives of their experiences. During my discussions with teachers about their perceptions of what their students were understanding, each had his or her own story to tell of classroom experiences. I have added my understandings, as well, gathered as I took on the role of participant observer in each of the classrooms that I visited.

I continued to use Polkinghorne's (1995) discussion of plot as a guideline when constructing a case study story for each teacher that worked with me.

In each case study the story was based, primarily, on one lesson that I observed. The plot delimited the temporal range of the story, provided criteria for the selection of events to be included, ordered those events and clarified or made explicit the meaning of the events.

I have attempted to make sense of the actions and thoughts of the teacher participants in this project by developing a second narrative configuration of the data collected. In addition to the case study stories, each case study chapter includes a section of reflections on the part of the teacher about his or her own instruction and assessment strategies. That section has been written in the teacher's voice and, indeed, is almost entirely made up of direct quotes from interviews with the teachers. The only changes I have made have been grammatical corrections to oral responses so that they flow better as written and read responses.

When constructing a story or narrative configuration not all data elements are needed nor have they been used. It is important that the emplotted data be congruent to the story and brings a higher order to the story than the flux of everyday life. "The final story must fit the data while at the same time bringing an order and meaningfulness that is not apparent in the data itself" (Polkinghorne, 1995, p. 16). The result of the narrative analysis is an explanation that is retrospective, having linked past events together to account for how a final outcome might have come about. In this study the final outcome sought is insight into how a teacher comes to understand what their students are accomplishing.

Data Analysis

"The right way to analyse data in a qualitative study is to do it simultaneously with data collection" (Merriam, 1998, p. 162). At the outset of a qualitative study the researcher knows what the problem is but he doesn't know what will be discovered, what to concentrate on and what the final analysis will be like. The process becomes more directed and the

analysis becomes more structured and definitive as each sample datum is examined (Guba & Lincoln, 1989). The responsibilities of the researcher in regards to data analysis include seeking patterns of data to develop the issues, triangulating key observations and bases for interpretation, seeking alternative interpretations to pursue and developing assertions about each case (Stake, 1994).

I have employed a paradigmatic type of analysis of narrative as I examined the data collected through observations, conversations and interviews with the teachers that participated in my research. Paradigmatic analysis of narrative has been described by Polkinghorne as "an examination of data to identify particulars as instances of general notions or concepts" and also as "a search to locate common themes or conceptual manifestations" (1995, p. 13).

I have included the teacher participants in the process of preparing final narrative case reports in the manner described by Guba and Lincoln (1989) as the constructivist methodology using the multiple iterations of a hermeneutic dialectic circle. The specific focus of this study was the perceptions that teachers have of student understanding and the manner in which those perceptions are derived. However, it was not possible to extract the process by which teachers determine student understanding from the overall process of instruction. Therefore, analysis of the teachers' perceptions as well as analysis of my own observations of their instruction and assessment practices has been included in the presentation of data. In addition to focusing on the manner in which teachers develop perceptions of their students' achievement, I have attempted to gain insight into the manner in which teachers are managing the contradictory pressures in the assessment of student achievement.

The analysis of my data began with the notes from the first class that I observed. Soon after I left the class I read and reread the notes that I had written and took notice of small patterns that I thought I detected in the way

that the teacher was determining student understanding, recorded questions about what I had observed and identified elements of the teacher's actions to look for during the next observation. This pattern of analysis was followed on an ever increasing scale as I added observations of one teacher and then again as I began to visit another teacher's classrooms. When the interview transcripts were available I began a process of cross-referencing what the teacher said to what I had observed. Gradually I began to identify elements that seemed to characterise each teacher's practice as well as the perception each had of student understanding in his or her classroom. This was a recursive process with frequent questions going back to the teachers and many conversations along the way to clarify points that I thought had been made. Each of these conversations led to an accumulation of more data to be used in the analysis process. The elements that were identified became the basis for a concept map providing a graphic organiser for the data I had collected. It showed specific ideas that the teachers individually had expressed as well as the relationship teachers felt existed between the ideas. Once I had identified those elements and organized them into concept maps I went back to each teacher's classroom to confirm the credibility and the validity of my analysis.

"The goal of qualitative research is to facilitate understanding" (Zeller, 1995, p. 75). If this case study report was to be a product of research and not just a record (Zeller, 1995), then I needed to choose a method of presenting the results of my data analysis that would preserve the nuances and complexities of each teacher's experience. As I moved from field text to research text I continued to look for patterns, tensions or themes (Clandinin & Connelly, 1994) recurring within each case study story. Following this iterative process rather than a linear series of steps and involving collaboration with the teacher participants, I began to develop their case studies. I used a concept map as an organiser for the construction of each case study story and the teacher's reflections. Then each teacher's reflections were written in the teacher's voice, and were composed almost exclusively of his or her own words. Once constructed, the maps, case study stories and narrative

reflections were shown to each teacher for review and comment. After discussion and review of the concerns expressed by the teachers, I constructed the final versions of the case studies incorporating in most cases the teacher's previous editing and suggested changes. Each teacher has confirmed that my account of their reflections is representative of his or her own thoughts. Discussion of my own observations and my response to the teacher's reflections follows the story in each teacher chapter. In that discussion section I have identified the elements that I found to be characteristic of each teacher's practice. I used as much descriptive information as was practical to support my thoughts.

Qualitative case study research ultimately attempts to describe or explain a pattern of relationships between the cases that leads to an understanding of the phenomena under study (Huberman & Miles, 1994). Once each case study chapter was completed I continued the analysis process by searching across the case studies for relationships between them. Polkinghorne describes two types of narrative analysis: one in which previously identified concepts are applied to data in a search of supporting examples and, one in which "concepts are inductively derived from the data" (1995, p. 13). Inductive analysis includes recursive movement from similarities in the data to research categories until a "best fit" is obtained. Polkinghorne (1995) identifies the strength of paradigmatic analysis of narrative as its capacity to develop general knowledge from a set of particulars. In Chapter Nine I identify and discuss the patterns I observed as common elements of practice among the teacher participants in this study. With case study stories, narratives and concept maps in hand, I followed a process of inductive analysis to identify common themes and commonalities of thought and action across the case studies that formed my database. Denzin and Lincoln (1994) describe the analytic process as one of moving from field notes and transcripts to a research text and then initial interpretive documents to a final public text produced for a reader. As I continued writing, rewriting and reflecting on the data I had collected, I found a number of elements common to each case study and used them to organise the combined thoughts and

practices of the teacher participants. From a discussion of these elements I developed several propositions, along with their implications for teachers who are teaching for understanding and for those who are interested in what teachers are thinking and doing in their classrooms. These are presented in Chapter Ten.

The product of my research has been shaped by the data collected and the analysis that has accompanied it. I have been integrally involved in the classrooms and with the students and teachers who became part of my research process. Because of the high degree of interaction that occurred during the data collection and analysis phases and because of my long-term relationship with the district itself, I was cognisant of my inability to maintain a high degree of objectivity throughout the process. As a consequence, I needed to identify several issues of concern that might be raised by stakeholders in the process as well as by those who might be interested in the final product.

Issues of Quality

Is it reasonable and, in a practical sense, possible for an investigator to guarantee anonymity for the subjects of case studies? Can trustworthy data collection, data analysis, and peer review take place in a situation where anonymity has been assured? Is the temptation to stray towards imaginative writing too great for case reporters who use fictive techniques? Is it really possible to ensure the integrity of mutually shaped qualitative case reports? These questions have been raised by Zeller (1995) and they need to be addressed if qualitative research is to pass the test of trustworthiness (credibility, transferability, and dependability as described by Guba and Lincoln (1989) and Denzin and Lincoln (1994)). Guba and Lincoln define credibility as a "match between constructed realities of respondents (stakeholders) and those realities represented by the evaluator and attributed to the various stakeholders" (1989, p. 237). Credibility can be achieved by use of techniques such as prolonged engagement, persistent observation, peer

debriefing and member checks. During the process of conducting this research I adhered to these suggestions including extended observations and conversations with the participants. As I developed the case studies I frequently checked with the teachers to see if I was accurately depicting their own understanding of their classroom environments as well as their thoughts about their instruction and assessment practices. If there were differences in our understanding of classroom activities I searched for additional support in my collection of data. At times the teacher's thoughts had evolved as a result, at least in part, of our conversations. In that case we generally continued the discussion and I accommodated the new dimensions of thought in my writing. By continually seeking input from the teacher participants I attempted to create a close match between the "constructed realities" as described by Denzin and Lincoln (1994).

Transferability is similar to generalisability, however the burden of proof is on the receiver rather than the sender. It is largely dependent on the degree to which conditions in different situations are similar or overlap. A researcher, operating from a constructivist orientation must provide as much salient data as possible "in order to facilitate transferability judgements on the part of others who may wish to apply the study to their own situations" (Guba & Lincoln, 1989 p. 242). I have addressed the issue of transferability by providing a rich description of each teacher and dependability of data by returning to each classroom for follow-up observations in an attempt to confirm my own ideas.

Guba and Lincoln (1989) parallel dependability with the more conventional criteria of reliability because it is concerned with the stability of data over time. In essence, data can be tracked to the sources and logic can be used "to assemble the interpretations into structurally coherent and corroborating wholes" (p. 243). I addressed the concern for dependability and reliability in different ways during the data collection, data analysis and writing phases of my research. I collected data from several different sources including direct observation of classes, discussions and semi-structured interviews with

teachers, student comments, and samples of student work. I used these data sources to check and cross check inferences that I made and details that I included as I wrote the case study stories. The teachers reviewed their own case studies and made suggestions for changes that would more accurately reflect their thinking. These suggestions were crosschecked for corroborating evidence in my data prior to my making any changes. The act of self reflection on the part of the teachers as well as on my own part during this process resulted in an evolution of thought and practice in many instances. As a result, I continually returned to the sources of the data and conducted several brief observations during the writing process to confirm the consistency of the observations I had made.

Blumenfeld-Jones (1995) brings the process of narrative inquiry into the arena of art by posing the criteria of fidelity and believability as the challenge to be met by qualitative research. The implication of fidelity is that there is a factual base for narrative inquiry. The narrative inquirer must maintain fidelity both toward the story of the person and toward what that person is unable to articulate. Narrative inquiry is an artificial endeavour imbued with the intent of the teller and the reconstruction of the tale to be told. In order for artists to enable an audience to derive meaning from their work they must create a piece that appears lifelike. Believability requires a combination of exactness and feeling. "To assign believability, audiences must experience a congruence with their own experiences of similar and parallel situations" (Blumenfeld-Jones, 1995). There should be believability in a narrative story as both a reasonable portrayal of the specific story and congruence with the audience's experience. In addition, Blumenfeld-Jones (1995) warns that the processes of both decoding data and recoding the narrative should be included in the account of the story. He compares these two criteria to an art form in which the artist must be selective in presenting characteristics of a situation that he or she feel will convey a certain perspective.

The interpretive process of developing a narrative story presents a dilemma for the narrative researcher in developing a research product that is trustworthy (Guba & Lincoln, 1989) and maintains fidelity and believability (Blumenfeld-Jones, 1995). The goal of interviewing has been described by Fontana and Frey (1994) as understanding. In order for that understanding to be acquired the interviewer must be able to put him or herself in the role of the respondents and attempt to see the situation from their perspective. That same rapport may also create problems as the researcher may lose his or her objectivity. Carter (1993) calls attention to the interpretive processes that go into the construction of stories and cautions that in the very act of story making it is necessary to decide what to tell, what to leave out. A story becomes a theory of something and is the product of an interpretive process. Researcher relationships to ongoing participant stories shape the nature of field texts. We assume that a relationship embeds meaning in the text and imposes form on the research text ultimately developed. What is told is shaped by the relationship. The field text may be more or less collaboratively constructed, more or less interpretive and more or less researcher influenced (Clandinin & Connelly, 1994).

Wallace and Louden (2000) identify two ethical implications in narrative forms of inquiry. The first concerns "the nature of knowledge, understanding and truth" and has implications for the telling of a story that include Blumenfeld-Jones' (1995) fidelity and believability or the trustworthiness described by Guba and Lincoln (1989). The second issue "involves the rights of the human subjects in the research process" (1989) and the fundamental relationships between all individuals involved in the research.

Qualitative researchers are guests in the private spaces of the subjects of their research. Stake (1994) cautions that their manners should be good and their ethics strict as the value of the best research is not likely to outweigh injury to a person exposed. In order to reduce risks to participants, issues of observation and reporting should be discussed in advance. Participants

should receive drafts of how they are presented, quoted or interpreted and their concerns should be attended. Clandinin and Connelly (1994) caution that as personal experience researchers we owe our care and our responsibility to the participants and how our research text shapes their lives. Anonymity and other ways of fictionalising research texts are important ethical concerns in personal experience methods. Problems of anonymity and visibility need to be considered. Guba and Lincoln (1989) advocate a contract between researcher and client that protects both the client from misrepresentation and the evaluator from client misunderstanding or false expectation. Such a contract should include a statement regarding the evaluator's intent to guarantee confidentiality and anonymity. The evaluator needs to make sure that these issues will be given high priority.

It has not been possible to guarantee a high degree of confidentiality nor anonymity of participants or information gathered as a result of my research project. While each teacher is discussed in the final report using a pseudonym and the district name has been changed in an attempt to establish a sense of anonymity, a belief that anonymity has been achieved would be founded on a very meagre hope. Teachers were very open about my working with them in their classrooms and we all participated in a discussion about the NSES along with several other colleagues and the assistant superintendent supported the research by offering a small stipend to teacher participants. Our district is a small one and, were the district to be correctly identified, the teachers would be easy to identify by a very simple description of their roles. If someone should have a specific interest in discovering who the teacher participants were, it would be an easy mystery to solve. In fact, in a few cases the teachers have shared their review copy of their own case study with co-workers. Anonymity was, therefore, discussed with each teacher prior to the beginning of this research as a parameter that, although attempted, would not be considered a priority in what we were trying to accomplish. The issues of trustworthiness, credibility, transferability and confirmability (Guba & Lincoln, 1989), fidelity (Blumenfeld-Jones, 1995) and the ethical implications raised by Wallace and Louden (2000) are ones

that I have had to address in a context where anonymity is pretence at best. The manner in which I took each of these into account was based on a sense of "connoisseurship" (Eisner, 1991) that I have developed as a result of the many years of experience and several roles I have assumed in education.

Connoisseurship

In a discussion of some of the methodological issues related to strictly observational research, Adler and Adler (1994) point out that observers are likely to employ all their faculties in data gathering and are also likely to draw on their broad cultural or commonsense knowledge. This use of commonsense knowledge is similar to Eisner concept of connoisseurship. Connoisseurship, according to Eisner (1991), is the ability to make fine-grained discriminations among complex and subtle qualities. True connoisseurship includes the abilities to experience qualities as a case or symptom of factors that have bearing on the new experience. In classrooms, knowledge of the history of the situation being observed, the teacher, the school and the values of the community can help an observer notice and interpret what is noticed. An understanding of teaching and learning theory, views of appropriate teacher-student relationships and understanding of what is important in the educational process also affect what a observer is likely to notice and how the information might be interpreted. Antecedent knowledge can heighten our awareness of the nuances within a classroom situation (Eisner, 1991).

Guba and Lincoln (1989) follow a similar thought as they compare the conventional and constructivist paradigms of research and evaluation. Conventional inquiry is guided by a belief in the objectivity of findings. Such a stance puts the researcher in a position of being a simple messenger for the messages that nature chooses to send and their findings are set above challenge (Guba & Lincoln, 1989). On the other hand, constructivist inquirers are subjective partners with stakeholders in the literal creation of

evaluation data. The researcher becomes "an accountable partner in the evaluation process" (Guba & Lincoln, 1989, p. 110). There is inevitable interaction between the researcher and those who are subjects of the constructivist research process. Guba and Lincoln pose a solution to the issue of the influence that interaction might have on the outcome of research. The solution is to require that the inquirer or researcher "come clean" about predispositions and feelings and rely on critical tradition (i.e. aggregated knowledge) and the existence of critical community to expose biases that may exist.

I assumed a constructivist position when I initiated this research. As explained earlier, my interest in the research topic was an outgrowth of previous discussions with my teaching colleagues. It was also a continuation of the process we had been following together to improve the quality of science education offered students in our district. Maintaining a position of complete objectivity was not possible when writing the story of each participating teacher in this study. Many of the teachers were previous colleagues and, as I worked with them in their classes, we developed a strong sense of collegiality. I was able to use the positive relationships previously developed with these teachers to gain ready access to their classrooms and to be able to initiate discussions as to what they were thinking without spending too much preliminary time establishing a level of comfort.

The nature of this research was exploratory and descriptive. The focus and intent was not to criticise the actions of teachers but rather to listen and learn from what they had to say. My previous experience in teaching, staff development and evaluating allowed me to bring the quality of connoisseurship to my collection and analysis of data providing a balance to the subjectivity of the research process.

Each teacher shared their ideas and opinions, knowing that they would have a chance to review what I had written and to express any concerns that they might have about the credibility of my text. The stories included in each case

study, both the third person stories of the classroom and the teachers' self reflections written in the teachers' voices were written almost entirely from a direct script of a class observed or combined quotes from our interviews. These were all reviewed and critiqued by the teacher depicted and the resulting comments, changes and additions were accounted for in the final rendition.

Chapter Summary

In this chapter on methodology and methods I have explained the process that I followed in developing an interest in what teachers were thinking about the level of student understanding achieved in their classrooms. I discuss the basis for my decision to use a qualitative case study research method and identify the nature of my research as exploratory and descriptive. The chapter includes a description of the specific procedures I used in collecting and analysing data. The paradigmatic analysis of narrative and use of case study story are explained as they apply to the procedures I followed. I also identify and discuss issues of concern relating to my research and the concept of connoisseurship.

The next five chapters, Chapter 4 through Chapter 8, present each of the teacher participants in a case study format. I bring the case studies together in Chapter 9 and discuss common themes in the practices of each of the teachers. I present the outcomes of my research in Chapter 10 and discuss the implications those findings and the research as a whole may have for the participants and their students, myself as an administrator, the district in which the research took place and for those interested in a wider perspective on the thoughts and actions of teachers in science classrooms.

CHAPTER 4 - JOANN SPRINGER

Joann Springer was an experienced elementary school teacher, having taught in kindergarten - sixth grade classes for the last 28 years. She was also a teacher leader in the Sonoran Foothills District in the area of staff development and, for several years, helped teach a requisite class for all new teachers that covered Madelene Hunter's Essential Elements of Instruction (Gentile, 1988; Hunter, 1979). During the past five years Mrs. Springer taught a multi-age, first through third grade, class.

Within her multi-age classroom, Mrs. Springer worked to build a sense of community among her students. When in her classroom it was very common for me to observe older students helping younger ones without prompting; sharing their knowledge and understanding of various concepts and helping the younger ones learn basic skills. By adhering to the multi-age concept that students learn best by learning from many different people in many different ways and with the help of many classroom visitors and volunteers, Mrs. Springer managed to balance the range of needs presented by her multi-age students in Language Arts, Reading, Math and Social Studies. Science, however, presented Mrs. Springer with some unique problems. The students worked through their science curriculum on a three-year cycle. In this manner all students would have covered the first, second and third grade curricula before they were promoted to the fourth grade. During the years that the first and second grade curricula were taught Mrs. Springer felt it was relatively easy to enrich the specified district curriculum requirements in order to engage the attention and interest of the third grade students. However, during this study the class worked on the third grade science curriculum and this presented a dilemma to Mrs. Springer as she planned her lessons. There were several instances when the younger students were presented with material that, in Mrs. Springer's opinion, was very difficult for them to understand.

The following case study story focuses on one of Mrs. Springer's lessons in a unit on electricity. Although this was actually a unit in the third grade

curriculum, all the students in the room participated in the lesson. I observed the case study story lesson close to the beginning of the electricity unit. During most of the lesson I sat with the students and scripted as much of the conversation between students and teacher as possible. When the students were assigned to work in their learning groups my role changed from observer to participant and I was no longer able to record the students' comments. Immediately after the lesson, I left the classroom and wrote as many of the students' words as I could remember in my own journal. I also recorded my impressions and questions about the lesson so that I would later be able to discuss them with Mrs. Springer. Within a day or so after my observation she sent me her journal notes, including her thoughts about what she perceived to be a dilemma posed by the electricity unit as a whole. Later, when we had an opportunity to talk about it, Mrs. Springer related the difficulties she was experiencing as she tried to maintain the integrity of her multi-age program while, at the same time, planning for appropriate science instruction for all of the students in her classroom.

Case Study Story

Students entered Mrs. Springer's class as soon as the bell rang. Class began with the students reciting the "Pledge of Allegiance" and then singing the class song. Mrs. Springer told her students that she would be reading them a story about electricity before they started on their "theme" (science) project for the day. She told them that the story would be about electrons travelling around making light and heat. The electrons would also be travelling thorough wires during the story.

The students sat on a rug and listened quietly as Mrs. Springer read. Immediately after the story was finished, they raised their hands to make comments. A third grader said, "I'm thinking about yesterday and I think atoms get recycled."

Mrs. Springer responded, "Atoms get recycled? What a wonderful concept and good thinking. What did the electrons in the story do?"

Another student answered, "Electrons go differently. Only one atom jumps. Then it dies and another one jumps."

"What else did you learn from the story?" Mrs. Springer asked the class.

Again a third grader answered. "I learned that at the power plant they send out a whole lot of electricity and when it gets to our houses it lights the lights."

"That fits into what I want to talk about today," Mrs. Springer replied. "We are going to add sources of electricity to our web." Mrs. Springer frequently used a concept map or web design to illustrate how various parts of a lesson interrelated. At this time she pointed to the web that had been started the day before "Sources are where electricity comes from. There are three places. One is the sun. Do you remember the others from yesterday?"

"Water," answered one student.

"Wind," another said.

"What did I ask you to write about yesterday?"

This time a second grader began to get in on the discussion. "What you think about electricity," he replied in answer to Mrs. Springer's question. "Could we read what we wrote?"

Another second grader joined in with, "I learned that when electrons jump we get electricity." Several students shared the comments that they had written in their journals on the previous day after seeing a Bill Nye movie

about atoms and electricity. Many repeated the idea that electrons jump from atom to atom.

"Do you remember what I said we were going to do next?" Mrs. Springer then asked. "Each person is going to do an individual report and each group is going to do a project as a group. Your reports can be about any part of our electricity web that you are interested in. The web includes the words atoms, sources, how it works, and safety centred around the word electricity. In order to write about one of these four parts we need to have a little more information about atoms. Can you understand about electricity if you don't know about atoms?"

"No", a third grader replied.

"Can you be safe with electricity if you don't know about atoms?"

And another student answered, "No!"

Mrs. Springer continued with a brief discussion of the structure of atoms. "So we have to learn about atoms. Look at the back of your hand. Do you see little sections? These are like cells and they are made of molecules. Molecules are made of atoms. They are very, very tiny. You can't see them with just your eye. Do you remember what an atom looks like?"

A third grader answered quickly, "Atoms have a nucleus inside and that is made of protons and neutrons and electrons around the outside."

Another question from the teacher, "And if electrons jump from atom to atom in a circle that is closed what do we have?"

A third grade student answered, "A circuit, electricity."

Mrs Springer then explained to her students that atoms are invisible to us and students would have to take the scientist's word for the fact that they exist. "This is one of the things that has to be taken on faith." She then showed the students a diagram of an atom. "It is just like you have described. Look how much space there is between the nucleus of an atom and the electrons. Atoms make up your body and your body is 99% space."

At this point a second grader, responding both to Mrs. Springer's statement and the picture in the book, asked, "So, like inside you, there is a golf ball and open space?"

"Well, that is just how the picture is showing the empty space. There really isn't a 'golf ball' inside you," said the teacher. "Take a minute before we go on and write about an atom in your journal. You little ones can draw and then put labels on the parts. The second and third graders need to write some sentences. I'd also like you to write about an "aha" moment that you had from the video, something that you now understand because you watched it. What were some of your "aha" moments?"

The students' responses included "energy takes lots of power," "a turbine makes water to electricity" and "I want to find out about kinetic energy so I understand it."

"How long do you think it will take to understand all there is to know about electricity?" asked the teacher.

A first grade student who had been silent during rest of the conversation didn't wait to be called on. "All your life!"

After a few minutes had passed and all the students had added something to their journals Mrs. Springer continued with the lesson by giving directions for the remainder of the class period. "OK, when you're done with your journals you are to get in your learning groups and start working on your

reports. You can also talk about your project with your group if you wish." "Remember that you older students are responsible for your own reports as well as working with the younger kids when they need help." Students were also instructed to decide on a group project with each student to be given a task appropriate to his or her grade level abilities and interests. Each group was composed of four students including at least one third grade, one second grade and one first grade student.

At this point in the lesson I stopped scripting the dialogue and began to help various children find books that they wanted to use. One group asked me to help them decide how to divide the work for their project so that everybody would be able to do something that they could and would want to do. I responded by asking each what they liked to do when they did a project and how they could include that activity in what they had decided to study. The topic was resources and the students were planning to make a poster. One of the group members could draw, another could write clear letters. The first grader offered to find books to use but couldn't read them and a third grade student wanted to do the reading. They all planned to decide together what to write and draw on the poster.

Another third grade girl asked me for help in locating information about how a hydroelectric dam worked. Together we found a book with a good picture and accompanying diagram with an explanation. I let her explain the process to me until she became frustrated with trying to understand how turning the turbines created energy that was stored in what looked like a big battery in the diagram. I reminded her of what her classmate had said earlier about it possibly taking a lifetime to understand everything about electricity and suggested that she did not need to understand every detail in third grade in order to do her report. She was visibly relieved and confided that she had been to a hydroelectric dam with her family and after this report she would be able to explain to them just how it worked.

As I continued to circulate around the room I had other opportunities to ask the students about what they had learned or were in the process of learning. One group, whose project was going to be about electrical storms, shared the following insights with me. A third grade student related that "electricity comes from storms and atoms, electrons jump from atom to atom making electricity"; another third grade student shared that "atoms are electricity, they are so small that we can't see them but scientists can and they know they are there"; the second grade member of the group explained "atoms are electricity, they jump through a wire to the light bulb. The one first grade student in the group had been following the direction of the older students during their project activities. He had spent most of the time carefully drawing a picture of an atom including a nucleus with electrons in a ring around the outside. When it was his turn to share his learning he smiled at me and said, "I love atoms. I'm doing my report on them. They are smaller than my sister's hair barrette."

A few weeks later I was invited to attend a presentation held for parents. Each student gave a brief report on what they had been learning during the "theme" project. The report topics ranged from a discussion of electrical storms, hydroelectric plants, energy resources and the causes of electricity as they relate to the structure of an atom. The last student to speak, the first grader quoted above, gave his report and ended it with a statement similar to the one he had shared during the lesson, "I love atoms. They are very small. I have to use my imagination to see them."

The lesson illustrated by the case study story raised many questions in my mind about the appropriateness of the content of the lesson and about how Mrs. Springer's assessment of what the students had actually learned compared to the observations I had made during the course of the lesson. She and I discussed these questions and others by an exchange of journal entries and in follow-up conversations. In addition, during the field study, I was able twice to question Mrs. Springer extensively about her background

in teaching, the strategies that she finds most useful in teaching science and her perceptions of what her students understood during the lessons that I had observed. The following commentary was constructed almost entirely from Mrs. Springer's words during our conversations and interviews. It represents her own reflections on her teaching and on the methods she relies on to determine what her students are accomplishing.

Teacher's Reflections on Instruction and Assessment of Student Understanding

"I can't," is rarely heard in my classroom. I have tried to create a classroom culture in which all the children feel like they can do whatever they are asked to try. I'm finding that the longer I teach multi-age the more that is happening. We are a group for a long time and it is important to create a sub-culture of sharing that encourages each student to support the others as they learn. One of the things we have made a point of is that our information or knowledge should not be kept a secret. It should be shared so we can all build on it.

I have had time to think a lot about my role as a teacher since I have been teaching multi-age classes. Although I think I still talk too much, I've become much more of a facilitator than a lecturer. To me, that means stepping aside and letting the kids be in charge of what they are doing. I have reduced some of my requirements for the completion of assignments and try to encourage my students to decide what they want to focus on within their learning clubs and what parameters they will follow when completing a project.

When I am introducing a new science topic or unit I like to use a "web" type diagram, much like a concept map. It traditionally includes the parts of the topic we are going to explore and what I want the students to find out. I use the same idea of a web to help the students build bridges between the

different units that we work on. My students build mental bridges not only from unit to unit but also from year to year. The kids will make statements to each other like..."remember last year, how we did that? Well this is how it fits."

Another thing that I think is useful for teaching is a clear understanding of Bloom's Taxonomy of critical thinking skills. The ability to use that taxonomy to ask questions and elicit responses is critical for discussion within my multi-age group. I expect responses at a higher level of thinking from my older students than from the younger ones. I try to deliberately phrase questions so that each child will have to stretch in his or her thinking.

I think it is vitally important that I am aware of my students' existing beliefs and understandings. We have to make connections between ideas if greater meanings are to happen. If students don't have a base to connect with, learning doesn't take place. As a teacher I have to know if everyone is on the same track or someone will get lost along the way while I am going on and on. You need to help students get back on the right track as soon as you can so they don't get lost. You have to talk with kids all the time to see what they are understanding. I try to check for understanding constantly by talking to my students, watching them work and asking questions. Sometimes I am very methodical about checking at specific stages in a long-term project. Typically my questions might be "What is...?; How do we know that...?; Where do we go from here...?" With my multi-age kids a younger one might not know how to answer each question but will benefit from having the correct answer repeated and explained by an older child.

I am not a proponent of standardized tests as a means of determining how well my students are doing. This was a pilot year for the district's CRM's and, at this point, they are not very useful in determining the extent to which my students understand science. The science CRM's are somewhat problematical for multi-age classes in any case. We do not necessarily teach the assigned curriculum to each grade level each year. Since I only use the curriculum from one grade level each year the test that has been developed to

assess student achievement of that material isn't necessarily appropriate for all of my students. As a district we would have to develop different tests for the multi-age kids if we wanted to use that method of determining their understanding. I question the validity in determining student understanding and achievement of the Stanford 9 tests as well. I don't think the format provides a fair test of what children can do.

To me, understanding is when students demonstrate they know the concept or skill by correctly performing it in a similar but not exactly the same way. This could be through conversation or demonstration. They are successful when they can bring the learning back and apply it to a different yet similar situation or build onto that learning to go to the next step. I think that levels of understanding are different. What one person understands at an early stage should deepen and expand with more experiences with the same or similar concept.

The most effective way for me to assess the progress of my students is to listen to them on an individual basis. Final assessments come from presentations and projects. Even when there are group projects, each student is expected to complete an individual component on his/her level. Overall, I think my students understand a great deal about their lessons. People ask about multi-age all the time. They don't understand how you can teach a first grader and a third grader at the same time. I wish they could see the students' presentations. First graders might stand up and say a few words about plants while third graders explain photosynthesis. This year, during presentations to parents, one of my students announced that he didn't wish to share his report. Instead, he talked about how everything is connected. He clearly was able to build bridges between topics he had discussed in class. This was just an ordinary kid that loved what we had been doing and was involved in his own learning.

Data Analysis

Many of the principles of constructivist teaching are identified as critical to effective science teaching by the NSES (NRC, 1996). Although Mrs. Springer did not claim to be knowledgeable about either constructivist learning theory or the NSES during the time that I served as an observer-participant in her classroom, she demonstrated several of the teaching standards suggested by the NSES in her classroom organization and in the instructional strategies she used in her classroom. I have observed and participated in Mrs. Springer's classes over the course of a year. I also talked with her students and listened to her ideas during several informal and semi-structured interviews. As I became more familiar with Mrs. Springer's classroom I began to recognise several elements that continually appeared in her practice, the structure of her classroom and her reflections on what she felt her students were accomplishing. They included

1) a strong sense of community built on a multi-age philosophy of teaching and learning;
2) specific instructional strategies that she used to help students recognise connections between many topics that they are learning;
3) additional strategies designed to encourage each student to take responsibility for his or her own learning and;
4) the methods that she preferred to use when assessing the understanding and achievement of each of her students.

During the course of several of our conversations, Mrs. Springer described the deliberate way that she included these elements in her teaching. Our discussions and my observations of her classroom also raised a few concerns in my mind about what seemed to be obstacles to her achieving the goals she had set for her students.

Building a Sense of Community

One of the most striking characteristics of Mrs. Springer's classroom was the strong sense of community that she developed among the members of her

classroom and between them and frequent volunteers and visitors. It was very natural in this setting for several different ages to be working together. Although her class included three grade levels, it counted among its members students whose ages spanned a range of five years. A severely handicapped girl, wheelchair bound, on a respirator and capable of only minimal speech was also a member of the class. Several adults were regularly present, including a registered nurse and a paraprofessional for the handicapped girl and daily parent volunteers that came to help with various activities. As participant observer I was just another source of help if needed for the students. My presence presented no novelty to them as they were very accustomed to receiving help from adults in the classroom as well as from each other. When I was included in a group discussion, the students were interested in my comments but it was perfectly fine if I did not know an answer. Occasionally I was asked for advice on how to approach a given assignment but there was no feeling that once offered, my suggestions had to be heeded and indeed they frequently weren't. As a result of the sense of shared learning this was the most comfortable class for me to observe of all the classes that I participated in during my data gathering activities.

One device that Mrs. Springer used to create that sense of community within her classroom was organising her students into learning groups composed of students from each of the grades in the classroom. Students were encouraged to actively participate in and take responsibility for not only their own learning but also the learning of others in their groups. The older students were specifically instructed to help the younger ones. Students frequently worked within these groups as they completed not just science assignments but any of the activities assigned during the school day. It was typical for Mrs. Springer to clearly specify the expectations for students in each grade level as they worked on various assignments. For example, she gave the following instructions during one of my observations: "You older students are to write about your reaction to the story using complete sentences in three paragraphs. You must make sure that all your words are spelled correctly. Second graders, you need to write one paragraph and your spelling is

important as well. The younger ones are to draw a picture about the story that shows the part they liked best. Then try to write some words that describe how the story made you feel."

In the case study story, Mrs. Springer instructed her students to work in their groups with the older students being held responsible for their own reports as well as working with the younger group members when they needed help. Students also were instructed to decide on a group project with each student given a task appropriate to his or her abilities and interests. As I participated in the "story" lesson I was continually asked to sit with one group or another for a few minutes to answer a question, help find information in a book etc. Students were very clear when they no longer needed my help. Frequently saying something similar to "We are OK now, thank you". I did not have the feeling during any of the lessons that any one student or group was willing to let me do their work. They were very involved in their own reports and projects. There was also continual interaction between the students and the adults in the classroom. All members of the class asked for and gave advice, helped and accepted help, and no one person served as the ultimate holder of knowledge. Mrs. Springer explained to me that she told a story about sharing to her students at the beginning of the year. They discussed what the story meant and used that discussion to establish the tone of the classroom for the rest of the year. In her words:

> A group of people went to hell. They were sitting around a pot of soup but they couldn't eat because the spoons were too long and they couldn't get the spoons in their mouths. Another group went to heaven and they, also, sat around a pot of soup and had long handled spoons. But they were feeding each other (Transcript of Interview, April 6, 1999).

Mrs. Springer used specific instructional strategies that promoted the sense of community and shared responsibility for learning that she has structured in her classroom. She also planned activities that illustrated the relationships between the many topics that she and her students discussed. The sense of community that she created resembled that described by Noddings (1992). In Noddings' words, "teachers not only have to create caring relations in

which they are the carers, but they also have the responsibility to help their students develop the capacity to care" (1992, p. 18)

Recognising Connections

Mrs. Springer frequently used a web diagram or concept map during instruction and, in fact, introduced the idea of the inter-relatedness of subject matter and interdependency with such a diagram when she initially established the classroom environment. The concept of "inter-relatedness" was the cause of an awkward conversation between a third grade student and me one morning. During one of the science classes that I was observing I asked this student if I might look at her science journal when she was done writing in it.

Her response, "I don't have one!"

"Well what do you call the journal that you are using now," I asked.

"My theme journal, I don't know what science is." "We don't have that in this class. "

She was quite clear about that although we had just finished an activity related to sound waves. I didn't think it appropriate to correct her so I simply asked why this was called a "theme journal". She went on to explain that every Friday was theme day and on those days the class talked about many things that were connected. Mrs. Springer explained later that this year's theme was "Home-Sweet-Home" and on theme day students worked on science using the skills learned in language arts, reading, social studies and math. Each month the activities were focused on one room of a house or the yard surrounding the house. Topics and activities were chosen according to the room of the month. For example during the "bedroom" month the science topic was the solar system and stars, math class included discussion of the geometric patterns found in quilts, and music included listening to

music by Pachabel and learning lullabies. Students did not view science as a separate subject. It was just part of everything else studied.

The emphasis on inter-relatedness was found within individual content areas as well as between them. A web connecting not only the subtopics of a particular unit but also showing connections between units and between science topics and those of other subjects, for example, illustrated each science unit. During the case study story on electricity Joann used a web to illustrate the subtopics relating to their study. The word "electricity" was surrounded by the words atoms, sources, how it works and safety. Each of these words in turn had related concepts connected in smaller letters.

Several webs were posted prominently on the wall during the times that I observed and participated in Mrs. Springer's class. One of them was a web on interdependency between members of a community and included components of the classroom community as well as the student's family and community at large. Another illustrated the relationship between various character traits that might be desirable to develop. Students were asked at several times during the year to reflect on their own learning and identify areas that they needed to work on in order to improve. They were also given opportunities to identify "stars" or areas of skill in which they were showing strong achievement. Occasionally students were asked to construct webs in their journals as a means of taking notes and other times as a means of illustrating what they had learned. Mrs. Springer used a web diagram or concept map to facilitate the learning of content material as well as to allow students to reflect on the role they held in taking responsibility for their own learning as well as taking responsibility for the community in which they were working.

Taking Responsibility

During a discussion of the NSES, Mrs. Springer commented that it seemed odd to her that the standards document even raised the point that students should be taught to be responsible for their own learning (Interview, May 25,

1999). It was such an obvious point to her, that she didn't understand why it was necessary to include it in the teaching standards. She routinely asked students to decide on how they wanted to learn something and to be aware that group members might have needed help. Students were typically given guidelines to focus their learning and then asked to decide what they were going to do and how they were going to do it. They could be heard frequently asking for and offering help to fellow students. When they completed an assignment they might have been asked to present and critique it for the entire class and they were expected to make suggestions and identify accomplishments when other students made presentations. During parent conferences, students conducted their own meetings and explained to parents why they were doing things one way rather than another as well as why they were achieving in different areas of learning. They identified for their parents those areas of learning in which they needed to show improvement and then explained how they are going to change their habits in order to improve.

As Mrs. Springer and I discussed the instructional strategies that worked best in her multi-age setting, she made it clear that she did not view her role as a teacher to be that of an instrument for knowledge transmission. While recognising that sharing information was at times necessary and could not totally be eliminated from a teacher's responsibility, she criticised herself for talking too much. She referred to the need to occasionally "lecture" and when asked to describe herself in the role of a lecturer replied:

> The way I lecture is to use my chart paper or the board and try to do the web business with the main idea in the middle and all the re-related ideas branching out from that. Lecturing means I give them the information and they record it somehow in their journals or in their minds with pictures or words so that they can go back to that record and pull up the information when they need it. (Transcript of Interview, April 6, 1999)

During that conversation she characterised herself as a "facilitator" of learning and went on to say:

> Being a facilitator means that I step aside and let the kids be in charge of what they are doing. I try to minimise the requirements that I set as well as the impression of what I want a final project or product to

> look like. For example, when giving them directions for their recycling project I told them that "I don't want to give you too many guidelines because I want you to come up with your own ideas". "I think that if I told you more about what you were supposed to do you wouldn't be as creative." (Transcript of Interview, April 6, 1999)

In the case study story, Joann gave another demonstration of how she balanced the need to relay some information to her students while preferring to facilitate their learning by encouraging them to make some choices for themselves. After some basic information was shared by means of a story centred on an atom, a movie on electricity and a discussion of the electricity web diagram, students were instructed to record in their journals what they had learned rather than what she had taught. They were also instructed to choose what direction they wanted to follow both individually and as a group as they continued their investigation of electricity. Although the district curriculum guidelines were very limited and listed few objectives to be achieved, Mrs. Springer used the ones for the third grade electricity unit as the basis for her lessons and then structured the class so that students had the opportunities to pursue their own interests. Students also heard the expectations for each grade level in each assignment. Younger students were encouraged to extend what they were doing to reach the goals of the next level of students if they chose. In the case study story Mrs. Springer gave directions for journal writing that served as an illustration of her practice of giving tri-levelled instructions. Another example of this practice, from a lesson on the scientific method and making observations, was given after students had spent some activity time making soap bubbles and trying to find as many different ways to make the bubbles with the materials provided.

> I want you to write down all the things that you observe and questions that you ask in your groups. After you are done the third graders are to write their observations and questions. First graders you may draw all the different shapes of bubbles that you made and try to draw the different ways that you made them. Second graders can do both but I want you to start trying to write as much as you can. The third graders can help you spell the words correctly. (Classroom observation, Sept. 30, 1998)

Not only were students given the responsibility for their own learning in this assignment, they were also given the license to design their own individual activities, try out their own ideas and record their own results in ways of their own choice.

Assessing Understanding and Achievement

In response to my question about the most effective strategy to use to increase student achievement Joann answered, "Students need to do it." Students in her science (i.e. theme) classes are frequently involved in hands-on activities, often following different directions depending on their own particular grade level. First graders may have been asked to simply play with equipment and draw what they see. Second graders may have been asked to record questions that they had along with their observations and then try to answer some of the questions. The third grade students may have been asked to describe exactly how they tried to answer a question or solve a problem and then report the results.

"Students need to do it and then talk about what they've done," Mrs. Springer continued in answer to my question. She then referred to the lesson just prior to the one depicted in the case study story. In that lesson students were given a variety of wires, batteries, bulbs and other pieces of simple equipment and asked to see what they could do with it. They then recorded their new learning in their journals. Mrs. Springer went on to explain, "I see that happening when we do our writing, our research and our sharing of projects."

Encouragement to reflect on their own learning was a strategy that Mrs. Springer referred to as a tool that she likes to use to "help students make connections between ideas in order for greater meanings to happen." Journal writing was used on almost a daily basis for this purpose.

As I observed her classroom activities I wondered how Mrs. Springer determined what each of her students, ranging in age from ages five to nine,

understood and achieved during the complex multi-levelled lessons that she orchestrated in her classroom? When I asked if she saw value or usefulness in an outside objective measure of student achievement her answer was clear. "I don't! I question the need for either the CRM's, the AIMS (Arizona Instructional Measures) and the Stanford 9's as well." "I don't need an outside measure to determine what my students are understanding. I know by experience, by what other people tell me and, most of all, by what my students are saying". (Interview transcript, May 14, 1999)

In fact, through the course of my observations Mrs. Springer demonstrated a variety of methods for assessing her students' level of understanding both during instruction and at the completion of instruction. She asked her students many questions about what they were learning and spoke, in her own journal reflections, of the importance to her of understanding and being able to use "Bloom's Taxonomy of Critical Thinking Skills" (Bloom, 1971) when asking questions of her students. When she asked questions of her students during my observations she would frequently change from one level of question to another as she called on students of different age levels. "Can you remember the word for...? asked of a first grade student might change to "tell me about", "explain to me" or "what do you think about..." when Mrs. Springer was asking a question of an older student. She frequently sat with one or two students as they were working and could be heard to ask them many questions about their learning and their goals for that activity. Such questions came at all stages of a lesson, beginning, middle and end. The journal writing, mentioned earlier, was a second source available to Mrs. Springer to use when assessing student progress during a series of lessons. After completing some of the projects, students made presentations to each other and included within their presentations a discussion of what grade they deserved based on a class rubric. Frequently other members of the group were allowed to participate in the evaluation by making positive comments as well as suggestions for improvement but never with criticism. The class rubric was one that even the youngest students could relate to, with a "4" being equivalent to a deluxe hamburger with all the "fixin's", a "3" the

equivalent of a regular hamburger with ketchup and mustard and a "2" representing little effort equating to two buns, a piece of hamburger meat and nothing else.

At the completion of a unit of instruction in Mrs. Springer's class, students frequently presented a project complete with a self-assessment to the class as a whole. This gave her the opportunity to assess the understanding of the presenter and also the students who were asking questions of and offering suggestions to the presenter. The depth of their understanding was reflected in their comments to the students presenting. A final project, prepared as a surprise for parents, also gave Mrs. Springer an opportunity to look at both science achievement and writing skills. Students were asked to use the writing process taught in their language arts classes to create a book based on their electricity reports.

A final device that Mrs. Springer used to assess student understanding was the process of helping them prepare for and conduct their own parent conferences. During those conferences students reviewed their accumulated work and choose samples that represented their own achievements and then discussed their "stars" and "wishes" with parents. Mrs. Springer then added her own suggestions for "stars" and "wishes" and the parents, themselves, are asked to suggest "stars" and "wishes" for their child. Parents, as well as Mrs. Springer, had an opportunity during the process to identify specific skill areas in which their child had grown as well as areas in which the child needed to continue working.

Issues to Consider

At several points during our discussions, Mrs. Springer expressed concern about a perceived dilemma created by her multi-age teaching setting. That dilemma was the conflict she felt in teaching material that was not, in her opinion, age appropriate to all the students in her classroom. She repeated her concern about this issue during later discussions of units on electromagnetism, sound and the causes of eclipses. In each instance she was

planning her instruction around district prescribed curriculum objectives designed for third grade students.

When asked about the level of learning her students had achieved in the electricity unit, Mrs. Springer responded, "my goal was that they could explain to me what made electricity in terms of electrons moving. That proved they had an understanding of an atom. Whether they believed it or not is another thing. They would just accept that as what we think. They also had to know that you had to have a complete circuit in order for electricity to work and that circuit could look a lot of different ways, not just a perfect circle." Mrs. Springer told me that neither of these goals was listed in the district curriculum guidelines for the third grade electricity unit. The curriculum only listed the need for students to name an electrical appliance and to identify a source of electricity.

Mrs. Springer was not satisfied that the curriculum guidelines covered the topic of electricity in a meaningful way for her students. Nor was she comfortable that she had done so either. However, she felt that her students had accomplished the two goals she had attempted to teach them and used both the conversations that she had had with them in class and the reports they wrote as evidence that they had done so.

When I reviewed the district curriculum guide for the first through third grade science programs I found that there was not a separate unit on electricity but that electricity was included as a smaller part of a larger unit on sources of energy. Within that context the simple objectives listed for student learning about electricity seemed appropriate. There was nothing in the guide to suggest that students needed to be taught or held accountable for learning about the structure of an atom or the movement of electrons. Mrs. Springer expressed concern that the district curriculum guide was too limited in expectations and felt that she needed to enhance the objectives that were listed as essential for her students to learn.

Did Mrs. Springer's students achieve the specifically stated goals set for them at the beginning of the electricity unit? My observations indicated that many of the students in the classroom repeatedly recited the memorised words describing the structure of an atom and the movement of electrons as the cause of electricity. Mrs. Springer, herself, admitted not knowing much about the subject of electricity and believing that you had to have faith in the scientists and just believe in what they said. In her assessment of student achievement, Mrs. Springer used her conversations with students as well as their reports to determine the level of their accomplishment. In most of these cases students simply re-explained to her, using the same words that she had used or the words copied from a book, the topics of choice. Their level of learning for the identified objectives was knowledge based and easily forgotten.

The district objectives required that student be able to identify an item that uses electricity and explain that electricity travels in a circuit. Each student in the room demonstrated either through answers to questions, journal writings and drawings and by creating circuits with wires and bulbs that they understood those basic concepts. Many of the students that had extended their knowledge beyond the curriculum expectations were quite pleased with the knowledge they had gained.

A second area of questions generated by my observations related to the role of facilitator that Mrs. Springer had defined for herself. She did not feel that she was a transmitter of knowledge and had given up that role in favour of one that encouraged students to take responsibility for their own learning. But, did the role of knowledge transmission disappear? At times during the classes that I observed, it seemed that the role of knowledge transmission had been shifted to the older students in each learning group. They were often encouraged to share what they knew or had figured out. At times they told the younger ones what to write in their journals or on a group project. Often the younger students recited facts they had learned from the older ones. What initially appeared to be opportunities for discourse and shared learning

among the students in the classroom, on closer inspection resembled more closely the direct transmission of knowledge from older to younger student.

During the case study story many of the younger students carefully drew the structure of an atom in their notebooks. They used correct labels for the parts of an atom and even included the positive and negative signs for electrons and protons. Mrs. Springer and I agreed that they probably did not have an understanding of what they were drawing. What then was the value to these students of repeating this information? Mrs. Springer used the example of the little girl who asked about having golf balls in our bodies to answer my question.

"She matched that drawing to something she understood. My students know that we learn in different ways and that what works for one doesn't necessarily work for another. Thinking about golf balls worked for this little girl. She probably will remember that there is a lot of space in our bodies but I don't think she has anything to connect that with yet". Mrs. Springer went on to say that most first grade students don't have a clue about atoms and electricity but they are learning that sometimes you have to take things "on faith".

I then asked Mrs. Springer if the little boy that loved atoms, because he had to use his imagination to see them, might better have spent his time on a subject he was capable of understanding. Her reply was that even if he didn't understand atoms he was clearly stretching his mind and reaching intellectually for a very high goal. In this way, in her opinion, the lesson was very much worth his effort.

The lessons learned in the electricity unit were not necessarily the lessons taught. As Mrs. Springer continued to discuss her students' achievement she described other ideas that they had developed during their work on the electricity unit. Several students related the concept of a circuit to the concept of a life cycle. Connections were made between the positive and

negative symbols associated with atomic particles and symbols used for mathematics. Students identified many occupations related to the production and distribution of electricity, they talked about producing and consuming and drew parallels to their similar discussion of food, and they spent time enjoying photographs of lightning and talking about the beauty of nature.

Chapter Conclusion

Mrs. Springer is an experienced teacher both in the classroom and as an instructor of other teachers. During the time that I observed her classroom, she was teaching in a multi-age setting of her own design and balancing the learning needs of a wide age range of students. Her classroom exhibited a strong sense of community including a shared responsibility for learning. Mrs. Springer incorporated several instructional strategies within her repertoire that she felt aided students in developing an understanding of the inter-relatedness of all learning. She also taught her students strategies to assume responsibility for their own learning. Students were encouraged to be self-directed as well as to be available to help others in the class. Her science instruction was centred on a theme that was inclusive of all subjects required for first through third grade students. Frequently she used a concept map to emphasise the interrelationships between topics and students were encouraged to do the same. Mrs. Springer viewed herself as a facilitator of learning rather than a transmitter of knowledge. One of the strategies that she used to encourage students to take responsibility for their own learning was the daily requirement for students to write in their journals. They also evaluated their own work within the parameters that Mrs. Springer set and they planned for and conducted their own parent conferences. Mrs. Springer was very clear in her rejection of externally imposed standardised tests as a means of assessing student progress, understanding and achievement. She much preferred the feedback she received from her students by way of discussions, journal entries, completed reports and projects, and the student led parent conferences as devices that gave her a valid picture of what her students had accomplished.

In spite of her years of experience in the classroom, teaching science presented a dilemma to Mrs. Springer that, in her perception, was caused by the requirement to teach age inappropriate material to her multi-age students. In review of my observations and notes on my discussions with Mrs. Springer, it would seem that additional issues contributed to her dilemma. Her limited knowledge of the concepts she was teaching sometimes seemed to result in her accepting memorised information as achievement of understanding. In her opinion, the curriculum that was provided by the district lacked substantive, age-appropriate objectives for her to focus on and she had not been provided with a district assessment instrument that she could use to effectively evaluate either her own teaching or student achievement. My review of the curriculum guide did not support her view of it but did suggest to me that she had neither been trained in how to use it nor provided with the resources to use it effectively. Mrs. Springer felt obligated to provide her students with a very content rich science program and went to great trouble to do so on her own. In her efforts and dedication she reached beyond her own knowledge and understanding of the science concepts she tried to teach. As she reflected on the learning that took place in her classroom during the electricity unit, Mrs. Springer identified several important but unplanned concepts that were explored as students interacted in group discussions, sharing their own thoughts and listening to others. The value of these somewhat vicarious learnings should not be ignored. Mrs. Springer's student loved their theme days and looked forward to "learning about stuff."

CHAPTER 5 - TOM GORMAN

Tom Gorman was completing his second full year of teaching during the time that I worked as a participant observer in his classroom. He began his teaching career after six years of undergraduate work, which included earning a major in history and making a change to an additional major in education during his junior year. After graduating from college Mr. Gorman substitute taught for two years, gaining experience with students of several age levels, abilities and backgrounds. He was hired to teach fourth grade by a private school and, the following year, joined the SFSD as a fifth grade teacher. Mr. Gorman was teaching fifth grade during the period that I was making my observations. He taught in a self-contained classroom and was responsible for teaching his students all content areas of the district mandated curriculum. When asked about the differences between science instructional methods and those he used in other subjects, Mr. Gorman discussed the similarities he found in the manner that he taught both social studies and science. Although social studies had been his major field of study, he said that he was quite comfortable in the science classroom.

Mr. Gorman informed me that he chose to join my project because he hoped it would afford him opportunities to reflect on his own teaching and allow him to gain insight into strategies that would increase his effectiveness in the classroom. With that in mind, he welcomed the suggestion that I might help him structure some of his science activities so they would include clear parameters and a focus for his students to follow. I enjoyed the discussions we had about designing lessons that would enable all of his students to achieve the objectives he had set for them. Those discussions provided me insight into his views about teaching and student achievement.

When asked how he learned best, Mr. Gorman answered that it was by reflection on what he had done or read. He modelled his belief in the importance of self-reflection by his journaling for me. He regularly gave his students opportunities for self-reflection as well. It was typical for him to ask

his students to write down and discuss their ideas about a new topic prior to the beginning of the lesson. He also would ask his students to look at their earlier thoughts at the end of a lesson and consider how those thoughts might have changed as a result of the new learning. There is an example in the story that follows which illustrates how Mr. Gorman used this strategy to encourage his students to reflect on what they knew before coming to class and on how their thinking had changed after participating in a lesson. I observed and scripted a series of lessons that preceded the one in the case study story as well as most of the lesson that is described in the story, helping only briefly with the last activity. It is a lesson that occurred towards the end of a unit on air and space. Students had completed several lessons and activities on the atmosphere and weather prior to beginning the discussion of flight.

Case Study Story

Mr. Gorman's class was excited and noisy when they entered the room after their lunch break. Typical high-spirited fifth graders, they were especially enthusiastic today because they were about to start a unit on airplanes. They were looking forward to the final activity in this unit, which would be a model airplane-flying contest. It was a few minutes before they started to settle down and Mr. Gorman was able to get their attention. "Thank you, Riley for sitting so quietly," he said to one student, to another, "I appreciate the way you are waiting for me to start. I see you have your notebook out and you are ready to learn." Gradually the students began to get their materials out of their desks and Mr. Gorman started the lesson.

"First of all I'm going to ask you to answer a few questions," he began. "You have seen these questions before. Jot the answers down in your notebook without asking your partner. What ideas do you have? Remember, there are no wrong answers at this stage! We are just trying to get some ideas going. Later on we will talk about the ideas and you can add to your own thinking during that discussion."

The three questions on the board were: what is the atmosphere and what makes it up; does air take up room and have pressure and; how do planes fly? The first two questions were designed to serve as a review of previous topics that the class had studied. The last question was asked as an introduction to the new lesson. At the beginning of the unit on air and space, Mr. Gorman had posed the same questions. Students had already spent approximately two weeks completing a series of activities and discussions in order to work out their answers to questions on the atmosphere and weather. The question on how planes fly, posed at the same time, was not addressed again until today. It was to be the focus of thought and activity for the coming week.

As the students began to write out their answers, Mr. Gorman reminded them that they were to write out as detailed an explanation, as they were able to at the time. "Remember," he repeated, "There are no wrong answers at this time except I don't know." Once each student had something written on his or her paper, Mr. Gorman opened up the class for a discussion. "Who knows, thinks they know or has an opinion about how planes fly?" he asked. Students began suggesting answers faster than he was able to write them on the board.

"Propellers and wings to help it glide," was the first response.

Another student added, "engines and gas."

Other guesses ranged from "the wheels and runway", "the pilot and his joystick" to "pressure and power" and the "shape of the wings and the curve on the bottom".

One student, who had taken several airplane trips added, "Flaps, the things on the wings help it take off. They push the air down and the plane goes up."

"We have lots of good ideas on the board," Mr. Gorman broke in. "I wonder if any of these are 100% correct. We will talk about these as we work for the next few days. Make sure that your idea is written in your notebook and then I want you to copy these ideas down also. In a few days I will ask you to think about what we have been doing and see if you can eliminate some of these answers and maybe think of some others. While you are writing, I am going to give you a paper with an explanation of an interesting scientific law."

Mr. Gorman distributed a paper explaining Bernoulli's Law. When they were finished writing in their journals, the students took turns reading the information aloud. At the bottom of the paper there was a cross sectional diagram of an airplane wing, showing a flat surface on the bottom and a curve on top. Arrows indicating air pressure surrounded the wing. The arrows on the bottom were bigger than those on top.

After reading the information students were asked to step outside the classroom and line up against the wall. "Face the wall and push on it as hard as you can," Mr. Gorman said once they were outside. Then he directed them to walk slowly along the wall while pushing as hard as they could without stopping their forward movement. The activity continued as the students repeated their actions first at a fast walk and then a run. At that point they were told to go back inside, sit down and think about what their activity had to do with the information about Bernoulli's Law.

When asked if they were able to push the wall as hard when they were running as when they were standing still, the general response was, "No Way!". A few students thought that they could have pushed the wall equally as hard in all instances but they were willing to be convinced that they might be wrong.

"What did this activity have to do with airplanes flying?" Mr. Gorman asked. "What was the wall representing and what were you supposed to be?"

It took a few minutes, as well as a suggestion by Mr. Gorman that the students to reread Bernoulli's Law, before one student raised his hand and asked, "Was the wall the airplane wing?"

Another quickly added, "Then we were the air molecules!"

In answer to Mr Gorman's question "were you pushing harder when you were walking slowly or when you were running," all the students agreed that they pushed harder when they were walking.

"What if the air on the bottom of the wing was moving slowly and the air on top of the wing was moving quickly?" asked Mr. Gorman. "Which side of the wing would be pushed the hardest?"

At this point in the lesson the students were beginning to understand Bernoulli's Law and Mr. Gorman had one more quick activity to further demonstrate it. I was enlisted to help. Each student was given a three by five note card and told to balance it on top of two books with the short edges of each card just barely over the edges of the books. They first predicted what would happen if they blew under the card and then observed the results. Although many students had predicted that the cards would bend upwards they did indeed bend downwards. The following discussion occurred.

Mr. Gorman: What happened to the note card or piece of paper?

Student: It went down.

Mr. Gorman: Why?

Student: It's like the wing thing!

Mr. Gorman: Explain what you're thinking.

Student: If something is moving faster it can't push as hard?

Mr. Gorman: And so....?

Student: The air underneath was moving faster so it couldn't push as hard so the air on top pushed harder. The card bent down.

The students cleaned up their materials and returned to their seats for the remaining few minutes of class. Mr. Gorman asked them to reread the ideas they had written in their journals about how planes fly. "Think about what you wrote at the beginning of the period and see if any of your ideas have changed since we did these two activities," he said. "Are there any thoughts that you have changed. Maybe you can add something to the list or cross off an idea that you no longer think is possible." The students wrote quietly for a few minutes. Then, just before it was time to dismiss his class for the day, Mr. Gorman asked them to raise their hands if they agreed that air has pressure. Only about 50% of the students raised their hands. "OK, students, you did a fantastic job today in science class and it looks like I have some more work to do myself to think of ways to help you understand." The students gathered up the things they were taking home and began to line up to catch the bus.

As they left one of the girls raised her hand and asked, "Mr. Gorman, I've been thinking. I get it about what keeps an airplane in the sky but, if that is true, how come planes can fly upside down?"

The bell rang as Mr. Gorman answered, "That's a good question, Ashley. Write it in your journal and let's think about it for tomorrow."

In addition to a follow-up conversation about the case study story lesson, I was able to gain insight into Mr. Gorman's ideas by reading his journal writings and through two semi-structured interviews that I conducted with him. Although I prepared a set of questions for those interviews to provide structure for our conversation, our topics often deviated from the prepared questions as Mr. Gorman pursued his own thoughts.

The initial focus of our conversation during the interviews was on the instructional strategies that Mr. Gorman found most effective and the methods he used to measure their effectiveness in helping students understand and achieve the goals set both by the district and by Mr. Gorman himself. I was interested in his perceptions of his students' understanding of the material he taught and the manner in which he derived those perceptions. The following commentary has been constructed almost entirely from Mr. Gorman's words during those interviews, conversations we had about specific lessons and his journal entries.

Teacher's Reflections on Instruction and Assessment of Student Understanding

I encourage every student in my classroom to develop his or her abilities to think critically. I hope that every student leaves thinking he or she is able to pick a problem apart, analyse the pieces and find final solutions. I learn from my own teaching by writing down what happens and reflecting on it. That process is invaluable to me in growing in my professional skills. It is equally as important to my students as they grow in their skills. Students learn more and understand more thoroughly when they are allowed time to reflect on their own ideas and explore paths of inquiry generated by their own questions. For this reason, I like to take time to listen to my students as they exchange ideas. In addition I am quite willing to let their needs and interests drive the instruction.

I don't think my role as a teacher is to stand up in front of my class and impart bits of wisdom; be a bearer of knowledge. While I do have information and sharing it is a part of the teaching process, I view myself more as a questioner and a guide. I don't want to just give my students answers. I prefer to nudge the kids in certain directions in their search for meaning rather than just tell them information that I think they need to know. I want them to find out some things for themselves.

I routinely use several different instructional strategies when teaching science. I try to be aware of the different learning styles that my students have. I like to ask open-ended questions and take everyone's answers. I always try to open up each unit with a couple of really broad questions about the big ideas of the unit. I take the first day of a new unit to discuss questions in order to pick their brains, find out what they are understanding at the beginning of the unit and just inform myself about where the students are "at" in their understanding of the topic. I think this works better than a pre-test for assessing students' current knowledge. Then I try to generate a bit of discussion and get people to stand-up for their own viewpoints. This makes the students really begin to think critically about their own ideas. Unfortunately, not all the students participate but, if I am able to structure the environment of the discussion so that there is general agreement that all ideas initially will be accepted, the quieter ones usually begin to join in. The order of the questions I ask usually follows the pattern in which the unit will be taught. During the unit I frequently return to the initial question and ask students to reconsider it in light of the new learning that they have experienced. At the end of the unit, I like to return to the same questions and see for myself how much consensus there is on the answers after we've been learning together. Sometimes I even copy their original answers so I can look back when we get finished and see how far they've come.

Another instructional strategy I use regularly is the assignment of activities or experiments. Students like to use their hands and do activities during the learning process and I believe that students learn better that way. The actual

learning occurs when the students have completed an activity and take the time to reflect on their actions. They keep the knowledge and understanding gained in this manner because it becomes more real to them by the process of deriving it for themselves.

I assign activities for my students to complete that will help demonstrate certain concepts. For example, we did several activities relating to Bernoulli's Law. This was a topic that just was not clicking and I had to find several different ways to illustrate the concept for my students before they began to understand it. Other times, the activities are designed to put kids in the position of using their knowledge to solve problems. An example of this type of assignment would be the final assessment I used in the electricity unit. They had to wire a model house and include a parallel and a series circuit.

It is very important to me to be aware of what my students are understanding not only in the beginning but throughout a unit. If you are going along teaching and the kids aren't with you, you need to be cognisant of the fact and be able to adjust what you are doing. Not only that though. Student beliefs and prior experiences colour all knowledge they bring to your classroom and their actions within your classroom. Awareness of them gives you an understanding of why students behave as they do in the classroom. I also think it is important to assess their current knowledge. It might be that they already know what you are intending to teach. In that case it might be legitimate to review and touch on what you want them to know but why totally reteach it? You can use your time and their knowledge to go farther than you had planned with a specific topic.

I have several effective ways of assessing student understanding. One-on-one interviews conducted by me with a student are great tools for finding out what student beliefs are and what their understanding is of one topic or another. Students also might write about a topic. Once they see their own ideas on paper they often come up with new thoughts. Projects and

experiments are also good indicators of student understanding if you have the students reflect on and discuss their own activities. Often kids help explain things to each other and if I listen to their conversations I get a very clear idea of what they are learning. Once, in a math class, I asked my students to write out explanations about the method they had used when trying to solve a problem and then to explain why it didn't work. They were pretty mad at me for asking them to do that but they began to think about why the steps they were following made sense when they wrote out their paragraphs.

Ultimately the goal in my class is learning. I'm not sure that the scores my students will earn on the district CRM's will correlate very well with the learning and understanding that my students have accomplished. There were some things on the test that I'm sure we didn't cover very well this year. I don't think the whole unit on Bernoulli's law was even on the test. Overall I think my students did pretty well although they didn't all achieve equal understanding of the topics we covered in science classes.

There are some things I would change as I look back over the year. I need to learn how to define the parameters of an activity more clearly for my students without being too directive in terms of what they are supposed to do. I also hope my students learned that they have the ability to think critically, to really pick a problem apart. I would hope that by the end of the year they all believe they really can do that. I know it's not my job to make sure everyone has a warm fuzzy feeling. It is my job to teach and see that they learn. It is important that they feel valued but it is not my....I don't know. This is a difficult concept for me. Ultimately the goal is learning and sometimes feeling valued helps students achieve that goal. The valued part is important. I have to continue to think about this.

Data Analysis

Mr. Gorman was a regular journal writer during my research. He consistently took time to record and share his thoughts about the lessons I observed. In addition to reading his journal writings, I scripted his classes as I observed and participated in them, and listened to his reflections during several informal and semi-structured interviews as well as during a round table discussion with other teachers. As I became familiar with Mr. Gorman and his classroom, I began to be able to predict the events that would be occurring during science lessons in his classroom. I identified several elements as characteristic of the environment he had created in his classroom, his instructional strategies and the methods he used to assess student understanding. Those elements include:

1) the posing of probing and open-ended questions in order to encourage students to explore the possibilities of different answers;
2) a habit of self-reflection and the deliberate way he encouraged his students to reflect on their learning;
3) the inclusion of more than one activity in each lesson that would provide opportunities for students to increase their understanding of the lesson objectives;
4) deliberate, ongoing assessment of student understanding both within as well as at the end of each unit of instruction.

Mr. Gorman used information gathered from each of these elements to develop his understanding of the level of understanding that his students were achieving as they participated in his lessons. Although he had no knowledge of constructivism, no specific training, that he could recall, in "teaching for understanding" and was not aware that the NSES existed, he was very specific about not wanting to be a teacher that stood in front of his class and delivered information. Whether he was operating on the basis of common sense or had absorbed and integrated strategies taught in undergraduate classes wasn't clear in our conversations. He did, in fact,

incorporate many of the tenets of science teaching as defined by the NSES in his daily teaching routines.

Questioning Strategies

Mr. Gorman responded to an interview question about how he viewed his role as a teacher by describing himself not as a "bearer of knowledge" but rather as a "questioner or guide". "I don't want to just give them (his students) the answer," he continued. "I want them to find out for themselves. I believe that students learn better that way. They keep that knowledge. It's more real to them."

As I began to visit Mr. Gorman's science classroom, I quickly came to expect classes to start with a set of questions for students to contemplate. The students themselves were continually urged to stretch their thinking and to determine reasonable answers to the questions posed, understanding that logical wrong answers were acceptable but "I don't know" was not. The questions Mr. Gorman asks at the beginning of the case study story provide an example of the typical manner in which Mr. Gorman would start a science class in that the students were required to review past knowledge and bring it forward to use in considering a new idea. In the story, he is hoping that the students will apply previous understandings of the atmosphere and air pressure to try to explain how airplanes acquire lift. Frequently, he would tell his students that there were no wrong answers when thinking about a new concept. Students often would brainstorm ideas and then sort through them immediately to determine the logical ones in spite of Mr. Gorman's willingness to accept any answer to start.

During one of our discussions Mr. Gorman reviewed the planning he had done prior to beginning the lesson. "Before starting this unit, I thought about what ideas the students would bring to the classroom, what they would need to learn and what they would need to unlearn." I asked him if he had been surprised by his students' responses to his question about what causes a plane to fly. He responded, "I was anxious to hear their answers at the

beginning and knew that I would be surprised by some of them. When they began to suggest answers, I knew that most of them didn't come to class with much understanding about this subject." The questions he had asked and the answers students gave informed him that some of the students were just beginning to accept the idea that air has pressure. Gaining understanding of the concept that air pressure is really what keeps a plane in the air would be difficult for many students to understand in his opinion.

The first lesson I observed in a unit on electricity, which focused on differences between series and parallel circuits, provides another example of how Mr. Gorman used questions to inform himself of his students' prior knowledge as well as to encourage his students to think about their own learning. The questions on the board, when students entered the room, were: What is electricity, what would life be like without electricity and how does electricity work? Student answers to the first question included the following responses: Electricity helps things work, electrical objects that work, wires that hook together, power that turns things on, friction and particles, neurons that move. That evening Mr. Gorman wrote the following passage in his journal:

> My goals for this lesson were very simple. I just wanted to introduce the concept of electricity. All the kids knew what electricity could do but very few, if any, knew what it was made of. They did a great job listing items that use electricity but none of them discussed electrons, protons or neutrons. My perception of what they would know coming in to this unit was a bit off. I thought some of the students would discuss particles or atoms. After "pre-testing the students I knew that we would need to begin at the basics. I also knew they were very interested in electricity. (Journal Entry, December 7, 1998)

Mr. Gorman used the student answers in this case to assess the incoming level of student understanding as he started the electricity unit and to adjust his lesson plans to a more appropriate starting point. He also discovered the level of interest that students had for the topic to be learned.

I observed lessons that were part of the unit on electricity for several consecutive days. One of the activities assigned to students was to connect

batteries and bulbs in several different ways that would successfully light the bulbs. As Mr. Gorman worked with the students and they came to him with questions, he would respond to them in most instances with other questions. "Which way worked best? What did that tell you was happening? Tell me why you drew your circuit that way? What else could you do to make the bulb light? Which way doesn't work? Why? That's an interesting answer. Can you explain it?" I heard all of these questions repeatedly as Mr. Gorman helped first one student then another. Each resulted in his students returning to their work and continuing their explorations. They also gave Mr. Gorman some insight into what the students understood.

Self-Reflection

The second element, characteristic of Mr. Gorman as well of his instructional strategies, was the use of self-reflection. It was one of his own personal habits and a habit he encouraged his students to develop. This was a common thread in all of his classes that I observed.

Mr. Gorman used questions as a tool to encourage his students to reflect on their own learning as they participated in activities and to assess their levels of understanding as they worked through each lesson. At the end of a unit, students were often asked to look back on their initial answers to the opening questions and think about how their ideas had changed. They used their original responses to assess their own increase in understanding. In my conversation with Mr. Gorman, he mentioned that occasionally the students would not even admit to their initial responses. They might explain by saying, "I don't know what I was thinking." He explained that, with regard to his own learning and that of his students, "learning comes when you reflect on what you did. People grow from that. If there is not critical thinking, learning doesn't happen."

Mr. Gorman modelled the characteristic of self-reflection when he used student responses to the questions he had asked in class as indicators of the success of his instructional techniques. There is an example of this in the

case study story when Mr. Gorman asked his students to raise their hands if they agree that air has pressure. Only 50% of the students raise their hands. His response is "you did a fantastic job today. It looks like I have some work to do to think of ways that will help you understand." Another example of Mr. Gorman's reflection, coming from a journal entry, also represents his ongoing consideration of his own teaching strategies.

> I found out through a very informal oral quiz that, while many of the students understood from the balloon activity that like charges repel and opposites attract, few of them understood why or how the charge of the balloons had changed. There were several reasons for that not happening ranging from my organisation to misuse (exploding balloons) of materials. (Journal Entry, 12/09/98)

As my observations continued, Mr. Gorman began to reflect on and record his predictions of student responses to his questions before he actually taught his classes. His ability to anticipate questions that the students might have and issues that they might struggle with as they were learning, enabled him to prepare several different activities ahead of time to illustrate various points covered in the lessons.

Multiple Related Activities

Mr. Gorman rarely taught anything during science class without the use of several different activities for each learning objective. This is the third element I found characteristic of his teaching. Invariably, he planned activities that enabled both those students needing enrichment and those needing reinforcement or remediation to operate at individually productive learning levels. Science, to Mr. Gorman's students, meant "doing" something and, frequently, it also meant "finding out" something on your own.

The case study story provides an illustration of how Mr. Gorman often included several small activities in one lesson to illustrate a difficult concept. In this story he used two activities to illustrate Bernoulli's Law. First, the students pushed against a wall while moving at different rates of speed and then, they blew air under a card and watched the resulting downward bend.

The following day students completed a third activity to demonstrate the same point. They then were asked to write about how they each illustrated the results of differing air pressures on the wing of a plane. Once students began to demonstrate some understanding of Bernoulli's Law, Mr. Gorman made a transition to a longer term activity that required them to apply what they had learned and experiment with their own ideas as they did so. Students were given instructions on how to make several different styles of paper airplanes and then explain how the air pressure affected the flight of each different style. The next step was to have the students invent their own paper airplanes or alter the sample ones and prepare for a contest to see who could make a plane that flew the farthest, stayed in the air the longest or did the best trick. Part of this assignment included the requirement that students predict how their planes would fly based on the design alterations they had made. This final activity was intended to become an assessment activity because students were asked to articulate a basic understanding of Bernoulli's Law in their explanations.

The unit on electricity provided another example of how Mr. Gorman used several small activities accompanied by a longer term activity to both illustrate a concept being taught and provide opportunities for each student to develop an understanding of the concept at an individually appropriate level. The focus of the lesson was pre-determined by Mr. Gorman to be the differences between series and parallel circuits. Students were given batteries and bulbs at the beginning of the unit and were asked to find out how many different ways they could make the bulbs light up. They then were taught about series and parallel circuits and asked to construct sample circuits using the same batteries and bulbs and adding switches, bells and small fans. These circuits had to be drawn and explained once they were constructed out of the equipment provided. The final activity was for small groups to work together with the equipment and a large box and design a two room house with wiring that included both series and parallel circuits. Some students kept their models very simple, while others created very complex

designs. The final assessment for this unit came from individual student explanations of why their models did or did not work.

A third unit involved students examining the factors that were needed to build a balanced ecosystem. Each group was given a set of materials to put together a simple aquarium, including container, rocks, water plants, snails and fish. They then recorded their own observations over a period of time, keeping notes on changes in the system and factors that might have caused the changes. Success was not determined by the successful maintenance of the aquarium, although that was indeed a goal. Final assessment, again, was based on student explanations. In this case the explanations needed to be focused on the reasons for the changes that had been observed.

When reflecting on his own practice, Mr. Gorman spoke about his use of hands-on activities for two purposes. When teaching a new concept he incorporated simple activities to illustrate specific points of information. Once students had begun to master the desired concepts he assigned activities that required students to apply what they had learned in problem solving situations. He questioned his students as they completed the various activities assigned and he used their answers to inform his own teaching, frequently adjusting his plans according to the level of understanding his students were demonstrating.

Assessment of Understanding

The fourth characteristic element of Mr. Gorman's instruction was the variety of methods he used to determine the level that students were achieving in his class. Each of the previous three elements described were practices that became part of embedded as well as final assessment of student understanding during a unit of instruction.

Mr. Gorman's use of questions served as an assessment tool by providing him with an understanding of the knowledge his students brought with them to his classes, an ongoing understanding of what they were accomplishing

during a lesson and insight into their final level of achievement at the end of a lesson or unit of learning. He demonstrated interest in the knowledge students brought to class and probed to discover this as well.

The opening questions posed in the case study story lesson allowed Mr. Gorman to assess his students' prior knowledge of the unit about to be taught. During one of his interviews he emphasised the importance of determining what current knowledge students might have prior to commencing a new unit. "Why," in his words, "reteach what they already know when you can go to an extended objective." Or, in the case of the electricity lesson, you might need to back up a bit in the objectives you have chosen and teach at a simpler level than you had planned. Ongoing assessment was frequent in the classes I observed. In the electricity unit, for example, students that were having difficulty were told to "stop, look at your project, get up and walk around it and try to figure out why it didn't work. Talk to me about why your circuits aren't working." In this way students were encouraged to reflect on their own learning and Mr. Gorman had an opportunity to understand exactly the level at which his students were thinking.

In the three units of instruction that I observed in Mr. Gorman's classes his final assessment was embedded in an analysis of the success or failure of a final project. When asked how he preferred to complete a final evaluation on his students' success he listed drawings, quizzes and an occasional test but emphasised the importance of talking one on one with his students and allowing them an opportunity to explain their beliefs and understandings about the topic being studied. He also liked to have his students write about their ideas because "once they put pencil to paper and see their ideas, sometimes they come up with another one." In the electricity unit Mr. Gorman did not feel a paper and pencil test was appropriate. "They were thinking and trying things and I was interested in their problem solving skills and whether they learned from their mistakes."

During the second interview I held with Mr. Gorman he expressed concern about the correlation between the district CRM scores and his own perception of his students' understanding. One of his concerns was that he had little knowledge of either the test scores themselves or any correlation between those scores and his own assessment of his students' achievement. He mentioned later during a round table discussion with other science teachers that much of what he had taught during the year wasn't even tested on the CRM's. That was upsetting to him because he felt he could have shifted his focus elsewhere if he had known the units he had emphasised would not be tested. Mr Gorman also acknowledged during that discussion that test scores would be with us for a long time because they can be communicated "graphically".

Issues to Consider

During our frequent conversations and the interviews that I conducted as part of my data collection activities, I had several opportunities to discuss questions that were raised in my mind during my observations of Mr. Gorman's classroom. Frequently his journal comments answered questions that I had about my observations before I had the opportunity to ask them of him personally. My interest was in what Mr. Gorman was saying and thinking about the level of understanding his students were achieving in his class and the mechanisms he used to inform himself of their achievement. I also wanted to discover what he considered to be appropriate and fair assessment strategies for his students in light of the amount of time they spent on activities in the classes he taught.

An area of concern that I raised with Mr. Gorman was the lack of correlation between some of the topics that he included in his science lessons and the topics outlined in the district mandated curriculum. This resulted in his students having to take a district mandated CRM test, aligned to the district curriculum, but not a true measure of what his students had learned in his class during the year. This was not an intentional act on his part. During one of our discussions he mentioned that he had not discovered that there was a

district curriculum guide until shortly before the CRM test was administered. During a discussion of the NSES, Mr. Gorman also made the comment that "test scores are going to be here longer than you think because they provide an easy indicator" of student achievement and can be presented in graph form for easy understanding by parents and the public. He went on to say that had he been aware of the curriculum guidelines he would have eliminated his unit on air pressure and airplanes and substituted something else.

Mr. Gorman clearly enjoyed teaching the unit on air pressure in spite of the difficulty his students had with understanding some of the concepts involved. I asked him why he included the explanation of flight and Bernoulli's Law in his curriculum since that was more detail than required by the school district curriculum guide. He was enthusiastic as he answered, "I think the reason why I get so excited about this unit is the fact that the concept itself is difficult for students to comprehend and it is quite fun to see how many of them actually begin to get a feel for the idea by the end of the unit. There are many activities that I can do to help my students and part of the fun of the unit is deciding which activities will help this particular group of students in their learning." This was a unit that he had enjoyed because it presented a challenge to him to find an effective way to teach it and his students had enjoyed as they accepted the challenge he presented them. I wondered if his students would have had as positive an experience had he substituted another topic, one more closely aligned to the district CRM's, for this one on flight.

Mr. Gorman preferred to use a performance type assessment at the end of his science units. Although the assessments were quite challenging and his students generally seemed to enjoy completing them, I had questions regarding the validity of the information on individual achievement that he was getting as a result of assessment activities he assigned. The three specific units I observed included group projects as a major component of the final assessment. The unit on ecology ended with each group of four students building an aquarium, recording results and explaining changes that

they observed. Assessment for the electricity unit consisted of a three to four student group constructing a house out of a cardboard box and wiring it using both a parallel and series circuit. Each of these were group projects with no component of individual accountability. Assessment of student achievement for the unit on air pressure was slightly different because it was an individual assignment that ended with a paper airplane contest. The students "invented" three different paper airplanes and then had a contest out on the play field to see which ones flew the farthest, the straightest, the fastest and which did the best trick. Their grades were based on explanations of why changes they made in a basic airplane design result in the changes in flight. Very few students used the concept of Bernoulli's Law in their explanations. While this was an interesting culminating activity for them it did not inform the teacher of the students' success in understanding the concepts he had been teaching.

A third area of concern that I had, as I observed Mr. Gorman's classes, was the frequent similarity between the content and activities in his class and those that I had observed in a multi-age first through third grade class. In both cases students were asked to learn similar ecology concepts, the structure of an atom and it's involvement in electricity, they performed many of the same electricity activities as well as similar activities with magnets. Both Mr. Gorman's fifth grade class and a set of sixth grade classes, that I also observed, worked to memorise the layers of the atmosphere and what was in each, as well as the planets' names and characteristics. In each case, there was no reference by students or teachers of any related prior classroom experience or that there was a continuum in the curriculum and what was learned in one year would be built on in the next. In fact, there was no outward recognition that the topics represented anything but new learning.

The NSES call for science teachers to facilitate learning by focusing and supporting inquiries while interacting with students, orchestrating discourse among students, engaging in ongoing assessment of their teaching and student learning and developing communities of science learners (NRC,

1996). Although unfamiliar with the NSES, Mr. Gorman articulated a strong interest in developing his instructional skills so that he might increase his abilities to provide his students with a classroom that mirrored these characteristics. My observations of his activities indicated that he already was implementing some of the strategies that promoted the learning environment described in the NSES.

Chapter Conclusion

Mr. Gorman was a young teacher with two years experience in self-contained classrooms. During the course of this study, he was teaching fifth grade and was responsible for teaching his students all parts of the curriculum. Although he earned a major in history he is very comfortable in the science classroom and finds similarities in how he approaches teaching both science and social studies. When asked about his role as a teacher, Mr. Gorman responded by describing himself as a "questioner and a guide". Indeed, the most noticeable characteristic of his teaching style is his questioning technique. It provides him a tool to assess his students' prior knowledge and beliefs when initiating a lesson and allows him to encourage students to reflect on their own learning. The responses to his questions give him information that he uses both to assess his students' progress and to reflect on the effectiveness of his own teaching strategies. In addition to the questions, I learned to expect a variety of activities whenever I visited Mr. Gorman's classroom. Each objective addressed during science classes was illustrated by several activities. Some of those activities were designed to illustrate the basic concepts and others enabled students to apply what they had learned and gave them the latitude to expand their learning according to individual interests. Frequently the culminating activity to a science unit became part of the final assessment of student understanding. Mr. Gorman preferred talking with his students and listening to their ideas as a means of evaluating their progress rather than relying on standardised test scores. The questioning, opportunities for all students to reflect on their own learning, many hands-on activities and ongoing assessments were elements that

typified every class I observed and in which I participated in Mr. Gorman's classroom.

Several questions were raised in my mind as a result of observing Mr. Gorman's classes. They included a concern about the lack of correlation between some of the science units he taught and the district mandated test, final assessment strategies that were performance based but focused on group success with little individual accountability and a parallel of content topics and activities between Mr. Gorman's classes and both third and sixth grade classes taught in the same school. I also observed several characteristics of Mr. Gorman's instructional strategies that promoted the type of learning environment described as appropriate in the NSES.

CHAPTER 6 - BETTY FREDERICKS

At the time of this study, Betty Fredericks had 17 years of experience teaching students in grades three through eight, including departmentalised science teaching in seventh and eighth grade classes. She had a Master's degree in elementary education with an emphasis in science instruction. She also had earned an administrator's certificate although she had no plans to enter the field of educational administration. Mrs. Fredericks participated in and taught several training sessions in Madeline Hunter's Essential Elements of Instruction. During the period of time that I conducted my field observations, she was teaching fifth grade students in a self-contained classroom. She and another teacher exchanged students for science and social studies instruction with Mrs. Fredericks teaching the science classes.

Prior to the beginning of this project, Mrs. Fredericks and I spent several years developing an outdoor education centre on district property for the use of all the district students. Together we presented workshops on outdoor education and desert ecology for district teachers of all grade levels. Mrs. Fredericks had become an unofficial science resource person to many elementary teachers in the district both because of her instructional skills and her interest in outdoor education. Because of our involvement together in a number of science projects, I was quite surprised when she told me, during one of our interviews, that she was a "social studies" person. One of the reasons she stated for participating in my project was to improve her own journaling skills. She described this as one of her poorest skills and, since she had been encouraging her students to journal, she thought it would be appropriate if she also developed the habit of recording her thoughts.

The case story related below describes one of the first of Mrs. Fredericks' lessons in which I observed and participated. When analysing this particular lesson she was somewhat critical because she didn't think the lesson had enabled the students to accomplish what she had intended. However a review of the students' journal entries after the lesson showed that they had

started to understand some of the basic concepts that Mrs. Fredericks had identified for the series of lessons to follow.

Case Study Story

At the beginning of class, Mrs. Fredericks reviewed several terms with her fifth grade students. Although they were science vocabulary words the terms had been written on the board for the week's spelling list. The students responded quickly to her request for definitions of the words repel, attract, electrical discharge, electrons, conductor and insulator. After the students briefly discussed the meaning of each word, Mrs. Fredericks turned their attention to a story that they had started earlier in the day.

"What did we decide was the most important thing about Ben Franklin?" she asked.

"That he discovered lightening and was the ambassador to France," was the reply.

Mrs. Fredericks added to that information by explaining that Ben Franklin had "made lots and lots of discoveries." "We need to find out why he did that," she said. "Let's start by reading a story about 'Curious Ben' in your language arts books.

For the next few minutes the students took turns reading the story about Ben Franklin and talking together about the ideas in the story as they read along. At the end of the story Mrs. Fredericks asked the class why it was that Franklin was able to make so many discoveries.

"Curiosity," several students called out at the same time.

"Yes," said Mrs Fredericks, "and you are going to have an opportunity to practice being curious during our next activity. You are going to have to try to have the same mind set as Benjamin Franklin. There are some hints on

the paper I am giving you to help you get started with today's activity." The students continued reading together. The two-page handout described what happens when a wool cloth is rubbed on a comb and then the comb is held up to somebody's hair. There was also a sample chart on one page that showed students how to record their observations. When the students had completed reading the passage Mrs Fredericks said to them, "I wonder why I brought salt."

One of the students, remembering what was in the reading, answered that salt repels "from the comb" and "attracts towards the glass".

"I am going to ask you to find out which things attract each other and which things repel," Mrs Fredericks continued. "You are going to have to do some thinking and designing before you start to work. There are several different supplies on the back table including wool cloth, balloons, salt, pepper, plastic, glass slides, string and some cotton socks. It will be up to you to decide how to demonstrate attraction and repulsion and then write down what you find out. What do you think you need to do first?"

"Describe the experiment," one student answered.

Mrs Fredericks asked, "Should you do the experiment first or write first?" Several students replied with different ideas as to how this project should be approached. Mrs Fredericks explained to them that each group of students needed to do their own planning and it wasn't necessary for them all to proceed the same way.

"Do we each get a balloon?" one student asked.

Mrs Fredericks repeated her previous statement that students needed to think and plan for themselves. Each team of two or three students was to decide what they wanted to try. It was not necessary that they all do the same thing.

"We will be working on two things today," Mrs Fredericks explained. I want you to practice your science skills of observation, collecting and recording data and, at the same time, I want you to find out which objects are attracted to each other and which ones repel each other." She then gave the students permission to get started.

The initial reaction of all the fifth grade students was to grab a balloon before they were all taken. This caused some confusion at first and, after about ten minutes of activity, Mrs. Frederick stopped them. "I think we have found out that we have a problem," she said. I haven't seen anybody plan a procedure, record observations or discover things that repelled. You also have not read enough of the material in your books that explains "why" objects are attracted or repelled each other. After a few minutes of redirection including students restating the directions they went back to their task. Gradually the students began to plan their investigations. Very few of them, however, planned their entire activities before starting. The majority of the students acted on each individual idea as it occurred to them, wrote down the results of their actions and then thought of something else to try.

A small group of girls read the suggested pages in their text and then began to rub a balloon and a comb with a piece of wool cloth. Following a diagram on their handout, they took turns holding the balloon and comb over a small pile of salt and pepper granules. A small amount of salt was attracted to both the comb and the balloon. A very few pepper grains seemed to be attracted as well. "Do you know what is happening?" Mrs Fredericks asked them.

"Static electricity," was the reply.

She asked the girls if they could explain what they were observing and they answered that it was the positives and negatives. "How does that work?" was her next question.

"Static electricity," they replied again.

A group of boys nearby had rubbed both a comb and a ping pong ball with the wool cloth. They showed me how the ball would follow the comb if they brought the two objects close together but didn't allow them to touch. "Can you tell me what is happening?" I asked.

"Static electricity"" was again the explanation given.

Mrs Fredericks asked another group "how that works" and was again informed "it is the positives and negatives."

After about 10 minutes of experimenting with the various objects the students turned to their papers to read a passage on static electricity, attraction and repulsion. "I think we have found out that we have another problem," Mrs Fredericks told her students. "You have demonstrated attraction. I have walked around and seen several examples of it written on your papers. However, you don't seem to be able to demonstrate repulsion. Does anybody have an idea of how to design an experiment to demonstrate repulsion?" There was no answer from the students. "That, I think, is the problem," Mrs Fredericks continued. "You still need to figure out how to demonstrate repulsion. When you do demonstrate it you also have to explain why it occurred." The students continued reading a short passage out loud and discussed the pictures as they read along. Meanwhile, two boys in the back of the room were pushing one charged balloon along the floor with another without letting the balloons touch each other.

There were only seven minutes left of class at this point and Mrs Fredericks ended discussion of the reading by saying, "I want you to design your experiment on "repel" and make some observations. Then I'd like you to write your journal paragraph telling why some objects attracted each other and others repelled each other. Tomorrow I'll ask you to read your paragraphs to the class and we will discuss them. That way I will find out what you are understanding."

In addition to the informal discussions that Mrs. Fredericks and I shared at the end of her lessons, she also participated in two extended semi-structured interview sessions. I brought several questions to these interviews in order to focus our conversation on Mrs. Fredericks' thoughts about her own instructional strategies and assessment procedures. The following commentary was constructed entirely from her statements during those interviews.

Teacher Reflections on Instruction and Assessment of Student Understanding

I have spent a great deal of time during my career researching ideas that apply to curriculum and instruction. I continually work on our Essential Elements of Instruction workshop presentation, making sure that the topics we cover are relevant for the new teachers starting in the district. I also put much effort into keeping current on professional journals, classes covering new ideas and work with other teachers on bringing our curriculum in line with the national standards. I think it is very important that I serve as a resource to other teachers. During both planning and teaching I set very high expectations for my students and in exchange I've tried to make education both valuable and fun for them. I would like my students to describe me as someone who taught them a lot and made learning fun, easy and important.

I have a great amount of knowledge to share with my students but you can't just do that. They don't learn that way, not by a teacher just standing in front of them and telling them what he or she knows. An important part of my role as a teacher is to provide students with opportunities to learn during which they have to do the work and to make those opportunities relevant enough to the students that they will want to do the work. I have to plan for activities that they will want to do but they have to be responsible for their own learning. I need to continually work on our curriculum development project to make sure that essential skills are included and sequenced

appropriately so that the order in which we teach the required material is conducive to learning.

One of the most important instructional tools that I use daily is the newspaper. I look for "real" science in the paper every day. We do current events each morning and the kids know that it thrills me when they come in with their current events about science. They are constantly teaching me wonderful things. It is interesting how rapidly events happen and how quickly we can now access information via the internet. Students learn more easily with the use of manipulatives when there is accountability for using them. I don't believe that shared discovery leads to any meaningful learning without a follow-up of reflection on what has been accomplished. Another instructional tool that I use is the process of journaling. Writing is one of my weaknesses so we are working on this together. I encourage my students to journal and I ask them to use their notebooks to make observations, write down their thoughts and procedures. The objective of most of their science journaling is to have them think about what they are doing and eventually to understanding why that is important. We don't really use the textbook as a tool but I often take my students out to the Desert Education Centre as a way of illustrating to them some of the things we talk about in class.

Instructional strategies that I use include encouraging my students to make many observations and to try to see things in a different light than they might have seen them before. Once they have made observations on something new, a new idea or concept, I have them tie that idea back to a concept we've talked about previously. An example that might illustrate how I like to use these strategies would be our discussion of decomposers. My class had spent quite a long time talking about biomes and ecosystems and thinking about the bottom of the food chain but the students couldn't figure out what the decomposers are in a desert. Instead of telling them, we went out for a walk in the desert to see what we could find. We observed ants, a snakeskin and a snake skeleton and with these in hand discussed the process of decomposition. It was easier to understand with real examples. I also work

with my students on the use of correct vocabulary. I think as teachers we need to continually help students build their vocabularies. Students need to know the right names for things so they can talk about them to other people. Knowing the right words makes things a little more professional.

It is very important for teachers to be aware of and understand the existing beliefs of students as well as the understandings they are gaining as a result of learning in your classroom. I like to conference with my kids, talk one on one with them in order to assess what they are actually learning. During parent conferences I have my kids run their own conferences. They have to tell their parents what they have learned. I find out some things about them that way also. If a teacher doesn't find out what the students are thinking they can develop huge misconceptions. While the teacher is under the conception that the students are building up all the pieces of learning in proper order it turns out that the students may be doing something entirely different than was intended as the lesson for the day. I try to check continuously for understanding either by talking with groups as I monitor the classroom during an activity or, if I am giving a lecture, I make sure to ask every student a question and see they are making connections within the material we are discussing. Many times I have them write in their journals after they do an activity. That also helps me check for their understanding.

I use a variety of techniques to determine the level at which my students are understanding. Some students are experts at memorising material for written tests. While that might be important in some instances I prefer to see them put their knowledge to use. The best way to determine the degree of student learning is to conduct one on one interviews. For the final assessment of our electricity unit, for example, I required each student to make a circuit board. They also were asked to construct a parallel and a series circuit during an individual interview with me.

For many of the science units that I teach, passing is an "A" and failing is not an option. Usually I work with the kids until they "get it" and if they don't

get it the first time they come to me for more help. Unfortunately, I don't think the district CRM test scores will correlate with the level at which I believe my students are understanding. The tests themselves are too "picky", too specific in the nature of the questions. I'm not sure I was that specific in my teaching. If I had a choice I would change the CRM's completely to an authentic assessment. I don't really think there is a place for multiple-choice tests, at least not at the fifth grade level.

I know that my students will leave my classroom this year with a good grasp of the concepts but probably not the small details tested on the CRM's. I think they all left liking science and with an understanding of the importance of looking at what is happening around them.

Data Analysis

Mrs. Fredericks worked in her district for many years and was known among elementary and secondary teachers in the district as a master at both planning and actual instruction. She served as a mentor teacher for several teachers new to the district. Because of her experience with the Essential Elements of Instruction (EEI) as well as her ability to clearly articulate the principles of EEI to others she was regarded as a valuable staff resource for the district. The characteristics that I recognised as typical elements of her instructional practice were also ones that she was frequently called on to model for other teachers. They included:

1) Extensive planning prior to teaching any science lesson;
2) Deliberate integration of science content instruction with the teaching of processes of science;
3) Continual efforts to establish relevancy and meaning of learning to her students and;
4) Using assessment strategies that ensured a level of success for all of her students.

The observations I made in Mrs. Fredericks classroom as well as the text of our conversations and interviews provided many examples of each of these

representative elements of Mrs. Fredericks' instruction and assessment strategies.

Extensive Planning

The process of planning a lesson based on the writing of a clearly stated objective and then task analysing that objective to identify subobjectives and appropriate activities is a critical piece of using the Essential Elements of Instruction. Mrs. Fredericks spent time teaching these planning skills to other teachers in the district. She modelled the use of them herself. Throughout the time that I was observing her classroom and collecting data, she both articulated the importance of planning and gave me evidence of the planning that she had done in preparation for the lessons that I observed. The case study story provides examples of several "Elements of Instruction" that had been woven into the lesson. The strategies identified as set, choosing the objective at the correct level of difficulty, teaching to the objective, establishing relevancy, active participation, monitor and adjust, and using the principles of learning as described by Madeline Hunter(1967) have all been included in the instruction. The use of this type of lesson framework was typical of the manner in which Mrs. Fredericks taught. During one of her interviews she told me "I constantly try to analyse what is going on and try to make sure that all students are involved. I continually work on our EEI program and make sure that things are relevant." As she discussed her role as a teacher, she continued to emphasise the importance of careful planning. "You have to try to provide the opportunities for students to do work and you have to provide things they want to do. I need to be responsible for curriculum development and make sure that essential (science) skills are included and appropriately sequenced in our curriculum." Later on, in a discussion of diversity in the classroom, she added, "I continually have to take into account all the different learning styles." She discussed the variations in learning styles among her students and the importance of considering those styles when planning instruction and when grouping the students to work together. In a later discussion of the patterns of instruction that she follows, Mrs. Fredericks went back to the importance

of planning, explaining to me that prior to beginning a lesson she looks specifically at the district curriculum and CRM's to determine the goal that would be the end point of her instructional efforts. Then she spends a "huge amount of time task analysing" the objective, determining step by step what her students will need to learn in order to reach the goal. The next three elements that I have identified as characteristic of Mrs. Fredericks' instruction are direct products of the careful planning that she does. A comment that reveals the importance she places on planning is one she made when I asked her what she would like included in a written profile of her as a teacher. Her first comment was that, "I would like them to say that I tried very hard to think about and took time for research that applied to curriculum and learning, and that I tried to make education valuable and I think the most important thing when I am planning is to set very high expectations for my kids."

Integration of Science Content and Process

The case study story provides an illustration of the emphasis Mrs. Frederick placed on teaching both the process of doing science and the science content information as related goals. In the story she informs her students that there are two objectives for the lesson: first, to make observations and record them in some organised fashion and; second, to learn which objects are attracted to each other, which are repelled and why the attraction and repulsion occurred. This particular set of objectives typified how Mrs. Fredericks integrated the teaching of process with the district curriculum mandated science content. In one of the interviews, when we were discussing how she thought her students would best learn the material she wanted to cover, she stated, "I have great knowledge to share with my students but you can't do that. They don't learn that way. You have to provide the opportunities for them to do the work and those opportunities must be ones they will want to do". Implicit in her comments was her belief that students would learn best by combining the completion of activities with the acquisition of knowledge. Mrs. Fredericks went on to explain that much of her instruction on process focused on the skill of "making observations, seeing things in a different

light and recording those observations in an organised fashion." She felt that, for the average student, manipulatives and hands-on activities are essential. Those hands on activities, in her opinion, need to be accompanied by a system of accountability in order for the students to take responsibility for their own learning. She also pointed out that she held her students accountable for learning vocabulary words related to the science lesson and frequently taught them some of the overriding science concepts that might help explain an experience they were having in class. In spite of the fact that neither the district curriculum guide nor the NSES recommended the teaching of some of the content material that she covered, she expressed the belief that a certain amount of information including vocabulary is essential for her students if they were to begin to understand the concepts that the curriculum prescribed.

The case study story provides a second illustration of how Mrs. Fredericks integrates the teaching of science process with the content material being learned. In the story, students were asked to determine which materials attracted and which repelled each other. In that process of solving that problem, they were to plan the procedural steps to be followed and determine how to record their observations. The immediate reaction of the students, once directions had been given, was to grab the supplies and play with them. However, after about ten minutes of activity, Mrs. Fredericks stopped her students and told to them, "I think we have found out that we have a problem." She went on to explain that she had not seen any of them plan a procedure, record observations or discover things that repelled. They also had not read enough of the material in the book to begin an explanation of "why" objects attracted or repelled each other. After a few minutes of redirection including students restating the directions the students went back to their task in a more organised fashion. As Mrs. Fredericks talked with the students about their activities in this lesson, she also looked at their papers to see if they were recording their observations. In a follow-up discussion to this lesson, Mrs. Fredericks told me that she felt the students had been too involved with playing with the materials and the process of using the

scientific method had been lost. "Tomorrow," she said, "We are going to try again by following the scientific method. Identify the problem, which is why are things attracted to each other, make observations, we are good at that. Then we will record the information. I think the students need to try to make drawings to explain electron transfer."

Mrs. Fredericks again tried to combined the teaching of process and content during a lesson on ecosystems In this particular lesson, she asked her to relate the concepts of food chains, producers, consumers and decomposers that they had learned about in their books to the desert ecosystem in which they lived. None of the students were able to identify specific desert examples for any of these ideas. Instead of simply telling them the answers, Mrs. Fredericks took her class outside for a desert walk to see what they could find. They were asked to list their observations as they walked along and then try to relate what they had seen to the concepts learned in the classroom. In her words, "It was easier for students to understand the concepts with real examples and we continued to work on the process skill of observation." (Transcript of interview, May 29, 1999)

Relevancy and Meaning

In the process of lesson planning Mrs. Fredericks included much thought about how to make lessons relevant and meaningful to her students. Each time I was in her classroom I noticed strategies she employed to help her students make connections between the science material they were studying and either the world and its events, their personal lives, or other subjects they were studying in school.

When asked to identify the instructional tools that she uses to enable her students to achieve success, Mrs. Fredericks responded immediately with a description of how she uses the newspaper. "The most important tool that I use daily is the newspaper. I look for real science in the newspaper everyday. We do current events every morning as part of our social studies program. The kids know that I love science and it thrills me when they come

in with their current event stories about science topics" (Transcript of interview, May 29, 1999). I observed this myself when I visited Mrs. Fredericks' classroom during a morning social studies discussion. She went on to say that she also encouraged her students to get on-line and research real time happenings. Two examples that she gave me of this were a web site that reported all volcano and earthquake occurrences as they happened and another that reported ongoing worldwide news events.

The case study story provides an illustration of how Mrs. Fredericks tried to create links between the different subjects that her students were required to learn. The reading about Ben Franklin came from the students' language arts book and was included as a reading lesson in the science activity they were doing that day. When discussing this lesson, Mrs. Fredericks told me, "I completely believe in curriculum integration. I feel it helps to make information relevant and more meaningful. This lesson included language, paragraph structure, social studies, Benjamin Franklin's influence on our country and science in terms of the basic beginnings of electricity"(Transcript of interview, May 29,1999).

When I participated in a lesson on desert ecology, Mrs. Frederick told me that she was reading her class a story about a young man who served as a desert guide for a big game hunter. The young man soon became the prey of the hunter and the book related his survival experiences in the harsh Mojave desert. Part of the students' science activity was to learn about both the Sonoran Desert, where they lived, and compare conditions there to conditions in the Mojave Desert. Desert survival was also a topic of conversation for the students and one that is considered an important part of the curriculum because of the location of the school district. Many of the students had stories to tell of problems they had run into as they were hiking or horseback riding in the open desert. Some had heard news stories of deaths that had occurred because people had taken risks in the summer heat when lost in the desert surrounding the Sonoran Foothills community.

I observed many other examples of how Mrs. Fredericks integrated science curriculum and other subjects during the course of my data collection. A science lesson on animal adaptations was focused on a game called "Who Am I". During this game students walked around the room with a picture of an unknown animal pinned to their backs. They had to gather clues from other students about the identity of their animals by asking questions that could be answered with "adjectives". At the end of the game students not only discussed the types of adaptations and the survival advantages they provided each different type of animal but also which words were adjectives, which were not and why. They then assembled themselves into various food chains and, for homework, wrote about the activity. The assigned essay was a language arts assignment. Students were asked to write three paragraphs describing their own activity during the class and then underline the words that were adjectives. They were also asked to include the vocabulary and spelling words from the week before. Those words included herbivore, omnivore, carnivore, predator and prey. There was no scheduled separation on this day between science and language arts.

During a lesson that focused on the scientific method, Mrs. Fredericks drew on her students' math lesson about constructing charts and graphs. Students were to observe the characteristics of various known powders and design a chart to record their observations. They were then to use that data to identify the identity of several unknown powders. They had just learned the difference between charts and graphs in math class and were instructed to use what they had, learned in math to help them design a chart for science. A follow up lesson on making observations and recording them in an organised fashion had students trying to determine the effect of varying the ingredient proportions for a bubble making formula. They first mixed up the standard bubble formula and recorded their observations of the bubbles that resulted. They then were asked to make changes in the formula in an attempt to produce "better" bubbles. Again students were asked to draw on their math knowledge in planning how they would set up a chart to record their formula changes and the resulting observations of the bubbles produced.

A final example of Mrs. Fredericks' efforts to increase the relevancy and meaningfulness of the learning for her students by integrating curriculum centred on the class trip. Her fifth grade along with the others in the school planned an overnight trip to the Grand Canyon at the end of the school year. An exciting trip for the students and an opportunity for the teachers to use the theme "A Trip to the Grand Canyon" to help their students make connections between many of the topics they had learned during the year. In Mrs. Fredericks' class, I helped the students make timelines representing the history of the Grand Canyon. We used metric measures learned in math class to mark off the years. During math class, they had determined the number of years each mark would need to equal; and in science, they had decided which events in the earth's history should be added to their timelines. A related language arts lesson consisted of reading about the history of the Grand Canyon and the flora, fauna, fossil record and rock layers that they would see as they hiked along one of the trails. Social studies discussions centred on the number of people from different places that the students might meet on their trip. Each subject was brought into focus as students planned for their trip. It was difficult to tell, as the students changed from one activity to another, whether they were actually aware that they were following their normal daily routine of switching from subject to subject. To them it was simply a daylong Grand Canyon workshop.

Assessment for Success

Mrs. Fredericks' own words speak of the importance she places in assessment of student progress.

> I think it is really important that we do every single thing we can to check for understanding. So many times they (the students) have the whole wrong idea or picture in their minds. I try to check continuously through lessons. I try to make sure that I ask every kid questions to determine if they are understanding and making connections (Transcript of interview, May 29, 1999).

The case study story provides illustration of her concern for ongoing assessment of student progress. At the beginning of the lesson Mrs.

Fredericks asked students to remind her of the learning that had been accomplished the day before. In this way, students had an opportunity to review the previous learning. At the same time she was able to do a quick assessment of the level of understanding they had achieved and the topics she might need to review or reteach. Later, as the students were initially experimenting with the equipment provided, she walked through the room asking students what they were finding out and if they could explain their findings. It was because of the information she gathered in this manner that she stopped the class after ten minutes of activity and redirected them. Questions and answers exchanged at the end of the lesson informed Mrs. Fredericks that her students did not yet understand that the cause of the attraction and repulsion was the transfer of electrons from one object to another. As a result she invented a simple activity for the next day that would illustrate the concept more clearly.

Following the case study story lesson, I asked Mrs. Fredericks about the level of learning she felt her students had achieved. She explained that her students had been introduced previously to the structure of an atom but that she was sure the majority of the students hadn't really understood it. "This is a very abstract concept and fifth graders are very concrete." She had hoped that this lesson would have made the movement of electrons more "observable and explainable". She felt that the students should have been given an opportunity to "play" with the static makers more and should have been encouraged to devise more examples of repulsion and attraction. In our conversation she discussed her feeling that the students had been successful in demonstrating the concepts of attraction and repulsion. However, as they tried to describe the "how" and "why", they did not include nor understand the negative electron charge.

After our discussion of the lesson, Mrs. Fredericks and I reviewed some of the journal writings of her students. She was surprised at the number of students that had referred to the movement of electrons in their explanations

of why other objects had become attracted to the balloons. Two examples of student explanations of the behaviour of the balloons in this activity were:

> Attract means to come together. We rubbed a balloon with wool and all the electrons in the balloon went into the wool so the balloon was positively charged. We touched the balloon to salt and since the salt was negatively charged they came together (attract). (Student journal entry, January 1999)

> Repel: when you rub a balloon with the wool the electrons move onto the balloon. When this happens to two balloons the balloons are charged the same. When they are both charged the same they don't attract. They repel. Repel means they don't touch each other. (Student journal entry, January, 1999)

Part of Mrs. Fredericks' objective in this activity was to introduce her students to the idea that electrons moved and that that was part of the explanation of electricity. After reading the student journals she felt that they began to recognise the basic idea that electrons moved.

Mrs. Fredericks' habit of opening a new lesson by reviewing the previous learning with her students was evident in almost every lesson I observed. At the beginning of one lesson on the scientific method she asked her students to "remind" her of the steps and explain what they meant. Another time they helped refresh her memory about atomic structure. At the beginning of a lesson on biomes she asked students to write in their journals some of the information that they remembered from a movie seen on the previous day. The students then shared their ideas before starting the new lesson.

Once a lesson was started much of the conversation in the classroom was between Mrs. Fredericks and her students as she asked them questions. Those questions included ones that required students to restate in their own words material she had just explained, questions about what they were doing during an activity in order to focus their attention on procedure and questions about what the students were finding out during an activity. Many times Mrs. Fredericks required students to write what they had learned in their journals after a lesson. A review of the journal writings further informed her of what the students had understood. The case study story also provides

examples of each of these strategies of assessing student understanding during the learning process.

The case study story represents one of the first lessons in a unit on electricity. That lesson was followed by several that built in complexity from one requiring students to make a simple circuit with a wire, battery and bulb to a final evaluation activity in which each student was required to make a circuit board. Each student individually explained to Mrs. Fredericks how it worked in a one on one interview. Students that did not understand or who had not completed their circuit boards were given help so that they would successfully complete the project and explanation. At that point, they were assigned grades and in this case there "were no other grades but "A's".

This final evaluation strategy used in the electricity unit was typical of the type of activity Mrs. Fredericks said she preferred over the use of the multiple choice tests such as those required by the district and the State of Arizona. Her statement to me regarding final evaluations included the belief that "students can memorise for written tests but that doesn't really show what they have learned. They need to prove their learning by putting it to use." Her preference was to evaluate student achievement by conducting one on one interviews after each unit. In her opinion there was little correlation between the district CRM's and the concepts she taught. Although the CRM's were designed to test the district curriculum Mrs. Fredericks thought they were too "picky", asking for answers that were too "specific". When asked about her opinion of the standardised tests that the school district and state required she administer, she completely negated their usefulness either as a measure of student learning or for the purpose of informing a teacher of student progress.

Issues to Consider

Prior to making the decision to include Mrs. Fredericks I had a personal issue to consider. My purpose in conducting this study was to gain an understanding of how teachers individually perceive the level of

understanding that their students are achieving in science classes. One of the criteria I used in selecting teacher participants was a recommendation from the teacher's principal based on the teacher's effectiveness in instruction and classroom management skills. I wanted to minimize as much as possible classroom management problems that might have tended to interfere with my ability to collect daily observational data on the teachers' instructional and assessment strategies. My goal in data collection was to focus on how the teachers were assessing student understanding without being distracted by nonrelevant issues. Mrs. Fredericks fit these criteria perfectly with one drawback that had a potential for preventing my ability to be objective in data collection and analysis. She and I had worked together for many years on several district projects and our relationship was one of friendship in addition to our mutual respect. We had several discussions about this before I was comfortable adding her to my list of participants. Part of my decision to include her was based on my personal experience in participating in many objective and analytical discussions with her about our individual teaching strategies. We knew well each other's strengths and weaknesses and neither of us felt threatened by the other's knowledge. I specifically wanted to include her because of her district wide respected skills in instruction, and her passion for teaching science in spite of a social studies background. Although cognizant of the difficulties I might have maintaining objectivity if she was a participant I felt that her thoughts and perceptions of student understanding would add a valuable dimension to the data I collected. We explored several issues regarding assessment of student understanding in our discussions and continue to do so on a regular basis.

I found two dilemmas in this case study that were similar to circumstances that I observed in other cases. The first might be described as an overlap of content being taught at the fifth grade level and at other grade levels. In spite of the existence of a district prescribed curriculum guide, the teachers I observed either weren't using it or were extending their lessons to include topics outside of the curriculum guide. While there was no restriction within the district against doing that, the result was an almost duplication of the

same lessons being taught at different grade levels. Mrs. Fredericks at the fifth grade level taught most of the same concepts that Mrs. Springer, at the first through third grade level included in her unit on electricity. In each of these situations Mrs. Fredericks used the district curriculum guide extensively in planning but found it fell short of providing her with the resources she needed to develop the lessons she thought would be appropriate for her students. She enhanced the curriculum requirements based on her own understanding of what students would need to know. She did not collaborate with her colleagues teaching at either the same grade level or teaching science at different grade levels. Nor did they consult with her on curriculum content or presentation of that content. Mrs. Fredericks was not aware of the fact that several of the lessons she was teaching were very close in expectations for learning to the expectations of lessons taught in the third grade. The lessons I observed on electricity, magnets, ecosystems, and scientific methods each provided examples of this overlap in instruction.

A second dilemma was one that occurred in Mrs. Fredericks' class as well as in others. There were times when there seemed to be a lack of connection between the concept which was determined to be the objective of student learning and the assignments and, sometimes, the assessment used as evidence that the concept was actually understood. Although Mrs. Fredericks mentioned that a limited knowledge of science content caused her some difficulty at times, she was quite comfortable working with students to discover and understand new ideas. However, in planning the activities that would lead her students to accomplish stated learning objectives she, in at least one instance, determined a behavioural outcome as proof of understanding that was not directly correlated to the learning objective. The objective, in this case, was that students would explain how electricity flowed in a circuit. That particular objective might better have been worded to read that students would explain "that" electricity flowed in a circuit. In the context of the related objectives in the curriculum guide, it was clear that the intended emphasis is on learning about series and parallel circuits and not

the behaviour of electrons. Mrs. Fredericks interpreted the objective to mean that students would need to understand the structure of an atom and the behaviour of electrons in order to meet the objective. Many of her instructional activities were focused on helping students grasp these concepts. However, her final assessment was the construction of a circuit board with an explanation of how it worked in terms of serial and parallel circuits. An opportunity to collaborate with colleagues might have saved Mrs. Fredericks and her students time and energy that would have been spent instead on the specific objectives in the curriculum. Mrs. Frederick's comments to me as we discussed the electricity unit revealed her discomfort with the success of the unit as she implemented her planned instruction. "Students were introduced to the structure of an atom, but I am sure they don't get it. This is a very abstract concept and fifth graders are still very concrete." "They can verbalise attract and repel but they can't describe electron transfer at the application level." "I think students began to understand that something was travelling through the wires. However, it is still hard to explain the concept of electrons. They will develop a better understanding as they design switches." At one point she directed her students to "find out what things attract and repel." She had hoped that this lesson would have made the movement of electrons more observable and explainable. Again there seemed to be a disconnection between what she was asking her students to do and what she wanted them to learn.

As I continued to discuss the electricity unit with Mrs. Fredericks, I tried to discover how she related the need to understand atomic structure and electron behaviour with the ability to construct a set of series and parallel circuits, the terminal objective of the unit. She explained, "sometimes the theoretical stuff is not in the curriculum or in the NSES but I feel like a fraud if I don't tell them what science is going on. Some do get it, I think, and they like it." She struggled with the problem of creating activities that would help her students understand the behaviour of electrons without recognising that that particular knowledge was not essential to achieving success in understanding the objective of the lesson. In fact, due to her assessment

practices, all of her students achieved an "A" grade for the unit and knowledge of electron behaviour was not part of the final assessment.

A third issue of interest that was raised in my discussions with Mrs. Fredericks, was her preference for using performance assessments when determining the level of understanding that her students had achieved at the end of a unit. She did not expect a correlation between the district mandated multiple-choice tests and her own perception of student understanding and expressed the desire to work on changing the district tests to a performance assessment format. She rejected out of hand any standardised test and substituted individual conferencing as a means of determining student understanding at the end of each unit. This did not seem to present a difficulty for her. She expressed no concern about a conflict between what she was doing and the district requirements and, in fact, carefully administered the district tests when directed to do so. She did not, however, find them to be a useful tool in her determination of student success in achieving understanding.

This issue was mine to consider alone as Mrs. Fredericks did not appear to be particularly bothered by the position of conflict with the district goals that she seemed to be in. She was and remains one of the most highly respected teachers in the school district. She continually served as a resource and mentor teacher to others during the time I was visiting her classroom. Here was a teacher that was regarded by the district as a role model for all others in the district and she, herself, had no regard for the district's primary goal of becoming the number one district in the nation as measured by standardised test scores.

Chapter Conclusion

Mrs. Fredericks is an experienced teacher who has taught several grade levels within our district. Her training in the Essential Elements of Instruction promoted by Madeline Hunter has made her a valuable resource

for other teachers in the district. The planning skills that are identified in the Essential Elements formed one of the characteristic elements of her teaching. Included in that planning and the resulting instruction were several strategies to make the content material both relevant to students and meaningful for them to learn. The deliberate process of weaving scientific methods and content objectives into one science lesson is a third distinguishing characteristic of Mrs. Fredericks's teaching. Assessment and final evaluation were part of her teaching process. Strategies that she employs to assess her students understanding were review questions at the beginning of a new lesson, continual questions at different levels of thinking throughout the lesson, student journal writings and, at the end of a unit, performance assessments including one on one interviews with each student. Mrs. Fredericks felt that the district mandated multiple-choice tests were too "picky" and "specific" and didn't give a true picture of student learning.

Analysis of the data I collected during my observations of Mrs. Frederick's classroom raised three issues that seemed to present dilemmas either for her or were problematic for the SFSD. The first was the repetitiveness of objectives between grade levels. Several lessons that I observed in Mrs. Fredericks room were very similar to ones that I witnessed during observations in lower grade classrooms. At times Mrs. Fredericks' limited knowledge of science content seemed to hinder her ability to recognise a lack of connection between some of the activities she asked her students to complete and the learning objectives that she hoped the students would achieve. The third issue that I considered was Mrs. Fredericks' rejection of the importance of standardised tests and her substitution of individualised conferencing as a means of determining student understanding at the end of a science unit. In a district that had established the goal of being the number one district in the nation as determined by achievement test scores, one of the teachers, regarded as a role model for others, simply did not show any interest in the goal.

CHAPTER 7 - LORI RICHARDSON

Prior to coming to the SFSD, Lori Richardson taught middle school students for five years in both public and private schools. Although her Bachelor's degree included a major in chemistry and a history minor, she had experience teaching all content area subjects including physical education. During one of our conversations she expressed interest in pursuing a Master's degree in counselling but did not want to become a school counsellor. She said that she would prefer to use the counselling skills within her own classroom. In addition to her classroom teaching responsibilities, Miss Richardson had always coached and continued to coach various athletic teams throughout each school year she has taught. Her coaching activities had been time consuming and as a result precluded her from continuing her own education. During our conversations she told me that she was unfamiliar with any current research on instructional strategies that she might use to augment her own pedagogical techniques.

At the end of this project, Miss Richardson had the opportunity to transfer to a new middle school in her district. She chose to make that transfer with the understanding that she would be able to teach both science and social studies to the same group of students and that she would stay with these students for both their sixth and seventh grade years. She felt that this opportunity would enable her to help students understand the relationship between the two subjects and thus make both more meaningful.

During the course of my observations in Miss Richardson's classroom she taught earth science to sixth grade students (eleven years old) in a middle school setting. The school had just changed to a block schedule and classes were 90 minutes each. This provided Miss Richardson with the time to complete extended activities during one class period and she frequently included hands-on activities during her lessons. She also included journal assignments for her students in each of the lessons that I observed. One of the reasons Miss Richardson volunteered to work with me on this project

was the emphasis I had put on journaling as a data collection technique. She espoused a strong belief in the process of journaling as a tool for self-reflection both for herself and her students.

The following case study story is a composite lesson resulting from my observations in Miss Richardson's classroom. Her lessons often continued over a span of two or three days and included extended projects that her students worked on both at home and in class. The story represents a ninety-minute lesson, part of an extended unit on weather and climate.

Case Study Story

As they entered the classroom, the students looked towards the board for the daily journal assignment that Miss Richardson had written. Within a few minutes the students had settled in their seats and were quietly writing about the "worst storm they had ever been in". While the students were writing, Miss Richardson dimmed the lights and turned on a CD. The sound of rain filled the room and was interspersed with the rumblings of thunder and loud cracks of lightning. The students were quiet and thoughtful for a while and Miss Richardson took care of attendance and homework checking while they wrote. As they began to finish their journal entries she turned the CD down and turned on the lights again. Then she invited the students to share their experiences. Many of these students were new to the school and had come from several different parts of the United States. Although none of the students had been in a disastrous storm, they had much to say about their own experiences.

A student from Nebraska talked about being kept home from school because of a blizzard. Others from the east coast described torrential rains during hurricane season. One student brought the previous night's news into the conversation with the comment that "there were some cool stories about a tornado on television last night."

"Did anybody else see that story?" Miss Richardson asked.

"My grandparents live in that city," replied a girl sitting in the front of the room. "There was a whole family of tornadoes last night. The biggest was a half mile wide and there was nothing left when it got done."

Other students added bits and pieces that they had heard including, "there was a baby found unharmed in the piles of rubble, a man's car door went through a tree and a description of the numbers of homes that were destroyed."

"Watch the weather report tonight and pay attention to what is happening," Miss Richardson suggested. "Pay attention to the terms that are used and see if you hear any that we are using in class. Let's take a few minutes to review the material we talked about yesterday." At this point Miss Richardson asked a series of questions in rapid succession, calling on different students for each answer. She first asked, "Michael, can you name three types of storms?"

Michael answered with "a thunderstorm and..."

Miss Richardson quickly added "a hurricane and a tornado. Good Michael! Then, to another student, "Tell me the cause of a thunderstorm."

The student responded with "ions".

Again Miss Richardson helped him with his answer. "They are caused by positive and negative ions. And what does that cause?"

When the next student answered with the word electricity, Miss Richardson expanded on that by explaining that the electrical discharge caused lightening and continued with an additional explanation that thunder was caused by air expanding. She continued with a few more questions and then ended with "Good job, I am surprised that you remembered all of that."

In many cases the questions required simple recall of terms introduced the day before. Most of the questions focused on storm types, weather related word definitions and the symbols on weather maps. Frequently Miss Richardson helped with the answers if a student didn't know the correct response immediately. Students were expected to check their notes and add any missing information before continuing on to the next part of the lesson.

"Today we will be talking some more about tornadoes but first I want to help you get started on the computer project that we discussed yesterday." Miss Richardson began a more formal part of the day's instruction. "Your class will be studying cities in the north-western part of the United States. The first thing we need to do is choose the cities that you will each research." Students were given the opportunity to draw the names of cities out of a hat. They then could make one change with another classmate if they didn't want the city they first were assigned. Once each student had the name of a city, they were all instructed to locate the city on the map of the United States that each had at his or her desk. They also were told they needed to find out some basic information about the city, in addition to the weather information that they would be looking up on the internet.

This was the beginning of a 30 day project, during which time each student would be required to log on to the internet and look up daily information about the weather patterns in the city assigned. The students were to keep that information in a chart and would be using it eventually to both create a weather map of their own and interpret weather maps that would be provided. Different classes would be gathering information about different sections of the United States and at the end of the unit the entire body of information would be combined to create a comprehensive map of national weather patterns.

There were only four computers in the classroom so students were directed to take turns in looking up their information. Those students not at the

computers occupied themselves by creating tables for use in recording the 30 days of information and by completing a worksheet that required students to put tornado data on a map and interpret that data by answering questions. I spent most of my time helping individual students log on to the computers and finding their cities on the www weather site that had been bookmarked for them. Miss Richardson spent the remainder of the class talking with the class as a whole about the answers to questions on the worksheet. As the class came to a close, students were reminded to "watch the news tonight and listen for any weather terms." "Your journal entry for tomorrow will be to list the terms that you remember hearing and to describe a weather condition that was on the news so be sure to listen for something or look in the paper for information," Miss Richardson cautioned the students as they left the room.

Throughout this project Miss Richardson sent me many journal entries of her own. They generally included her reflections on the success of particular lessons and her perceptions of what her students actually understood. We also participated in several informal conversations both during and after the lessons that I observed and in which I participated. Data collected in this manner as well as in two semi-structured interview sessions was used to develop the profile of Miss Richardson that follows. The comments are almost exclusively in Miss Richardson's own words taken from the interview transcripts and my notes on our conversations.

Teacher's Reflections on Instruction and Assessment of Student Understanding

I come to school every day loving what I do. I teach kids. I don't just teach kids science. I want kids to understand that science is not just an isolated subject but rather has a relationship to everything out there - language arts, social studies and math. I think my students understand a lot. They take

concepts that we've talked about and seem to really understand them. I also think they will use what they've learned in my class as they continue in school and in their personal lives. They have enjoyed science and had fun in my class as they learned.

My role as a teacher is to make my students explorers, to help them understand that they do have the ability to go out and explore new things and to encourage them to "want" to go out and explore. I use several strategies to accomplish this. One thing that I try to do is to let the kids know that the things that they are interested in are important and I am interested in finding out about them. Those things such as their music may not be what I prefer but they know that I will pay attention to what they care about. A strategy that I use to encourage kids to learn is to let the students know that I am interested in them and care about them. I always want my students to know how important they are to me. Another strategy that I use to increase understanding is to relate science to history and culture. I think students learn more when they understand why certain developments have occurred and the historical context in which those events occurred. I encourage my students to learn how to journal. I give them a journal topic to reflect on when they walk in the door. The topic might be about a previous lesson or unit in order to tie it to the next unit or it might require the students to reflect on what they need to study to pass an upcoming test. I use journaling myself to review my own lessons and analyse what I can do to improve.

I frequently use what you might call a "review tool" in my instruction. Review is used on purpose. When I start a new unit I try to tie in what we were doing in a previous unit and explain how it fits into the new material. I use the student's prior knowledge, gained in the previous unit, to build a bridge to the new unit. On the day we start the new unit the journal question on the board will be from the unit before. Throughout the year I continue building that bridge from one unit to the next. The last strategy that I use consistently is to include "hands on" activities in every unit with a culminating activity that ties in all pieces.

EEI stresses the use of prior understanding as a tool for learning. I've used it (prior knowledge) previously but more instinctively than I have this year. It is very helpful for me to know where the students are at in terms of knowledge. It helps me plan lessons. I also can use their diversity of understanding and maturity to help group my students so that their individual characteristics complement each other in learning groups. My students also have diverse learning styles. Recognising that keeps me honest. I understand that their way of learning may not be the same as mine.

Although the grades my students earned on their CRM tests may not reflect it, I think they have understood science really well this year. I think, for example, of the weather unit and the maps they were able to produce as a culminating unit. They did much better than I expected and much better than the CRM scores will show. The CRM test questions were poorly worded for sixth graders. The questions need to be revised. But in terms of learning I am impressed with what the students have done. My students had a lot of prior knowledge as well. I give credit to the teachers that they had before. In any case I know they will use what they've learned in my class both in school and in their own lives.

I love kids; the look on their faces when they succeed; how they show off their knowledge when their parents come to the classroom to visit. I'm having a blast!

Data Analysis

Miss Richardson brought a sense of enthusiasm to each of the classes I observed and in which participated. Her classes always included a combination of several activities including journaling, lecture, oral questions and answers, worksheets and hands-on activities that enabled the students to interact and share ideas. Students in her classes made frequent use of the internet to gather information for their various projects. Miss Richardson regarded herself as a facilitator of learning and frequently expressed the

importance of developing a personal interest in her students as a strategy to help them increase their own interest in learning. She continually identified connections between past and current learning for her students, regarding this "bridge building" as a critical piece of her instruction. She also emphasised the importance to her students of reflecting on their own learning and encouraged them to use a daily journal for that purpose. Their journal entries allowed her some insight into their achievement as well as their ideas about subjects discussed in class. Although she gave quizzes and tests, Miss Richardson preferred to assess her students' end of unit achievement by performance and authentic assessments. I found the following four practices to be consistent elements of Miss Richardson's instruction and assessment strategies:

1) An emphasis on taking a personal interest in her students;
2) Her deliberate attempts to help her students build bridges between previous and current learning;
3) Her frequent use of journaling and;
4) Her emphasis on the importance of variety of assessment strategies.

Each was clearly defined both in our conversations and in my observations of her classroom teaching. Each practice provided her with insight into her students' understanding of the concepts she taught them in class.

Developing Personal Relationships

During our first interview Miss Richardson emphasised how important it was to her that her students knew she cared about them. "I always want my kids to understand how important they are in the room," was one of her comments early in our first interview. At one point I asked Miss Richardson if she thought it important for a teacher to be aware of students' prior understandings and beliefs about science content. Would that knowledge perhaps help a teacher increase the effectiveness of instruction? She responded from a personal rather than an academic point of view.

> I make it a point, if a kid comes in new to find out a little about him. If students are talking about a group that's popular and it's new I make a point to listen to that music next time I'm at the store. On my way to school in the morning I listen to the same radio stations that

> my students are listening to so I have an understanding of their beliefs for the day. To me belief is what they feel is important in their lives, what they believe in, their role models, their ideas of the world, fashion, culture, all those things that change from decade to decade. (Transcript of interview, March 11, 1999)

As our interview continued Miss Richardson explained why she thought it was important to be aware of what her students were thinking.

> I remember when my teachers took the time to know what we were doing. I felt more a part of a class when a teacher wanted to know who I was as a person. I'm hoping that my students are getting the same feeling in my classroom. (Transcript of interview, March 11, 1999)

The case study story provides an illustration of one way in which Miss Richardson drew on students' prior experiences when she is teaching. In the story she asked them to recall a dramatic storm that they might have experienced. She created a situation in which their interest in their own experiences might then be transferred to an interest in the weather experienced in other parts of the United States.

At the beginning of another lesson the journal assignment on the board when the students entered the room was "If you were a cloud, what type cloud would you be and why?" Student journal entries told as much about themselves as they told about the students' recollection of the previous days lesson on cloud types. One student wrote:

> If I were a cloud I would be a cumulo-nimbus cloud.... because it produces many kinds of storms. When it is windy I am just sitting outside whistling because I am happy. On other days it might have lightening in it. That is because I am mad and stamping my feet. It is usually windy instead of stormy because I am usually happy not very mad. (Student journal entry, April 29, 1999)

Another wrote:

> I am a cumulo-nimbus cloud. I get mad often and cause high winds with lots of lightening. This cloud is like me because when I get mad and hit the table my eyes flash like lightening. I don't cry often, but that could be the rain. (Student journal entry, April 29, 1999)

Miss Richardson felt that a review of these journal entries gave her insight not only into the content understanding that her students had achieved but also information about them as individuals.

In our final interview I asked Miss Richardson what comments she might like included in a profile of her as a teacher. Her reply; "That I never let a student give up; that students know that I care about them; I teach kids, I don't just teach kids science. I teach kids about life and that means much more than what you find in a book."

Building Bridges to Increase Meaning

Miss Richardson's school was on a block schedule during my observation time. She had her students for two alternating nine-week periods during the school year with each group of students scheduled for a 90-minute class daily. Her classes met for either first and third quarters or second and fourth quarters with the instruction in each quarter equalling the instruction generally offered during an entire semester of classes on a normal schedule. The district required that she administer CRM's covering the entire year's curriculum at the end of the second nine-week instructional session for each set of students. This situation made it necessary for Miss Richardson to help her students remember during the second session what they had completed nine weeks earlier.

During our conversations Miss Richardson frequently referred to helping her students "build bridges" and make "connections" between units, between daily lessons and between classroom learning and the students' lives outside of the classroom. She also referred to using review as a tool to help students recall past learning and make connections to new topics. I asked Miss Richardson for an example of this type of connection making and she reminded me that during the first nine-week session her students had studied the atmosphere in detail. Prior to introducing the weather unit at the beginning of the new session, nine weeks later, she reviewed the layers of the atmosphere with her students, discussing the characteristics of each layer.

The review was "used on purpose," not just so that students would remember the layers of the atmosphere but more importantly so that they would begin to recognise the relationship between those layers and the weather they would be discussing in the new unit. She then opened up a discussion of climate and asked her students to think about the climate in the places where they had lived previously. The journal assignment used in the case study story provides another illustration of how Miss Richardson felt she was helping students build bridges between everyday experience and classroom learning in order to increase the relevance of the content to be learned. In the story students were asked to think about the worst weather conditions they had experienced. Later in the daily lesson they would begin a long-term project tracking the weather via the internet in another part of the country. With those pieces in place Miss Richardson began the unit on weather that would include understanding the causes of different weather conditions and different climate zones, the ability to interpret the symbols on weather maps and the ability to make weather predictions.

Another example of bridging units, described by Miss Richardson, was the connection she asked her students to make between the water cycle and the weather cycle. A journal question at the end of the water cycle asked students to discuss what the water unit might have to do with a weather unit.

In this discussion, Miss Richardson referred to using students' prior knowledge and experience as a teaching tool and felt that she had gained awareness of the effectiveness of this use through her EEI training. Referring to the understanding that students might have brought from previous classrooms to her class, Miss Richardson was surprised at the lack of knowledge students demonstrated and felt their misunderstandings might have been caused by lack of life experience rather than lack of teaching in earlier grades. She did not give any examples of connections she had made between her curriculum and the curriculum her students had been taught in previous years.

Journaling to Inform Instruction

Each day that students entered Miss Richardson's room they were asked to begin a journal entry for the day. The journal assignment was on the board and students almost automatically looked there as they sat down. Assignment questions may have required students to think about their own personal experience or to reflect on the learning of the day before. They might also have required that students use the learning in a new way, to think about connections between the current topic of study and topics from previous science units or even other classes or to build bridges in their thinking between events in the current news and topics discussed in science. In the case study story Miss Richardson used journaling for two distinct purposes. First, it provided information about the personal lives of her students and allowed them to share, if they chose, some of their own experiences, including where they had come from and some major events in their lives both with her and with the rest of the class. A second purpose of journaling, according to Miss Richardson, was the tool it provided students to use in bridging news of the "real world" with the events and information being discussed in the classroom.

The case study story provides an example of a journaling question that asked students to draw on their own experience. In this particular case Miss Richardson not only used the journal entry to generate interest in the up coming weather unit. She also was able to quickly assess what weather experiences her students had had and could decide how to make the weather unit relevant and "more meaningful" to them.

Earlier in the year, Miss Richardson's students, along with the entire sixth grade, spent a week together at science camp. Each evening the students were required to write about the day's events in their journals. When the students returned to school they finished their journals, illustrated them and gave them to their teachers to be used as part of the assessment of their participation and achievement while at camp. Miss Richardson talked with me about how she planned to use them not only to assign a grade for her

students but also to analyse the camp program. The information in the journals provided information about which parts of the program the students had enjoyed and benefited from the most and which activities they didn't like. Miss Richardson's team of teachers would use this information when planning the trip for the next year.

Miss Richardson indicated that journaling was a tool she used personally to improve her own teaching. Claiming that she made a journal entry for almost every day she was in the classroom, she explained that by reviewing her daily notes from the year before or even from days or weeks before she was able to identify reasons why certain lessons did or didn't go well. Journal notes allowed her to reflect on times when she was frustrated at or excited by a particular student and search for causes that might be controlled. Miss Richardson used the notes in her journal to revamp the manner in which she presented material to her students and to "learn more effective teaching strategies" as a result.

Journaling is a technique that Miss Richardson encouraged all of her students to adopt for many of the same reasons she practiced it herself. She felt that it allowed them to think about what was important in any situation. They might use journaling in class to reflect on a previous lesson, think about a previous experience that was relevant to the topic being studied or, identify weak areas of understanding that might need some focus prior to a test.

Miss Richardson used the journaling technique to reflect on her own behaviours and feelings about her instruction and to inform herself of her students' progress as a result of that instruction. Student journals served as a multiple use tool for her. They provided insight into her students' personal experiences, helped inform instruction, served as one means to help students build bridges between learning and provided an assessment mechanism for determining student progress.

A Variety of Assessment Strategies

"I check all the time," was Miss Richardson's answer when I asked her how often, when and why she checked for student understanding. She then described several methods she implemented for checking during a class period. Those methods ranged from a simple raising of hands if an idea was understood, checking on a partner or neighbour to see if they had the correct answer to an end of class assignment that would be graded each night. She also relied heavily on facial expressions as she was explaining something. In her words, "their faces show it" when they don't understand. One assessment strategy that Miss Richardson didn't mention was her habit of asking a series of rapid-fire questions near the beginning of each lesson to review the topic taught the day before. This period of questioning occurred in almost every lesson that I observed. In many cases, when Miss Richardson asked students these review questions, she would provide the answers for the student called on if he or she didn't know it. Generally these were knowledge-level questions requiring students to recall specific bits of information rather than to apply prior knowledge to a new situation.

Miss Richardson described understanding as knowledge that "the student can explain in his or her own way. I know they are ready to move on when they can explain things." In our discussion of assessment strategies, she described a culminating activity, assigned at the end of the weather unit, which typified the form of assessment that she preferred. This was a project-based assessment assigned to a group of four students and turned in after completion of the weather unit.

One of the questions asked during our second interview was, "How will student achievement on the required district CRM and Stanford 9 tests correlate with your own perception of the achievement of students in your class this year." Miss Richardson expressed confidence in the amount of understanding that her students had achieved in her science classes. She was particularly excited about the weather unit, illustrated in the case study story. The final assessment for this project had been a group activity in which the

members of the group had had to use a variety of sources of weather data to construct a weather map that could be used to interpret the information collected and make weather predictions for the coming week. Miss Richardson felt that by applying what they had learned in class and to a realistic situation the students had demonstrated a complete grasp of the concepts she had taught. However, the scores that her students earned on the district CRM science test (specifically on the weather related questions) were much lower that the district goal of 90% mastery. The overall scores for the objectives relating to the weather unit ranged from 81% to 35% with an overall mastery percentage of 50%. Her comment when I questioned her on the discrepancy between her perceptions and the student scores, "The CRM doesn't carry that much weight in their overall average to hurt them (the students). That is not how I measured their understanding throughout the year."

Issues to Consider

Miss Richardson's instructional practice seemed to exhibit many of the characteristics described as the model in the NSES and by advocates of constructivist teaching. As I watched her teach and studied the data that I had collected over a period of time in her classroom I observed many examples of times when her students were asked to understand content and curriculum objectives that had been adapted to their interests, knowledge, and abilities. They frequently participated in activities that involved interaction and sharing of ideas with their peers. They were also regularly challenged to share in the responsibility for their own learning. I had some questions about what I saw and Lori and I shared several conversations regarding my questions. I was interested in some of her specific teaching practices such as the rapid-fire questions that she asked for review purposes and the dynamics of the students' behaviour when assigned to group projects. When I focused our conversation specifically on how Miss Richardson determined the level of understanding that her students had achieved, I was very interested in how she interpreted prior understanding and experience relative to the other teachers in my study. An additional

issue that separated Miss Richardson from the other teachers in the study was her dichotomous view of standardised testing.

Miss Richardson had not enrolled in any additional training in either pedagogy or science content since she had graduated from her university almost 8 years ago. In the interim she had acquired and put into practice several effective instructional strategies but did not articulate a clear idea of how one might teach for understanding. She asked her students many questions, for example, but the majority of the questions were at a simple recall level and she answered many of them herself. In fact, during one conversation about that she realised what she was doing and began to insert more open-ended questions into her questioning strategies thereafter. A second instructional strategy that began to change as a result of our conversations was the structure of the group projects that Miss Richardson frequently assigned. She chose students carefully for each group, joining students with different abilities and learning styles, etc. But she did not give them clear parameters for what they were to actually do each day. Consequently a few did much of the work and others had a good time watching. There was often quiet talking within the group but little actual discourse on the subject to be learned. The end product for most of the group projects involved a group final assessment with no individual accountability. Many of what she referred to as the class discussions were quite teacher centred and consisted primarily of Miss Richardson asking questions and her students repeating back to her information that she had previously given.

Miss Richardson talked with me about the importance of knowing about students' prior understanding in order to help them build bridges between science concepts and their every day lives. She deliberately developed activities that would require students to use material previously learned in her class to new material. She did not, however, demonstrate any interest during my observations or our conversations in helping her students build bridges between her class and content learned during previous years. She

referred to previous school learning only once when she mentioned that she knew the teachers "had done a good job but the students didn't remember anything." Although she had a district curriculum guide available to her, she had never looked back to the curriculum objectives of previous grades to see what she might use as points of connections between her classes and earlier ones. She had an alternative and rather unique way of interpreting the idea of student prior understandings and experience compared to the other teachers. She consistently interpreted "prior experience and understanding" to mean personal interest and experience rather than to experience that might bring meaning to the content being taught. She found it very valuable and made a point of utilising any information that she could discover about student interest outside of the classroom. This prior, outside experience was a tool for her to develop positive relationships with her students. She wanted them to know that she was interested in them and took specific steps to get that accomplished.

Each of these practices, the questioning, group assessments, class discussions, and the limited use of prior knowledge and understanding were also strategies that Miss Richardson claimed to use to develop an idea of what her students were actually understanding in her class. I observed instances when she accepted student recall of fact for student understanding at a conceptual level. She did use student prior knowledge within her own classroom as a tool to use in building new understandings. She might have found it more effective a tool with more training herself.

Miss Richardson was in the minority among the teachers who participated in my research in that she expressed interest in and willingness to use standardized tests as a tool for assessing student understanding. However, as we discussed the test results and compared them to her own perceptions, she also described two serious concerns that she had about the potential error inherent in relying on the standardised tests scores to evaluate her students' achievement. She explained her first concern with the standardised tests in terms of her own style of instruction and assessment. I "don't teach that

way." I don't write a single test all year long that is a multiple choice test." When it comes time for the mandated standardised tests in Miss Richardson's classroom the students are faced with a task that they haven't previously practiced. It wasn't so much the idea of an outside test that bothered Miss Richardson as the fact that she didn't feel that type of test adequately assessed the concepts she was teaching.

Miss Richardson expressed a second concern that resulted from her participation in the construction of the district CRM tests. She discussed the process that the teachers who had written the tests went through, particularly the choice of representative questions and the specific wording of each question.

> If as adults we can't agree on the wording how can we guarantee that students will even understand what the question is asking. I prefer performance assessments I think they take kids to a higher level of thinking that you can't get out of a multiple choice. If I had to rely on one outside measure of whether my students are performing I'd go with a performance test. But then I have to trust that that test will actually test the objectives I am supposed to teach. I don't think we have that level of trust with any outside test. (Transcript of interview, May 25, 1999)

She did not, in this conversation, acknowledge that the district CRM tests were anything but "outside" tests although she had helped write them. One of her frustrations was that she had worked for several days earlier in the year making changes to the test along with several other district science teachers. According to Miss Richardson, the teachers who had worked on the committee, as well as their colleagues, had spent the year teaching with the understanding that their students would take the revised version of the test. They, therefore, had adjusted their teaching so that the test would actually test what they had taught. When the tests were actually administered to Miss Richardson's students in April none of the modifications appeared on it.

Chapter Conclusion

In this chapter I have identified four general practices as characteristic elements typical of Miss Richardson's instruction and assessment practices.

The first was the importance she placed on developing a personal relationship with her students. She interpreted the phrase "prior understandings" to mean the personal points of view and personal preference of her students rather than academic understandings. She considered knowledge of this to be important both in making the students comfortable and able to learn in her classroom and in providing personal information about them that might help her facilitate their learning.

The second element characteristic of Miss Richardson's teaching was her deliberate attempts to help her students transfer knowledge gained in one unit to the next unit - a practice she calls "bridging". She also helps her students construct bridges between science, other subjects and the world outside of the classroom. In her words, "It makes things easier to understand if the students see connections." Miss Richardson's choice to move to a setting in which she could teach both science and history is an example of the importance she placed on the building of academic bridges for her students.

The practice of using "journaling" as an instructional tool was the third element of Miss Richardson's teaching that was apparent in every class that I observed. She discussed its usefulness for herself in reflecting on the effectiveness of her daily lessons. She also assigned her students daily journaling assignments and used them both to encourage them to reflect on their own knowledge, build bridges between science and other subjects and to inform herself as to her students, thoughts, feelings and progress in learning.

Miss Richardson's preference for varied methods of assessment to determine her students' progress and to inform herself of their achievement was the fourth characteristic element of her instructional strategies. She continually questioned them during class, perused their journals for insight into their level of understanding, and assigned them frequent group projects and hands-on activities that required them to apply what they had learned from the book and her presentations of content material. She relied on performance

assessments rather than multiple-choice tests to determine final achievement. She explained that the low test scores that her students earned on the standardized tests were a result of both lack of practice in her class and a poor choice of words and questions on the tests themselves. Although quite willing to use the standardised tests for purposes of assessing understanding, Miss Richardson was also adamant about the lack of trust she had in the accuracy with which the district tests actually reflected what her students had accomplished.

As I reviewed the data I collected during my observations of Miss Richardson's class I was interested in several teaching practices that I observed. Each of these practices, the questioning, group assessments, class discussions, and the limited use of prior knowledge and understanding were strategies that Miss Richardson claimed to use to develop an idea of what her students were actually understanding in her class. Her lack of training in science pedagogy frequently seemed to result in her mistaking student recall of fact for student understanding at a conceptual level.

Miss Richardson was unique among the teachers in her willingness to implement standardised testing as a tool to determine student understanding. She did not accept the existing test as adequate, however, for assessing the understanding of her particular students.

CHAPTER 8 - CATHERINE CORNETTE

Catherine Cornette was in the middle of her first year of teaching at the high school level when she participated in my field project. Prior to coming to SFSD, she had spent eight years teaching biology and microbiology at the community college level. She had both a Bachelor's and a Master's degree in microbiology and had also completed three years of work on a doctorate in genetic research. In the high school, where she was employed during my study, her assignment included teaching chemistry to 10th and 11th grade students. These were heterogeneous classes with some students taking as many science credits as they were able to schedule and others enrolled in the bare minimum for graduation.

One of the skills that Miss Cornette thought she brought to her high school students was her understanding of the processes of science as a result of her research background. In addition, she felt that her knowledge of biology allowed her to make connections between the sciences for her chemistry students that other teachers might not be able to make. She also realised that that same knowledge base could be a problem if she wasn't careful about talking at too high a level for her students to understand.

Much of the activity in Miss Cornette's classroom was based on the established routine of the entire high school science department. The "warm-ups" completed at the beginning of each lesson were done in all classrooms. Each unit taught included a learning cycle activity as an introduction and all lab activities were prepared by the team of chemistry teachers and taught in all chemistry classes. The teamwork within the department provided consistency from class to class but also created some instructional issues that Miss Cornette discussed in several of our conversations. She did not always agree with the logic of the sequence of lessons and occasionally thought that the questions asked at the end of activities assumed that students had made greater leaps in understanding that, in fact, they actually had.

The following case study story has been composed of a combination of lessons that I observed and in which I participated during Miss Cornette's classes. However, the story is primarily based on one lesson, including a lab activity. A few lesson components, characteristic of the majority of lessons I observed in Miss Cornette's classes but not necessarily in this particular lesson, were added to the story.

Case Study Story

When Miss Cornette's students entered room they immediately sat down, took out their chemistry notebooks and began to copy the information written on the board. After writing down the objective for the day and the homework, they began to work on the warm-up problems. While they were doing this, Miss Cornette recorded attendance and walked up and down the rows of desks checking homework. The warm-up questions centred on the relationship between the structural formula of several compounds and their possible boiling points, rates of evaporation and physical states at room temperature. After a few minutes, when most of the students had completed answering the questions, Miss Cornette began a discussion of the answers. She asked a student to "first tell me what you see" as she pointed to the structural formulas on the board.

"There is an 'O' in acetone" was the quick reply by one student. "London forces are important in holding the molecules together. They are weaker so they don't hold as tightly. The molecules can spread out so acetone is a gas."

"He's good!" Miss Cornette smiled. "How many of you got that?" Two students timidly raised their hands. "About 2%! That makes a teacher feel good." Miss Cornette continued, "I was hoping you would get this by process of elimination. Let's talk about it for a minute and then see if you understand." At that point an active class discussion ensued with students asking questions about London forces, dipolar molecules and other topics

that they thought were related. After a few minutes, Miss Cornette asked the class to predict the relative rates of evaporation of several compounds based on the class discussion. This was part of the warm-up exercise. She then handed out copies of the lab activity for the day and informed her students that they had already done the "prediction" part. Once they read the lab the students were to start working on it with their teams.

The lab exercise was entitled "Why do liquids evaporate at different rates". Students were to complete the lab activity by measuring the evaporation rates of liquids, generating and testing alternative hypotheses concerning differences in evaporation rates of four initial liquids tested and then use the preferred hypothesis to predict the evaporation rates of several additional liquids. In order to complete the objectives of the lab students needed to decide how to conduct fair tests of the liquid evaporation rates. They also needed to find the structural formulas of the liquids given as examples.

The students were quiet for several minutes while they read the lab instructions. They then began to talk within their groups, planning how they would accomplish the lab objectives identified in the handout. Once they had a plan or, often, the beginning of a plan several students went to the supply counter to gather the materials they would need to complete the assigned activity.

Students spent the remainder of the period perfecting their techniques in determining the evaporation rates of the liquids provided. Miss Cornette worked with individual groups, helping them first to identify hypotheses based on what they knew about each molecule and then to decide if they had set up "controlled experiments" and were doing "fair tests". Students were required to collect data from several trials of each liquid before they completed the activity. Miss Cornette asked them many questions while they were working. "Why aren't the trials the same?" "Why did the order change on the second trial?" "I don't see how there is a difference in these two molecules?" And several times, "Is that a fair test?"

It was time to clean up before any group had completed the required trials. Most of the groups ended the class with a plan in mind for answering the questions and a few practice runs completed. As they put away their supplies Miss Cornette asked them to review the structures of the molecules and be prepared to defend their findings with an explanation that included intermolecular forces and any other factors that would affect the evaporation of liquids.

As they left the room one student asked, "Does this have anything to do with why you get droplets of oil on the driveway after a rain?"

"That's a good question," Miss Cornette replied. "You know I like to think of everyday things that relate to our class. I'm glad that you thought of something this time. See if you can explain that for us tomorrow."

Although not as active a journaler as the other teacher participants, Miss Cornette was always eager to share her thoughts after each lesson that I observed. She frequently compared her approach to instruction and assessment to the approach she had taken when teaching at the community college level. In that comparison she expressed a preference for the time she was able to take in her high school classes for laboratory activities and discussion. This was an opportunity she felt led to greater student understanding and one that she had not had during her earlier teaching assignment. The following commentary about Miss Cornette's thoughts on her own instruction and assessment practices is taken almost entirely from her own words during our interviews and our conversations immediately following the lessons I observed in her classroom.

Teacher Reflections on Instruction and
Assessment of Student Understanding

This is my first year teaching a high school class and I've discovered that, while you can "do fun" you have to be careful of "fun". But I encourage my students to think for themselves and to try to do some things on their own. I try to challenge them to come up with their own ideas. The process of generating their own ideas helps their understanding of content and increases their learning. Much of the process of learning centres on respect. If my students are comfortable knowing that I am going to respect the suggestions or answers that they use in response to my questions then they work harder and learn more. They also know that I care about them. It is quite normal for people to make more of an effort if they feel that some one cares about them. That quality of caring is important in the classroom also.

When teaching I often feel like a coach. Most students have the ability to learn. What I need to do as a coach is direct and redirect them if need be. I provide the background information, new information and concept connections and then they apply what they've learned. Learning has happened when a student understands concepts from beginning to end; they understand how to use information for problem solving and can work independently. In order to learn, students need to have concepts presented in several different ways. What might be presented in lecture form one day is reflected in an assignment of problems the next day and possibly found again in a lab activity the following day.

One of the instructional strategies that I use absolutely every day is to have students enter the room and immediately do a warm-up exercise. These consist of questions or problems on the overhead projector that they have to answer. This procedure provides reinforcement for the previous day's instruction before we continue on and it also provides information to me about the level of understanding my students have achieved. If they have totally missed something the day before it comes out immediately during the

warm-up activity. I also use a lot of questions in my teaching: "Why is this so?" or; "What is the relationship between this and what we talked about yesterday?" I also try to bring in everyday applications or examples of the concepts we are learning in class. For example, the students finally understood the basic logic of stoichiometry when I asked them about changing the recipe for making brownies. Why not double the eggs, or if you make two batches how many eggs would you need. After I discuss several day-to-day applications the students themselves begin to bring up every day examples of the concepts we learn in class.

Use of a brownie recipe to introduce the concepts of stoichiometry would be a good basis for the development of a learning cycle. That would be another instructional strategy that I use frequently. My colleague and I try to establish a discovery/learning cycle type activity for every unit that we teach. It is a wonderful way to generate questions and have the students begin thinking about the topic before we begin an explanation. I think that whenever you have somebody think of a concept by himself or herself they seem to learn better. It is far more effective than having me pound the information into their heads with a hammer.

It is very important to me to have a clear idea of my students' understanding as I go along. I'm not going to be able to proceed in teaching information if there isn't a basis of understanding in students' brains to build on. You can't build on nothing! I would not be able to do my job without a fairly clear idea of the level of understanding that my students are achieving. The warm-up activities that I assign give me immediate knowledge of how my students are doing. They allow me to monitor and adjust as needed on a daily basis. I also give weekly quizzes and grade homework but those grades come after the fact. It is the warm-ups that allow me to adjust my teaching. I also check for student understanding by giving regular quizzes and by checking their homework. I feel very strongly that I can't move them forward in their learning if I don't know where they are at in the first place.

The final achievement of my students this year will be assessed by our district CRM's. Unfortunately I'm not confident that the CRM questions really correlate with what I have taught. I think that the majority of my students have done very well this year. The stoichiometry unit provides a good example of how they have grown in their understanding of some very difficult concepts. After learning the basic procedures for solving problems they had to apply what they learned to an actual lab reaction, determining both a theoretical yield and the reason why the actual yield differed from the theoretical. Many students were frustrated because they couldn't apply what they learned in the lab to the quiz problems that followed. Those that came in for extra help were able to sit down and just work through the steps. They probably had a better understanding in the end than was shown by the CRM results.

I know for a fact that students who have to take any other science class will be glad that they have had this class. They might not be glad they learned stoichiometry but they will find college classes much easier because of what they have learned here.

I wish I had more time with students. I would use it to teach them some of the skills that they will need when they go on to college. They are terrible note takers and they need basic study skills. Given more time I would be able to take part in more one-on-one discussions with each student. I would gain a better understanding of how they are doing that way and be able to help them more. I'd like to ask "how did you understand what I just presented?" That would help me improve my teaching skills.

Data Analysis and Discussion

Although much of what Miss Cornette did in her classroom was dictated by established science department procedures, the manner in which she presented material, asked questions and discussed ideas with her students was a factor of her own experience and interest in what she was doing.

Several times during our conversations she commented on her approval of the number of lab activities her classes were able to complete compared to her classes at the community college level. On the other hand she expressed frustration at not being able to take the time needed to see that all her students understood concepts before the class moved on to new ones. Occasionally, during my observations, she mentioned to her class that another teacher had devised the lab questions or the test and the questions were not quite satisfactory to her.

As with the other teachers that I observed during this project, Miss Cornette had certain consistent practices that were characteristic elements of her own teaching style. Typically, these elements of instruction and assessment of student understanding were evident in almost every class that I observed. They included:

1. Checking for understanding, illustrated by the warm-up activity in the beginning of the case study story;
2. Using a variety of activities to teach each concept, although part of the science department procedures, was an element that Miss Cornette emphasised as critical to help students with a diversity of learning styles to master essential ideas;
3. Making connections between the content of the lesson and everyday experiences and
4. Relying on the district multiple choice criterion reference tests as a final assessment instrument.

Checking for Understanding

During both of the interviews that Miss Cornette participated in, she discussed how important it was to her to continually determine what her students were understanding. She regularly attempted to assess the level of understanding gained during the previous lesson by planning a warm-up exercise that they did when they entered the room. The warm-up illustrated in the case study story was typical. Usually that exercise consisted of questions relating to the previous days' lesson. Student responses on the

warm-up provided Miss Cornette with some insight into the level of understanding students had gained from the previous day's lesson. As Miss Cornette asked questions about the warm up in the case study story a class discussion ensued, taking a large portion of the time allotted for that class. It became apparent during the discussion that the majority of students in class had just begun to grasp the concepts necessary for understanding of the lab activity. In discussion after class, Miss Cornette commented that she had expected more than half the class to be able to use their prior knowledge, from previous lectures, to explain intermolecular interactions. She felt that, by the time the discussion was over and students had completed collecting their lab data, most students were able to predict the relationship between intermolecular forces and evaporation rates. But she had a further and not uncommon concern. "I thought they would be able to discuss the interactions during the remainder of the period but they did not have time and I ended up feeling they needed to be responsible individually for the concepts." In the end "the lab did not work correctly so I ended up telling my students that the structures affected the relationship. The students seemed very comfortable with this." Her means of determining that comfort level was her conversation with them during the ensuing class periods.

During one of our interviews I asked Miss Cornette how important she thought it was that teachers have an awareness of students' existing beliefs and understandings. Her response was immediate and reflected many of her actions that I observed during the time I spent in her classrooms. "It is very important (teacher awareness of student understanding) and easy for me to get at in conversation." After giving students an assignment to work on in class, Miss Cornette consistently walked around the classroom and talked with her students about their work. She explained that frequently students would ask her a question that led her to understand what they were thinking about things in a way she hadn't intended. "I can't tell you how many times I've turned around and asked how many of them think blank is going on. Then it is time for me to go over the learning again. I may have no understanding of a stumbling block that had been interfering with student

learning until I discover, often by accident, that students have misunderstood my teaching from the day before. The stumbling block might also be a preconception they brought into my class as a result of past learning. Sometimes the students themselves aren't even aware of a preconception that might keep them from moving forward in their learning." Miss Cornette used her conversation with her students to inform herself as to adjustments she needed to make in her own teaching. In the case study story she makes a comment that about 2% of the students understood the concept she was trying to teach them and then turns that comment back on herself as an indication that she needed to adjust what she was doing. Several times during my observations, when students were working on problems, she would tease them a bit saying something such as "O.K., nobody has done number 5 (for example) yet. Does anybody get it?" Students would respond readily with questions. "That helps me understand what I need to do," she explained to me.

The idea of prior understandings that might present stumbling blocks to student understanding was discussed twice during our conversations and Miss Cornette used the term in two distinct ways. In each case the implication was that relevant prior understandings were derived from previous classroom experiences. In the one instance she was concerned with students who might have misunderstood her teaching from the previous day or earlier in the year. She also brought up preconceptions that students might have brought with them to chemistry class from classes they had had in previous years. The example she used to illustrate this point was the concept that many students have of an atom as taught in elementary schools as opposed to the more sophisticated model they were learning about in her class. She also said that they bring many science vocabulary words to class but frequently don't really understand what they mean. As we continued our discussion she expressed a desire to know what had been taught in previous science classes, thinking that a knowledge of student experience with concepts relating to the physical science as well as their previous

opportunities to practice logic and deductive reasoning skills would be a useful tool to inform her own teaching.

Although Miss Cornette also used frequent quizzes, homework checks, worksheets and student presentations to check for student understanding, the primary strategy that she relied on was interaction with her students during class as they answered her questions and asked their own. Warm-ups were often starting points for discussions. Those discussions both informed her of the level of understanding that her students were achieving and clarified concepts for her students that had been presented stumbling blocks to their progress.

Using a Variety of Activities

As students entered Miss Cornette's room each day they were presented with a "warm-up" activity on the board. They were familiar with the class routines and quickly began this assignment. Along with the warm-up questions was a list that included the objectives for the day and a brief summary of the planned activities. Those activities varied considerably from day to day. Together the chemistry teachers planned the discrete units that were taught and Miss Cornette, as the newcomer, had some input but was still in a position to rely on what the others suggested. However, she was very enthusiastic about the basic pattern that was followed and certainly, within her own classroom, was able to develop her personal instructional strategies as she chose.

As new units were introduced students often participated in a learning cycle activity. The benefit of this, according to Miss Cornette, was to generate questions in students' minds about previously unfamiliar concepts. By making observations and collecting data they would begin to think about new ideas and discuss them. Miss Cornette could then ask questions that would connect the observations that had been made to the new learning that was to follow. She described her pattern of instruction as one that included the learning cycle, then a lecture to fill in information, followed by an

application activity, perhaps a worksheet, and then a quiz. If many students did not do well on the quiz then it was her habit to go back and reteach portions of the unit before going on.

During my observations of Miss Cornette's classes I observed her integrating several different activities into her daily procedures. The warm-up activity always started the class. It was frequently followed by a class discussion of the warm-up questions. That discussion would lead either to a lecture or a lab activity that reinforced the daily objective. Lab activities usually served as the focus of small group discussions as students worked together to understand how to answer the questions assigned at the end of the activity. Those small group discussions might become study groups to review for a quiz or problem solving groups to share ideas about finding the solutions to homework problems. During all of this time Miss Cornette would often sit with a student who was working and participate in a one-on-one conversation either to facilitate the students learning or to inform herself of the level of student understanding that was being achieved. Occasionally students would spend some time reading and reviewing in preparation for quizzes or tests that were coming up. When asked what was the most effective strategy for students to use when learning new content, Miss Cornette told me, "They (the students) told me that it has to be presented in several ways. If I present a lab one day, a lecture the next and then problems, they get it."

Making Connections to Enhance Meaning

Although she cautioned that you had to be careful of "fun" when teaching high school students, Miss Cornette's lessons frequently included relevant and often amusing examples of everyday occurrences that might be explained by concepts being taught in the chemistry class. "As I go through a lesson," she told me, "I always try to bring in an application, something they see in their life." Students also would suggest examples of chemistry in their daily lives that they could understand or try to link to the required learning. The case study story includes a simple question at the end of the lesson about oily water on the driveway after a rain. The student asking the

question was thinking about the connection between intermolecular forces and an observation made at home.

Many other examples of everyday illustrations of chemistry concepts came up in conversation during class time. The swelling of a bag of potato chips as students drove from home to a nearby ski resort, making a considerable altitude change along the way, was used to illustrate the gas laws. Hitting the water hard when making a "belly flop" dive or when jet skiing came into a discussion of hydrogen bonds. The need to mix salad dressing before pouring it was used as an illustration of differential densities of liquids and it came up again during a discussion of intra versus intermolecular forces. When students were struggling to understand basic principles of stoichiometry they were greeted with a lab activity that required they increase a brownie recipe and prepare enough for the entire class. The concept of a mole was likened to the need to package eggs in cartons of a dozen each. Oil spills, kool-aid (a popular children's drink) and beauty products and a story in the news of two people standing on a propane tank to get a good view of a nearby fire were used at other times to make a point. Finding partners at a dance served as an illustration limiting factors in a chemical equation.

Miss Cornette did not discuss the use of everyday examples to illustrate new concepts in the context of her own instructional strategies. I did not observe any instance when she used such examples as a method of generating interest or assessing initial understanding when she began a new unit. Nor did she include questions about everyday occurrences on the quizzes or tests that she used to determine student achievement at the end of units or for the semester grading period. However, when students suggested and were able to relate examples in their own lives to new concepts she took that as an indicator of their understanding.

Evaluating Achievement

Miss Cornette expressed concern during our conversations about the restraints she felt were imposed on her when she was ready to determine student achievement. The high school science department had determined prior to her arrival that they would use the district CRM tests at the end of the semester to assign final grades. She did not think that the district test results reflected a true picture of the student understanding she was witnessing in class. "I honestly don't think they are aligned to the way I teach. The problems may be the same but they are not presented the way I present them."

Assessment of student understanding is an ongoing process to Miss Cornette. She does not wait until a final evaluation of achievement to determine student success. At one point, as we talked, she wished that she had more time to talk one-on-one with individual students in order to evaluate her own teaching success and to allow her to adjust her plan to suit her students' needs. She also felt that students were able to articulate a much greater degree of understanding in a conversation than they evidenced on paper. One of the strategies that she liked to employ was the use of group presentations as a final assessment for individual units. She also preferred her own quizzes to those used by the department because she felt they reflected the content of her class more closely than the standardized ones.

The high school science department actually gave two standardized tests during the period that I was collecting data. The district CRM's were mandated and the department chair had requested that the district also provide Stanford 9 testing materials as well. Miss Cornette and I were able to examine the CRM test results from her students shortly after I had completed my classroom observations. It was difficult to interpret what we were given due to the method in which test results were reported. Each objective tested was represented by 5 questions on the test. There were only 10 objectives tested. The report did not show individual percentages either overall or for individual objectives. Instead the report indicated whether

students had achieved mastery of each objective as indicated by answering four of the five related questions correctly. Mastery was indicated simply by a + or - sign for each objective. Miss Cornette's students mastered few of the objectives tested. It was not possible to tell, from the test score analysis, how close they had approached mastery. The Stanford 9 test scores arrived at the end of the school year. This was quite an expensive test and the science teachers had waited for the results expectantly. They, too, were a frustration because of the reporting format. Student success was reported individual and for objectives only indicated by number. There was no group report and no indication of what the objectives were. Much time had been spent in Miss Cornette's classes on testing but she was not able to use the results to inform her teaching.

At the conclusion of my data collection for this research I facilitated a one-day workshop on science instructional strategies for ten district teachers. All but one of the teachers that worked with me as participants in my research were included in the workshop participants. Part of our time during the workshop was focused on the NSES and a discussion of the ideas contained within them. At one point during that discussion the value of multiple choice tests such as the Stanford 9's and the district CRM's was questioned. Miss Cornette asked, "When do you start teaching this (i.e. how to take these tests)? This is the real world. These students are going to end up taking these tests. Academically, the real world is multiple-choice based."

Issues to Consider

Miss Cornette participated in my research during her first year in the SFSD. This was also her first year teaching below the university level and she made frequent references during our conversations to the differences she perceived between the lectures and separate laboratory assignments that she had been accustomed to and the integration of lab activities with brief lectures that she was practicing during her current teaching assignment. She also expressed some frustration with constraints that she felt had been imposed on her by previously established procedures in the high school science department. A

second source of frustration that concerned us both was the difficulty that she and other science teachers were having in getting standardised test score reports in a usable format. This department had made a commitment to the district goal and had requested extensive science standardised tests to be administered. However, by the end of the year they had not received usable information about the test scores results from the previous year.

When Miss Cornette joined the staff of the SFSD high school she joined a department with both established routines and a strong sense of collegiality. She had much support from her colleagues while she developed expertise in teaching younger students and a subject, chemistry that she had not taught previously. During this time she had the opportunity to implement science specific instructional strategies such as the use of learning cycles due to the training of her colleagues. She had had no knowledge or experience with these methods before. It had been the practice of the people in her department to work closely with new teachers, sharing all lab activities, appropriate worksheets, and sets of problems, setting up labs and giving them quizzes and tests that were being used in other sections of the same classes. This practice was designed to promote consistency between the classes as well as to give new teachers some time to get used to the routines of high school teaching and to concentrate on classroom management during their first years as practicing educators. In spite of her appreciation for the support received from her colleagues, Miss Cornette expressed frustration several times during the year with the constraints that she felt the support offered imposed on her own activities. She did not always agree with the logic of the sequence of the lessons and occasionally thought that the questions asked at the end of the activities assumed that students had made greater leaps in understanding than they actually had.

Miss Cornette chose to do nothing about her frustration during that first year, feeling that she had yet to earn the right to suggest changes. From my observations of what seemed to be a close working relationship between members of this particular science department, I felt that Miss Cornette's

reticence to suggest changes was due to self-imposed constraints. As a consequence, her students were frequently subjected to assignments and evaluation activities designed by another teacher who was unfamiliar with their particular levels of achievement. There wasn't always a consistent correlation between what was tested and what was taught in her classroom. Miss Cornette was frequently left with a "feeling for" what her students understood but no specific data to support her feeling.

Of the teachers that participated in my research, Miss Cornette was the one most open to using standardised test scores as a tool to assess student understanding and to inform her teaching. While she didn't strongly embrace the opportunity to use these tests she understood them to be part of the "real world" and was prepared to use the district tests as a final evaluation of her students' understanding and achievement. The high school science department administered two standardised tests during the period that I was collecting data. The district CRM's were mandated and the science department chairperson also requested that the district provide Stanford 9 science testing materials. Miss Cornette and I examined the CRM test results from her students shortly after I had completed my observations. It was difficult to interpret what we were given due to the manner in which they were reported. Each of the ten curriculum objectives tested was represented by five questions. The report did not show individual student percentages either overall or for individual objectives. Instead the report indicated whether students had achieved mastery of each objective as indicated by correctly answering four of each set of five questions. Mastery was indicated by a + or – sign for each objective. Miss Cornette's students had mastered few of the objectives tested. It was not possible to determined how close to mastery they had scored. The Stanford 9 test scores arrived at the end of the year. This was an expensive test and the teachers had been waiting expectantly for the results. Again there was frustration. Individual student's scores had been reported in relation to specific tested objectives, as requested. However, the objectives were indicated by number only and there was no other indication as to what the objectives were. There was no group

report and no way to determine if particular teaching strategies had resulted in increased success for the students. Much time had been spent in Miss Cornette's classes on testing but she was unable to use the results in inform her teaching.

Chapter Conclusion

In this chapter I have identified four elements that were characteristic of Miss Cornette's instruction and assessment strategies as I observed them. I have also used a case study story to illustrate an instructional session typical of the experience that students have in her classroom. Miss Cornette's own reflections on instruction and assessment reinforce the observations I made over a period of several visits to her room. The first element that was characteristic of her instruction was her ongoing efforts to check for student understanding as she was teaching. Daily warm-up exercises that asked questions about the previous learning, many questions asked during lectures, and continual student-teacher interaction as students completed their various assigned activities were part of the daily routines.

Although Miss Cornette defined a pattern to the way she structured each unit of learning she used a wide variety of activities within that pattern. This was the second element that characterized her teaching and that students could expect when they joined her classes. A typical three to five day continuous period of observations would find students in as many different activities focused on one concept. Learning cycle activities were used to introduce new units. They were often followed by a lecture, small group lab activity and discussion and whole class discussion. Weekly quizzes were also used to assess student progress as they went along.

It was common to find, embedded in discussion of most of the new concepts taught, practical, everyday examples of occurrences that might be explained by the chemistry lesson of the day. The third element that I identified as typical of Miss Cornette's instruction was her habit of making connections between classroom learning and the experiences they had had in their

personal lives. She frequently suggested an application of the new concept but often her students would raise questions about something they had observed.

Miss Cornette differed from the other teachers that I observed in her use of standardized tests for the final evaluation of her students' achievement. Although she did not completely support their use and preferred alternate assessment strategies during the course of the semester, she used the multiple-choice tests to determine final grades. This decision was not entirely hers as she was the newest member of a department that had established several routines before she arrived. In the course of our conversations, Miss Cornette expressed conflicting feelings about the validity of the district mandated CRM tests and the frustration with the reporting style of both the CRM and Stanford 9 tests. She did raise the question, however, about the value of using standardized multiple-choice tests to prepare her students for the "real world" that they presumably would join when they graduated from high school.

Miss Cornette had some restricting parameters on her activities that were unique to her among the teacher participants that I worked with. None of the other teachers worked in such close conjunction with colleagues. She felt that she was restricted in many of her classroom plans to those that had been agreed to by her colleagues. While she expressed appreciation for the support that she was receiving this first year in the district, she did not always agree with the assignments that her students were required to complete.

CHAPTER 9 – OVERVIEW AND DISCUSSION

"The students had memorised everything but
they didn't know what anything meant."
(Feynman, 1985, p. 212)

While teaching in Brazil, Richard Feynman discovered what to him was a strange phenomenon. Immediately after explaining the answer in a lecture his students were able to provide an answer to a question asked. But the next time he asked the question, "the same subject and the same question", they couldn't answer anything at all. He realised that "the students had memorized everything but they didn't know what anything meant" (Feynman, 1985, p. 212). As he watched students taking notes in another setting, he more clearly understood that "everything was memorized, yet nothing had been translated into meaningful words. They could pass the examinations, and learn all this stuff, and not know anything at all, except what had been memorized" (Feynman, 1985, p. 213).

In the last two decades science education reformers have espoused a theory about the importance of teaching for understanding, consistent with a constructivist view of learning. When teaching for understanding, practices of assessment vary considerably from the type of assessment, the focus of Richard Feynman's observations, that requires students to recall memorised information. Oftentimes, assessment practices are recommended for the determination of conceptual understanding that represent alternatives to the standardized multiple choice achievement tests.

In Chapter Three, I argued that, during the course of this study, science teachers were subjected to the pressure of two national trends affecting the decisions they made about their instruction and assessment practices: one, to see that their students were achieving high scores on external standardised achievement tests; and the other, to align curriculum, instruction and

assessment practices with the recommendations made by the NSES. My interest in exploring science teachers' thoughts, determining what perceptions they had of their own students' understanding, and identifying the means they used to develop those perceptions was generated by the challenges set for the teachers in the SFSD. In 1997 the district school board voted to adopt the goal of becoming the number one school district in the nation as measured by standardised test scores (SFSD, 1997). At the same time the district administration supported the process of aligning the district science curriculum with the NSES. The teacher participants in this study were working within an environment that was supportive of their efforts to revise the district science curriculum and increase their skills in instruction and assessment in accordance with the NSES proposals. Teachers were encouraged to adopt assessment strategies that would enable them to determine a deeper level of student understanding than most multiple-choice tests are capable of indicating. They were also being directed to increase student scores on national and state standardised multiple-choice tests.

Teacher support was critical to both bringing the district science program into alignment with the recommendations made by the NSES and raising the district test scores as directed by the governing board of the district. The purpose of my study was to find out how science teachers in this one school district, receiving direction from different and somewhat conflicting sources, actually assess student achievement and perceive their students' level of conceptual understanding. My interest has been in finding out what teachers were actually saying and doing within the environment of contradictory directives.

I began this research with a general focus on the perceptions that five teachers had of student understanding and the manner in which they developed those perceptions. As the research continued, a process of responsive focusing (Guba & Lincoln, 1989) directed my attention, along with that of the teacher participants, to more specific concerns which we began to identify as relevant and particular to the business of determining

student understanding. These specific concerns, generated by the research process, have been identified and discussed in the data analysis section of each participating teacher's chapter. I chose a qualitative and interpretive case study approach to this research. Separate case studies of each of the teacher participants are presented in Chapters 4 - 8. Each of these chapters includes a narrative story of one lesson and a self-reflective essay by the teacher discussing individual thoughts on his or her own instruction and assessment practices. I followed these pieces in each chapter with my own discussion of the elements I found to be characteristic of each teacher's practice and my observations and reactions to the individual teacher's practices and comments. Taken together the information gained from the teacher participants provides insight into how these teachers understand their own obligations to their students.

In this chapter I, first, bring the case studies together and present an overview of my observations. Then I focus on similarities between characteristic practices of individual teachers and common strategies they use to develop perceptions of what their students understand. I also discuss specific concerns relating to the determination of student understanding that were generated by my observations and conversations with the teachers. The common practices and specific concerns are related to existing theory on constructivism and teaching for understanding as I discuss them.

Case Study Overview

My intent in presenting case studies of five different teachers as they were engaged in and discussing their thoughts about teaching science was to provide extended descriptions of what they were thinking and doing. Each case study included information gathered from three different perspectives: a narrative story about a typical class session with dialog taken directly from my observations; a self-reflective profile of each teacher compiled from their own words during our interviews; and, discussion of my own thoughts on both my observations and conversations with the teachers. Although my

initial interest was in how these teachers developed an understanding of their students' achievement, in each case study, the teacher's practices of assessment were intertwined with practices of instruction. In this section of the chapter I briefly describe the elements of both that I found to be characteristic of each teacher. All of these elements either directly or indirectly contributed to the teachers' perceptions of the level of understanding that their students were achieving in their respective classrooms. The individual elements are identified by terms or phrases that each teacher used in our many conversations. I have also identified, in this case study overview, questions that I had and issues that I considered as I analysed each set of data. In some cases the teacher participants expressed concern regarding these same questions and issues as we discussed the processes involved in determining student understanding.

Joann Springer

Building A Sense Of Community

While other classrooms exhibited many of the aspects that would be equated with a strong community feeling, Mrs. Springer deliberately orchestrated activities to create cohesion within the multi-age group. Along with the sense of community was a sense of shared learning. Each member of the class was assigned tasks that enabled others to learn. Several adult members, volunteers, of the class community also had shared responsibility for the learning of all.

Making Connections

Mrs. Springer used concept maps or web drawings when presenting new learning or reviewing previously taught concepts. She did this to help her students relate new concepts with previously taught material within the same subject and, also, with content material from a different subject. Students who had been with Mrs. Springer for more than one year frequently suggested connections between present learning and something that had been studied in the multi age classroom the year or two previously.

Teaching Self Responsibility

Mrs. Springer taught specific strategies designed to encourage each student to take responsibility for his or her own learning. Students were typically given guidelines to focus their learning and then directed to decide what they were going to do and how they were going to do it. During parent conferences, students conducted the meetings and explained why they had chosen to learn one thing over another.

Multiple Assessment Strategies

Mrs. Springer used multiple strategies to assess the understandings that her students had achieved in her class. Her questioning strategies, student journal assignments, class discussions, group and individual project presentations, and student-led parent conferences all informed her of the level of individual student understanding. Although she demonstrated quite a variety of assessment strategies, she rejected completely the usefulness of an external standardised measure of student achievement.

Issues to Consider

Mrs. Springer voiced some concerns in our discussions together. I also had questions. She was disturbed by a dilemma she perceived was created by her multi-aged setting. The dilemma was the necessity of teaching science content that she felt was not age appropriate to all of her students. In her opinion, the third grade curriculum was not developmentally appropriate for her first grade students and the first grade curriculum was too simplistic for her third grade students. Students remained in her classroom for three years and needed to cover the science curriculum material for first, second and third grade at some time prior to leaving the class. It was her habit to teach the curriculum from only one grade level each year. She was also not satisfied that the district curriculum provided her with enough material to teach complete science units at any of her three grade levels. Admitting that her knowledge of many science units was limited, she tried to supplement the mandated curriculum with what she thought were appropriate additional learning objectives and correlating activities. Her perceptions of the limits of

the district curriculum were different than mine. I found quite a bit of material in the curriculum guide but little in the way of guidance in how to use it or information about resources available for its use.

I had additional questions about my observations. The first concerned what appeared to be a subtle shift of the role of transmissionist teaching from Mrs. Springer to the older students in each learning group. The second was the lack of clarity of learning objectives that, in my perception, stemmed as much from Mrs. Springer's minimal science knowledge as it did from the district curriculum. At times Mrs. Springer did not seem to understand exactly what she wanted her students to accomplish. The activities she designed for them did not always match the objectives she was attempting to teach.

Tom Gorman

Questioning Strategies

Mr. Gorman posed probing and open-ended questions throughout his lessons in order to encourage his students to explore the possibilities of different answers to problems presented to them. Student responses to his questions served to give him feedback on the depth of their understanding.

Self-Reflection

Mr. Gorman not only consistently reflected on the effectiveness of his own actions in the classroom, he also encouraged his students to reflect on their actions and the learning they were accomplishing. By listening to his students and reading their journals he was able to use their reflections to further inform himself of their successes and his own success as well. He also adjusted his own practice when his students expressed frustration or lack of understanding in those reflections.

Multiple Related Activities

Routinely, when preparing for a new unit, Mr. Gorman planned several different activities for each learning objective. He included opportunities for

enrichment and reinforcement enabling his students to operate at individually productive levels.

Assessment of Understanding

Mr. Gorman used a variety of methods to determine the level of understanding that students were achieving in his class. His questioning strategies, the results of student self-reflection activities and the products of the many activities all served to inform him of student learning. He also expressed the belief that standardised tests would be with us for a long time because the scores provide "an easy indicator of student achievement."

Issues to Consider

During our conversations I became aware that Mr. Gorman had not been given the district curriculum guidelines until shortly before the end of the year, when the district tests were administered. He had not used the guidelines during the year to plan his lessons, relying on another teacher, the text and his own ideas when deciding on which topics he would teach. The result was that the district mandated standardised test did not test, in all cases, what Mr. Gorman had taught his students. The test items did not necessarily correlate to the learning objectives that Mr. Gorman had emphasised and entire units that Mr. Gorman's student had studied did not appear on the test.

I also questioned the accuracy of information on individual progress that Mr. Gorman was getting from the group projects he used for final assessments. The other questions I had centred on the frequent similarity between the content and activities taught in his science classes and in the multi-aged, first through third grade class that I also observed. The topics of magnets, electricity, solar system, atomic structure and ecosystems were presented in much the same way with few differences in learning expectations.

Betty Fredericks

Extensive Planning

Mrs. Fredericks, in her own words, "spent a huge amount of time" planning for the lessons she would teach. Included in her planning were careful task analysing of lessons, planning for activities that would address different student learning styles, strategies for integrating science content and process, methods of establishing relevancy of the learning and methods of assessing her students that would enable each one to achieve success.

Integration of Science Content and Process

In each of the science lessons that I observed, Mrs. Fredericks included both a learning objective focused on content and one that focused on the processes of science. She expressed the belief that students learned by doing but that they must be held accountable for the doing.

Relevancy and Meaning

Mrs. Fredericks planned specific strategies to make lessons meaningful to her students and relevant to their world. She used the newspaper daily as part of the social studies program and frequently related news stories to science topics. She also linked learning in mathematics and language arts to science lessons so that learning in one area of the curriculum was used in another.

Assessment for Success

Mrs. Fredericks "tried to check for understanding continuously through lessons." She used questions at the beginning of each lesson, throughout the lessons and again at the end of each lesson to help her students review the material they were working on and, also, to inform her of their progress. In addition, she used her students' journal writings to gather information about their level of understanding. Final assessments were designed to insure success for each student. Mrs. Fredericks did not accept the usefulness of standardised tests as a tool to assess student understanding of the various science topics that she taught. Although she followed the district mandate carefully and administered all required tests she felt that their was no place

for multiple choice tests at the fifth grade level, preferring performance based assessment as a more meaningful tool.

Issues to Consider

I had questions about the overlap in content that I observed being taught in Mrs. Fredericks' fifth grade class. Another concern that I had was the lack of knowledge that Mrs. Fredericks seemed to have about many of the science topics she was teaching. There were at times a lack of correlation between the stated learning objective and the planned activities used to teach that objective. A third issue that interested me was Mrs. Fredericks' clear rejection of standardised tests as a valid means of assessing student understanding. She administered them as directed by the district but did not regard the information provided by the scores as valid in assessing student understanding. Her preference and her practice were to substitute individualised student conferencing for written tests within her own lessons. She did so as often as possible.

Lori Richardson

Developing Personal Relationships

It was very important to Miss Richardson to develop a strong personal relationship with her students. She believed that a teacher's knowledge of her students on a personal level would increase the effectiveness of instruction.

Building Bridges to Increase Meaning

During our conversations Miss Richardson frequently referred to helping her students "build bridges and make connections" between units, daily lessons and between classroom learning and the students' lives outside the classroom. She used several strategies including journaling assignments to encourage her students to reflect on their learning and on the connections that learning had with other experiences they had had during the year.

Journaling to Inform Instruction

Daily, Miss Richardson asked her students to record an entry in their journals as class began. Miss Richardson indicated that the process of journaling was a tool that she used personally to improve her own teaching. Student journals provided insight into her students' personal experiences, helped inform her instruction, served as one means to help students build bridges between learning and provided an assessment mechanism for determining student progress.

Variety of Assessment Strategies

Miss Richardson used several methods to check for understanding both during daily lessons and at the end of units of learning. The methods included asking many questions, reading student journals, raising of hands, watching facial expressions, checking to see that a partner understood and homework. She assigned many group projects as culminating activities and, at one point, held student interviews with parents present to assess achievement at the end of a unit of instruction. Miss Richardson wasn't adverse to using external standardised tests as an evaluation tool but didn't trust their accuracy in reporting student achievement. She did not think that multiple choice tests had the ability to assess what she had asked her students to learn.

Issues to Consider

Miss Richardson and I shared many conversations about questions generated in my mind by my observations of her teaching practices. During the time that she had been teaching she had acquired and practiced several potentially effective instructional strategies. However, she was not able to articulate a clear idea of how one might teach for understanding. Many of her practices seemed to be based on instinct and personality rather than conscious planning and training.

Although very concerned with helping her students "bridge" daily lessons, lessons between science and other subjects and, science lessons and their

personal lives, Miss Richardson rarely explored or established connections between her class and science classes in previous grades. While she had a curriculum guide at hand, she didn't use it to develop cross grade level connections of any sort.

Miss Richardson expressed some interest in, and willingness to use, standardised tests as a tool for assessing student learning. Even though she personally had spent considerable time writing the district CRM tests she did not trust the multiple choice format nor the correlation between the questions and the district mandated curriculum. She did not feel that standardised multiple choice tests adequately assessed the concepts that she focused on in the classroom and preferred other methods of assessment.

Catherine Cornette

Checking for Understanding

Student responses to daily warm-up activities provided Miss Cornette some insight into the level of understanding that they were achieving. Questions, one-on-one conversations with students, homework, group projects, and class discussions all provided her with information. Teacher awareness of understanding "is very important and easy for me to get at in conversation," was her statement.

Variety of Activities

The use of a variety of activities related to the teaching of each concept was part of the school science department's overall procedures. Each unit of instruction based on one terminal objective typically included daily warm-ups, direct instruction, many questions, class discussions, at least one learning cycle, other lab activities, and a group project or test as a final assessment.

Making Connections to Enhance Meaning

Miss Cornette often tried to connect the required learning with something from her students' everyday lives. She encouraged her students to do the

same and when they did she took it as an example of the level of their understanding. She did not use such connections to relate newly introduced material to previous learning nor to assess learning from prior experience. When constructing her own tests, Miss Cornette did not use test questions that related learning to examples of connections that had been discussed in the classroom.

Evaluating Achievement

Assessment of student understanding was an ongoing process to Miss Cornette. She used many different strategies to determine understanding, for example, the practice of asking questions at the beginning of class each day that would allow her to assess how much her students remembered from the previous day's lesson. She expressed belief that students demonstrated understanding of the learning when they could articulate it in a one-on-one conversation. However, she was the only one of the teachers with whom I worked that relied on standardised tests for the final assessment of her students' achievement. She used the district criterion reference test scores to determine the end of semester grade for her students.

Issues to Consider

Miss Cornette was completing her first year of teaching at tenth and eleventh grade levels when she participated in my research. While somewhat frustrated by the departmental structure imposed on her as a first year teacher in the school, she also appreciated the help she was receiving from her colleagues.

Miss Cornette was quite open to the possibility of using standardised test scores as a tool to assess student understanding and to inform her teaching. A second frustration to her, and one that I shared, was the difficulty in gaining access to the actual test scores in order to use them to inform instruction. The Stanford 9 test results were delivered to the school site after school had been dismissed for the summer break. They were stored in the school vault and not found for some months after school had reopened.

When they were discovered and attempts were made to analysis them, the data reported was in a very difficult form to interpret. In the interim between giving the district CRM tests and receiving the scores, the order of the questions on the test was changed and the original version disappeared. Student scores were assumed to be accurate but it was not possible to determine which objectives had been successfully learned and which ones needed to be readdressed.

Discussion

The purpose of this study was to describe how teachers developed perceptions of student understanding. My data also includes observations of the teacher participants' instructional and assessment strategies. It was not possible, with these five teachers, to separate their practices into two disconnected sets of actions, one being of instruction and the other of assessment. In each case study, assessment of student understanding was embedded in instruction, as was instruction, in some instances, embedded in assessment.

Polkinghorne (1995) identifies the strength of paradigmatic analysis of narrative as its capacity to develop general knowledge from a set of particulars. During the data analysis process I have attempted by inductive analysis to identify common themes and commonalities of thought and action across the case studies that formed my database. In this section of the chapter I organise the elements of the teachers' individual practices into groups of related strategies with common themes. The groups are defined by the themes of community, connections, reflection, instructional variety, and assessment. In addition to these themes, I have added teaching science content as a specific theme related to the question of how teachers develop perceptions of student understanding. These themes were generated by my observations of and discussions with the teachers involved. I discuss each in relation to the principles of teaching for understanding, constructivist learning theory and the NSES proposals for instruction and assessment. By comparing and contrasting the practices and ideas of these five teachers I

hope to provide some insight into what they were actually doing and thinking about assessment strategies. I also hope to provide insight into how they were responding to the need to assess student achievement in somewhat contradictory ways.

Community

Each of the teachers in this study either deliberately or as a function of their individual personalities and style created a sense of community within their classrooms. This building of community was identified as a specific element of Mrs. Springer's practice. She attributed the importance of building community to her multi-age setting and she took deliberate planned steps to create cohesion within her group of students. Along with the sense of community, she also spoke about creating a sense of shared learning. The emphasis within the student learning groups in Mrs. Springer's class was for older students to help younger ones with their various projects and for students that had acquired knowledge of a certain amount of information on a subject to share that information with others. Although Mrs. Springer did not acknowledge that the sense of community in her classroom contributed to her ability to assess her student's level of understanding, she, in reality, created a situation that allowed her to work regularly with individual students and with small groups. She was able to ask students questions, listen to what they had to tell her and develop a sense of what they were understanding as they were working on various projects. In spite of this opportunity for interaction with individual students, Mrs. Springer seemed to view the actual creation of a sense of community within her classroom as one of the important goals of her multi-age setting. It was the end product of her careful planning rather than a strategy to use in striving to reach the bigger goal of teaching for understanding.

Although Mrs. Springer was the only teacher in this group to discuss the deliberate planning for the creation of a sense of community within her classroom, a sense of community as a place where risks could be taken was evident in other classes as well. An element related to this and including the

creation of an atmosphere where there was mutual trust was the practice of "developing personal relationships" that Miss Richardson emphasised in her interactions with students. Her specific hope was that students would feel "more a part of the class" because she wanted to know who they were as people. Students did seem to feel comfortable expressing their ideas in her classroom and there was a tone of respect that existed within the classroom. Miss Richardson did not directly gather information for use in assessing her students' understanding during interactions designed to develop personal relations. She seemed to keep the processes of developing personal relations and assessing student understanding separate during her interactions with her students. During my observation she did not design specific activities for her students to interact with each other on a personal level. Nor did I observe students involved in any interchange of ideas independently of her being a partner to their conversations. As with Mrs. Springer she created a community setting which emphasised a quality of caring rather than focusing on teaching for understanding.

The belief that it is important to the learning process to build an atmosphere of trust was reflected in Miss Cornette's comment that "much of the process of learning centres on respect. My students are comfortable knowing that I am going to respect their questions and answers. They also know I care about them. That quality of caring is important in the classroom as well." While not a specific, planned element of her practice, Miss Cornette, by nature of her own personality, had created an environment in which students worked comfortably together, shared ideas and collaborated on assignments. She structured laboratory activities to encourage student collaboration in solving problems related to the content taught. Unfortunately, and probably due to time constraints, the students' interaction during these collaborations was focused primarily on preliminary procedural questions rather than an exploration of ideas relating to phenomena that they observed. Many times Miss Cornette ran out of time for students to do more than collect data and follow-up homework assignments substituted for discussion of the results of their activities. She did spend time during student activities talking with

different groups about what they were doing and was able to gather some information about the level of student understanding from the types of questions that they asked her and the answers they gave to her questions. She used this information and that gathered from the related homework assignments to plan her instruction and made changes when necessary if her students needed more time on specific concepts.

Mr. Gorman did not specifically identify his actions as being designed to build a sense of community. In fact he was unclear as to his role in making his students feel valued or in creating a "warm, fuzzy feeling" in his classroom (Interview, May, 1999). However he set a tone of respect in his classroom as he asked questions, and took "all of their answers as being valid" at the beginning of a new unit. He created an environment in which his students were able take risks and try out new ideas by modelling the behaviour he expected from them. He used these discussions to assess the prior knowledge of his students and made changes in his instructional plan based on student comments. He also used the information he gathered during introductory discussions to compare with that gathered during end of the unit discussions and assess the progress in understanding that his students had made.

The process of creating sense of community within a classroom presents a dilemma for teachers who are teaching for understanding. Mrs. Springer's goal for deliberately building that sense of community reflected the thoughts of Noddings (1992, p. 18) who describes the need "to create a warm and welcoming place in which students are helped to develop caring relations." That "nice place to be," as Mrs. Springer described it, might not encourage an environment of intellectual rigor that would allow students to develop a deeper understanding of concepts being taught. Creating an environment in which students focus on the building of knowledge and understanding is much harder than just asking and answering questions in a respectful manner. Mr. Gorman's actions gave illustration to what McKeown and Beck (1999) identify as the toughest issue in developing a constructivist

environment. That issue is the need to treat students' comments in such a way that "they invite other students to extend and elaborate on them, moving the discussion forward in meaningful ways" (p. 27). The teacher participants in this research either deliberately or as a function of their own personalities and style created a sense of community in their individual classrooms. The classroom communities they chose to create served different purposes in the learning process. All of the teachers used information gained in the settings of their classrooms to inform themselves of student progress. However, Mrs. Springer's community building practices were specifically designed to create an effective multi-age community in which each member felt responsibility for the others. With the exception of Mr. Gorman, each of the other teachers created classrooms that were "nice places to be". They did not deliberately use that environment of trust and respect to encourage their students to exchange ideas, and interact with each other in ways that would increase understanding. Mr. Gorman created a classroom environment built on mutual respect in order to provide a setting in which students could freely exchange ideas, reflect on each other's thoughts and assess their own development of understanding. He used student comments, as they explained their thinking, to determine their level of understanding and to adjust his instructional plan accordingly.

Connections

Four of the teachers in this research described, and deliberately included in their practice, elements that were designed to increase the meaning of new learning by relating it to or making connections with previous lessons. Elements such as Mrs. Springer's "recognising connections," Mrs. Fredericks' "relevancy and meaning," Miss Richardson's "building bridges to increase meaning" and Miss Cornette's "making connections to enhance meaning" were practiced by these teachers in order to provide students with opportunities to use their prior knowledge in making connections with and sense of the new concepts being introduced. Mrs. Springer used concept maps or web designs extensively to help her students understand the links between what they were learning in each subject including learning from

lessons conducted earlier in the year and lessons conducted when focusing on other content areas of study. Mrs. Fredericks encouraged students to find examples of science in the daily newspapers. She also used science readings for her class's reading lessons and frequently used readings from her language arts text to supplement science lessons. Miss Richardson planned ways to build bridges between units, emphasising the interrelatedness of knowledge and encouraged students to make connections between knowledge gained in science class with that from previous and future classes in all content areas. Miss Cornette encouraged her students to find real world examples to connect with scientific explanations. Her attempt at times was to bring some "fun" into the classroom but she was also trying to make the classroom learning meaningful and relevant to her students.

When asked if it was important that a teacher be aware of the prior knowledge and experiences that students bring to the classroom, all five teachers agreed that it was. They each went on to discuss prior knowledge in the context of school mandated science content, often taught by himself or herself or another teacher. Prior knowledge gained as a factor of diversity was discussed in terms of maturity and learning styles rather than experiential, ethnic or cultural differences. Only Miss Richardson deliberately drew on the diversity of experiences that students brought to class from their daily lives.

Miss Richardson's practice of encouraging her students to make connections that were focused on learning concepts as well as making connections that made learning interesting and relevant seemed to support Madeline Hunter (1967), who said that to be successful a teacher must take both the student and the learning into account when planning. At times the teacher might focus more sharply on knowledge about the student that can be used to assist learning. At other times the focus in making connections may be on the actual material to be learned. During our conversations, Miss Richardson discussed the need to develop a personal relationship with her students and used knowledge of their personal lives to help understand them rather than to

help them understand the assigned learning. However, there were several examples in her practice of having students draw on their recollections of past personal experiences to make school learning more meaningful. She also helped them make specific connections between current and previous content learning that had been taught in her classroom. She spoke of the importance of helping her students to "build bridges" from one unit to the next.

Both Miss Richardson and Mrs. Springer used web designs showing learning connections as assessment tools in determining student understanding. In the examples of web drawing that I observed in Miss Richardson's class, the students did not design their own webs when asked to construct them during projects or on tests. They usually copied or memorised and rewrote concept maps that had been presented to them during class discussions. In Miss Richardson's classrooms, the webs included only concepts learned in the particular classroom where they were assigned. The focus on these webs was most often specific to the content unit being taught but was occasionally used to connect content units. Students in Mrs. Springer's class were frequently asked to draw on their memories of past experiences they had had and understandings that had gained within Mrs. Springer's classroom to construct drawings. They did this during a class discussion with Mrs. Springer allowing students to have input as she guided them in the construction of a basic web design that she had previously planned. The focus on these webs was also generally specific to the content unit being taught but was occasionally used to connect content units. Students were then asked to transfer webs to their journals and Mrs. Springer used those journal writings as an indication of understanding.

Mrs. Fredericks, in addition to Mrs. Springer and Miss Richardson, focused specific connecting activities in her classroom on previously learned concepts and current instructional topics. She deliberately planned reading lessons that support science learning and encouraged class discussion of connections between science, social studies and reading. In the examples

that I observed, the concepts being connected were ones that were or had been taught within her own classroom.

Miss Cornette's and Mrs. Fredericks' practices supported the idea that, as motivators of students, teachers may choose to connect new concepts to something that has intrinsic meaning for students, something that might be considered exciting or novel (Hunter, 1967). Miss Cornette sought "fun" examples of the chemistry concepts she was teaching. She wanted to help her students relate chemistry to experiences in their world outside of school and she used many relevant everyday examples from student experiences to do this. Mrs. Fredericks also sought examples of science in the daily news that might make classroom learning meaningful to her students. Each of these teachers' practices of having students make connections using experiences they had had in previous lessons or in their lives outside the classroom would seem to be supported by Levy's premise that connecting concepts to experience is at the heart of understanding (Levy, 1999).

In any one instance and in any one lesson the challenge for teachers who are teaching for understanding is to decide both the purpose and type of connections to make in order to facilitate learning. Unfortunately most science instruction in school is neatly separated from other, also separated, subjects. Each subject, particularly at the middle and high school levels, is taught in discrete time periods. The learning experiences of the school day are, in turn, separated from students' other life experiences by opening and dismissal school bells. These bells become signals that disconnect each student's thoughts from the focus on learning in the classroom and the focus on other aspects of their lives. Teachers may decide to deliberately make connections between student learning in their classrooms and other student experiences for different reasons. One reason might be to increase student motivation to learn by linking the new learning to something exciting or interesting in the students' lives. Another might be to enable students to understand material more easily by connecting it to previously learned material either in the present class or classes that the students have

participated in at other times. In the majority of the lessons I observed in this study the teachers chose to make connections between new concepts and student learning for motivational reasons, to make learning fun or more interesting.

Reflection

Mr. Gorman deliberately taught self-reflection strategies, Mrs. Springer taught her students to take responsibility for their own learning and Miss Richardson regularly asked her students to reflect on what they had learned the day before or even the unit, week or month before. Each of these teachers used journaling activities with their students to encourage them to reflect on their learning or experiences. Typically those journaling assignments were either descriptive of learning or reflective on growth in understanding. These teachers also conducted journaling activities of their own to reflect on the results of their own instructional strategies. At the beginning of the year in which I conducted this study, Mrs. Fredericks had just started to encourage her students to keep journals. She stated that one of the reasons she joined my study was to put herself in the position of having to keep her own journal. She described this as one of her "poorest" skills and thought she ought to model what she was expecting of her students.

Mr. Gorman regularly used journaling as a tool for "teaching self-reflection strategies", encouraging students to reflect specifically on their new learning experiences in relation to what they already understood. On completion of a unit of study, Mr. Gorman would ask students to share what they had written at the beginning of the unit in response to his opening questions. During an interview with me he commented that many times students' ideas had changed so much by the end of a unit that they denied their original thoughts, claiming a mistake in writing them down rather than a change in their own thinking. He often kept and used the student papers that recorded the changes in their ideas as a means of informing himself of their level of understanding.

Miss Richardson's journaling assignments varied. At times she asked students at the beginning of a class to write down what they remembered from the day before. Other times she might ask them to record an experience they had had earlier in their lives that related to the unit under study. She had an additional, very specific reason to use journaling and self-reflection as an instructional strategy and that was an oddity of scheduling that her classes followed. In her school, students studied science for nine weeks and then rotated to a social studies classroom each semester. Miss Richardson used journaling as a tool in helping her students to build connections between what she had taught in the first semester science classes and what she taught in the second semester classes. She also used the journal entries to learn more about her students personally as discussed in the section on building community.

Mrs. Springer practiced an instructional strategy identified in the case study chapter as "taking responsibility." In the process of insisting that her students take responsibility for their learning she frequently asked them to reflect on their own interests and the current level of their knowledge and understanding as it related to particular topics. Students were encouraged to choose an activity or project based on those reflections. Mrs. Springer also asked her students to keep journals and, at the end of a lesson, to write or draw a picture of what they had learned. Mrs. Springer felt that she was able to observe and inform herself of the level at which her students were learning by observing their choices of activities and the manner in which they designed their individual projects. She used the student journal writings to determine the extent of understanding they had achieved after she had made a presentation or they had completed an assignment.

Mrs. Springer, who had just begun the practice of requiring that her students keep journals, asked them to write down their procedures for completing activities and their thoughts about what they had done. She believed that, while students learn more easily with the use of manipulatives, meaningful learning doesn't happen without a follow-up of reflection on what has been

accomplished. Each of these teachers used the students' reflective writings and drawings as indicators of what they were learning and, at the end of a series of lessons, of what they had achieved in terms of final understanding of the content taught.

Of the five teacher participants in this research, Mr. Gorman came the closest to the suggestion of Lorsbach and Tobin (1992) that an important part of a constructivist curriculum should be the inclusion of opportunities for students to make sense of what is learned by "comparing what is known to new experiences and resolving discrepancies between what is known and what seems implied by the new experience" (p. 2). By having students record their original ideas at the beginning of a unit and then going back to those ideas and to reflect on how they had changed, Mr. Gorman allowed them to compare the new to the previously known and identify discrepancies. He also encouraged them to keep asking questions and continue thinking about issues that they needed more time to resolve.

Mrs. Springer, Mrs. Fredericks and Miss Richardson used the journal writings to assess understanding at the end of a unit of learning and also as a tool to determine the degree of student growth in understanding. Their students did not use the journal writing process to compare new understandings with previous ones and reflect on their own development of new understandings. Miss Richardson encouraged her students to remember experiences that they had had outside of school as a way of introducing new content material and making it interesting to her students. She did not have them reflect on those experiences after a unit of instruction and determine their new learning fit with previous understandings.

Experience is the beginning but only the beginning of understanding. To learn from it we must reflect on it. We don't learn from just having it (Levy, 1999). The process of self-reflection can happen in many different ways and did in the classrooms I observed. In addition to the journaling assignments teachers asked many questions of their students, had them write essays and

participate in self assessment activities. In the classes I observed, the process of self-reflection served different purposes ranging from simple recall of facts learned to reflection on understandings gained. It also was used to describe previous experiences in order to make lessons relevant and meaningful. In some cases teachers used journaling assignments as motivational tools and, in other cases, as a strategy that would encourage students to focus on learning. The challenge faced by teachers who were teaching for understanding was in making judgments as to how and why to use particular strategies that encouraged self-reflection.

Instructional Variety

As the teacher participants in this study planned for their daily instruction they were faced with the need to decide between a myriad of choices on the most effective way to teach each of their students each of the individual concepts that had been identified as being important to understand. They approached this choice of instructional activities in different ways. Mrs. Fredericks talked about the NSES (NRC, 1996) teaching and content standards and discussed the need to provide activities that would enable students with different learning styles to succeed. Other teacher participants were familiar with the theory of multiple intelligences and took that into account when they planned their lessons.

Mrs. Fredericks spent considerable time on "extensive planning," an instructional element identified in her case study, for each of the variety of activities that went on in her class. Perhaps because of her background as a trainer of teachers, she articulated, more clearly than the other teachers, the importance of carefully planning each part of a lesson. Her planning for each lesson that she taught included mode of presentation, activities, and specific means of determining, throughout the lesson, how her students were assimilating the new learning. She liked to "back plan." First she decided on the final assessment of each unit of instruction and then, set up the activities that she would be assigning her students in order for them to achieve the understandings necessary to be successful on the final assessment. In spite

of the detail of her planned lessons, Mrs. Frederick was very flexible and twice I observed her adding alternative activities because she felt her students were not ready to move on to the next step in her original plan. Mrs. Fredericks spent time talking with her students while they were working on the various activities that she assigned. She used those opportunities to question individuals and develop an understanding of what they were learning.

All five teacher participants in this study planned for and used a variety of activities to teach each individual concept. Mr. Gorman spoke of sometimes having to find several different ways to teach certain concepts before students began to understand. Mrs. Fredericks talked about addressing students with several different learning styles. Mrs. Fredericks also wove lessons on the scientific method into her hands-on activities so that students would have the opportunity to practice the ideas they were being taught. Miss Richardson included "hands-on activities in every unit". Mrs. Springer did not specifically discuss the deliberate use of several activities to teach each concept but, as an outcome of the multi-age teaching strategies that she employed, she adjusted her assignments and expectations for learning according to the age of her students. She also allowed individuals and groups to plan activities based on their own interests relating to the assigned learning.

I observed both Mr. Gorman and Mrs. Fredericks make changes in their planned activities when they had determined that their students did not clearly understand specific concepts. In each case they either added a new and related activity or eliminated an activity that had been previously planned because the students weren't ready for it. Miss Cornette expressed some frustration at the need to follow the same instructional path as her colleagues when she detected that her students didn't understand particular concepts. Because of the consistency between classes that her department tried to maintain, she did not feel comfortable changing her plans in spite of knowing that her students were not understanding the material that had been

presented. She did offer alternative times when her students could seek help in redoing certain assignments but I did not observe her devising different ways of presenting material that had been difficult for her students to grasp.

As students were working on their various activities the teachers, in each case, took opportunities to talk with small groups and individuals about what they were doing and what they were understanding. Each of these teachers mentioned during one of their individual interviews that their preferred method of determining the level of understanding that their students were achieving was to simply hold one-on-one interviews with students as they were working or after they had completed a unit.

Teachers, when teaching for understanding, face a formidable challenge as they plan for and orchestrate the activities in their classrooms. The actions of the teachers in this study seemed to support the ideas embodied in constructivism and teaching for understanding, principles that require teachers to shift away from lectures, front of the class demonstrations and rote memorisation as these lead to very little long term understanding or correction of misconceptions about the natural world (Zemelman, Daniels & Hyde, 1998). Learning science is something that students do rather than something they have done to them. None of these teachers used a strictly traditional model of instruction. Although each took some time to "lecture", each teacher used a variety of different activities to teach content in their curriculum. Mr. Gorman discussed the different reasons he used to choose activities. Some were designed to simply demonstrate an idea. Others required students to apply previous learning. As part of the planning process, teachers typically decide the purpose of the activities planned for each specific stage in a lesson. While some activities may simply serve the purpose of providing illustration of specific concepts, constructivist learning theory suggests that teachers must organise and guide students in activities that engage them in real problem solving. The challenge these teachers faced was in making the decisions as to which specific activities would most effectively enable their students to achieve understanding.

Assessment

Several of the elements identified in previous chapters as being characteristic of individual teacher's practices can be brought together under the heading of assessment. Both Mrs. Springer and Miss Richardson directly discussed using multiple strategies of assessment to determine the level of understanding that their students achieved. Ongoing assessment, an element characteristic of Mr. Gorman, involved using several strategies to determine student understanding at the beginning, during and at the end of each unit taught. His "questioning strategies", included as part of his ongoing assessment practice, was singled out as a separate element because he deliberately planned his questions prior to teaching a lesson in order to inform himself of his students' achievement as well as to encourage them to reflect on their own learning. Mrs. Cornette spoke of "continually checking for understanding" and used several different methods including questions, individual conversations with students, group discussions, assignment sheets, quizzes and tests to inform herself of her students' understanding. Mrs. Fredericks also used multiple methods to inform herself of her students' success. In addition she had a unique strategy of both using "Assessment to ensure success" in helping her students achieve understanding and to evaluate the level of understanding that had been achieved. At the end of each unit of science learning she interviewed students individually and had them demonstrate their new learning with an appropriate activity. If students were unable to clearly demonstrate understanding, she worked with them until they "got it".

The five teacher participants expressed a range of opinions on the usefulness of standardised tests. Mrs. Springer and Mrs. Fredericks rejected them outright. Mrs. Springer questioned the need for any of the three mandated tests that she was required to administer to her students, saying, "I don't need an outside measure to determine what my students are understanding. I know by experience, by what other people tell me and, most of all, what my students are saying" (Interview, May 22, 1999). Mrs. Fredericks completely

denied the usefulness of standardised tests for either measuring the level of student understanding or informing a teacher of student progress. Echoing Richard Feynman's sentiment, she stated that, "Students can memorise for written tests but that doesn't prove what they have learned. They need to prove their learning by putting it to use" (Interview, Jan. 20, 1999).

Miss Richardson recognised the potential usefulness of the standardised tests as a possible source of information about her students and expressed some willingness and interest in using the information that might be gained from standardised tests. However, she described two serious concerns that she had about them. The first was that she didn't teach "that way" and her students had little experience taking multiple-choice tests. Her second concern was that the tests didn't test learning objectives that she had taught. Although she had helped to write the district CRM test, she expressed distrust of the test results as an accurate reflection of her students' understanding. She felt that her students had understood a great deal of what she had taught them and used evidence from a performance assessment to support her claim. She rejected the accuracy of the achievement test scores that her students earned as not being indicative of the level of understanding they had achieved in her classroom.

Mr. Gorman said little about the district mandated standardised tests other than he wasn't aware of the objectives that his students would be held accountable for learning on those tests. In his first year, Mr. Gorman was simply uninformed about the connection between what he was teaching and what his students would be tested on at the end of the year by the district. He had little knowledge of previous test scores or any correlation between those scores and his own judgment of how much understanding his students had achieved. In one of our discussions Mr. Gorman acknowledged that standardised test scores would be with us for a long time because they can be communicated to the public graphically. His preference was for performance testing. However, he did not seem particularly disturbed by the necessity of testing his students according to the district mandate.

Miss Cornette was the only one of the teacher participants in my research who used standardised tests for final assessment of her students. She, too, did not think the results reflected what her students had accomplished. However, according to her department's practice, she did include the scores on the district CRM's in her calculations of the final grades earned for the course she taught. The intent of her department was to use the scores from the Stanford 9 tests as part of the final grade as well but those scores were not available when grades were calculated. Although Miss Cornette used the district CRM test as a final exam, she wasn't convinced it was a fair test for her students since she didn't "teach that way". She also expressed interest in the information that the state mandated Stanford 9 tests would provide and expected to analyse the results with her science teaching colleagues as a means to improve the science program. Ultimately, both the SAT 9 and the district CRM test scores, in the form in which she received them, were incomprehensible to her. Miss Cornette believed there was a need to teach students to succeed at multiple-choice tests and wondered when it was appropriate to start teaching students how to do that. In her opinion, the students were going to end up taking multiple-choice tests. She stated, in one of our discussions, that "academically, the real world is multiple choice based" (Transcript of interview, May 12,1999). If asked, Miss Cornette and Mr. Gorman would have agreed with Taylor and Walton (1997) who challenge those that are convinced that logic will lead to the demise of these tests to "ask themselves how frequently substantial changes are made to long-standing policies" (p. 67).

The teacher participants used many different strategies to inform themselves of the level of their students' understanding. Questions, discussions, individual interviews, individual and group activities, performance assessments and tests and quizzes were all part of their assessment practices. Each teacher continuously assessed student understanding, not waiting to the end of a unit and a final test. Each claimed to know the level of their students' understanding based on their own assessment strategies. Although

Miss Cornette used the scores in determining her students' final grades, neither she nor the other teachers relied on the mandated standardised test results as a useful tool for informing their teaching or understanding their students. In spite of their clear concern about the district mandate to administer standardised tests, district CRM test results were only available to two of the teachers involved. In both cases the teachers denied the validity of the results when they saw then by simply stating that the tests didn't test what they taught.

The actions of the teachers, during the course of this study, supported the trend toward performance-based methods of assessment as it is espoused by the NSES, the literature on teaching for understanding and constructivist learning theory. Meanwhile the SFSD, like other districts in the state and nation, had placed strong emphasis on the importance of having its students achieve high test scores on norm-referenced and criterion-referenced multiple choice tests. In spite of district attempts to encourage them by offering a monetary incentive, teachers had not accepted the district goal as important to their students or to themselves. The result of this situation was a sense of frustration that the teachers, with the exception of Mr. Gorman, expressed regarding the district testing program. This frustration was an issue raised by the other four teachers during the course of our discussions. Although they were being called on to passively administer external assessments of student achievement, they expressed a preference for taking on the role of more actively constructing forms of assessment that probe for deeper student understandings. The teachers recognised the fact that standardised testing was a political trend and a district mandate that needed to be acknowledged but they didn't grant much credence to the results of such tests as measurements of student achievement. These teachers, striving to teach for understanding, were caught in a dilemma-laden situation.

Teaching Science Content

As teachers in this study approached the challenge of teaching science content they faced the need to resolve three dilemmas. The first was in

identifying content objectives that maintained a focus on the concepts chosen for each lesson. The second was maintaining coherence between lesson segments and between different lessons. The third dilemma was recognising the level of student understanding that was achieved as a result of the lessons taught. The need to make decisions regarding the appropriate science content to be included in particular units of instruction presented dilemmas particularly for the elementary teacher participants. Abell, Bryan and Anderson (1998) aptly described their situation when they described that of another teacher of young children by saying that it is reasonable to expect that her science background was limited and focused on the products of science rather than the process of inquiry.

An example of how the first dilemma presented itself to the elementary teacher participants occurred during one conversation that I had with Mrs. Springer. She asked if I didn't think her students needed to understand atomic structure in order to understand electrical circuits. Her objective was for students to understand that electricity travelled in a circuit. Her lesson included a description of atomic structure, the charges on atomic particles and the movement of the particles because of the charges. Mrs. Springer was not sure what she should do to help her students understand that electricity travelled in circuits. She defined a circuit in a preliminary discussion and told the students that electricity needed a closed circuit in order to travel. She was then left wondering what to do next. It was at this point that she added the information on atomic structure. In her struggle to identify what to include in her lesson she gave support to Prawat's statement that "a good grasp of what ideas are most central to the discipline and how they relate to one another bears a necessary relationship to conceptual level teaching" (Prawat, 1989, p. 319).

The introduction of concepts that were only indirectly related to the concept that electricity travels in circuits did not seem to deter Mrs. Springer's students from learning the original objective while exploring new ideas. The students at least memorised the fact that electricity travels in closed circles

and were able to draw a diagram showing a circuit. They were given opportunities to demonstrate this fact with a set of batteries, wires, and bulbs after taking notes in their journals. However, Mrs. Springer's focus in the lesson shifted from helping students with the process of understanding this simple concept to having them draw and memorise the what Abell refers to as the product of science (Abell, in press).

Mrs. Springer freely admitted her lack of science content knowledge and encouraged her students to help her discover answers to questions they asked. Mrs. Springer used the guidelines for the development of a multi-age classroom as the basis for all of her planned instructional activities. In science, as well as in other subjects, she frequently gave students the opportunity to develop their own projects relating to the concepts to be learned. She would set basic parameters, as she did in the case study story, and allow individuals to work in groups or alone depending on their interests. In the case study story, students were encouraged to choose a topic relating to electricity, its sources, how it works, atoms and safety for their reports. In many instances, her students took advantage of opportunities offered to pursue their personal interests and sought knowledge at a level that satisfied them. Occasionally that knowledge was of the mysteries waiting to be understood in the future, for example, the boy in the multi-age classroom who liked atoms because "they were so small you could only see them in your imagination."

There were other instances, in my observations, of teachers who faced the dilemma of choosing lesson content that would maintain the instructional focus on their stated objectives of instruction. Mrs. Springer, in the example above, extended the focus of her lesson on circuits to a much broader range of topics than had been suggested by the original objective. At one point she asked her students if a person needed to understand atoms to understand electricity. She accepted a "yes" answer as correct to that question but later told me that she wasn't sure if that was true. In another example, both Mr. Gorman and Mrs. Fredericks taught a series of lessons on electricity to their

fifth grade students. At this grade level the curriculum guide specified that they teach the difference between parallel and series circuits. In the process of teaching this concept they included the same lesson segments that Mrs. Springer had included in the lessons she prepared for her first, second and third grade students. At one point in our discussions Mrs. Fredericks explained to me that "sometimes the theoretical stuff (referring to the inclusion of atomic structure as one segment of her lesson) is not in the curriculum but I feel like a fraud if I don't tell them what is going on" (Interview transcript, January 20, 1999) as her explanation for including extra content in her lesson. Abell (in press) clarifies the situation of these teachers by explaining that the school experiences of many elementary teachers has led them to believe it is their responsibility to ensure student knowledge of the product of science. As a result they often end a lesson by providing the scientific explanation of the processes that their students observed during classroom activities. Although both Mrs. Fredericks and Mr. Gorman claimed that their learning objective in the electricity unit related to the differences between series and parallel circuits, they each made the decision to include activities on the attraction and repulsion of different objects in their choices of instructional strategies. When Mrs. Springer, Mr. Gorman and Mrs. Fredericks planned their units on electricity they needed to make the decisions suggested by Prawat (1989) concerning which were the most important ideas for students to understand and how they could best be organised and sequenced to maximise student understanding. In the case of the electricity units, the focus of the lessons was identified in the district curriculum guide. Each of these teachers decided to add content material that was related to but not necessarily a part of their chosen lesson objectives.

Maintaining coherence, or a logical continuity, within a lesson seemed to present a second dilemma to some of the teacher participants. Prawat (1989) discusses coherence as a critical component of teaching for understanding. He defines it in terms of making connections within a lesson, between lesson segments and across different lessons. Within individual

classrooms, for example that of Mrs. Springer during her electricity unit, there were often many different activities for students to do that related to several different concepts in spite of the fact that her stated objective was for students to understand the concept of an electrical circuit. There wasn't enough time to pull together discussion of the ideas generated by the various activities in which students were engaged or to relate the outcomes to the original learning objective. Neither she, nor Mr. Gorman in his electricity unit, spent time with their students on discussion of how the different activities led to an understanding of the differences between series and parallel circuits. While she did not plan time for discussion of the connections between lesson segments in the electricity unit, Mrs. Fredericks did plan time for discussion of the relationships between social studies lessons on the needs of humans and the science lesson on electricity with her students.

Miss Richardson, with a greater knowledge of science content than the elementary teachers, continually helped her student understand the connections between segments of her lessons as well as the connections between different lessons and units. Maintaining coherence between her lessons was not as problematic for her as it was for Mrs. Springer, Mr. Gorman and Mrs. Fredericks. When she was teaching her unit on weather and it's causes, she frequently stopped students in their activities and ask them how what they were working on related to what they had accomplished the day before. An example of the type of connection she wanted her students to make would be the discussion she conducted with her students on the connection between the water cycle, an earlier unit of study, and the weather cycle, the unit of study at hand. This was an example that she specifically described to me in one of our conversations as an illustration of how she liked to help her students "build bridges" between units of learning.

Miss Cornette thought that her knowledge of science content and science research processes allowed her to make connections between the sciences for her students. She also felt her knowledge base could be a problem if she

wasn't careful about talking at too high a level for her students to understand. Miss Cornette worked with colleagues in her department who had had extensive training in science content pedagogy and she followed their lead in developing lesson plans for her students. Her plans for student activities often included opportunities for her students' interactions to focus on the concepts to be learned. As they worked in small groups during lab activities students were given specific questions to discuss and asked to report their lab results and decisions about specific questions to the class as a whole. She implemented the learning cycle format for most lab activities as she operated according to a set of directions from her colleagues. As a result of time constraints, Miss Cornette frequently assigned what would have been the discussion sections of the learning cycles to be completed as homework by individuals. In reality, student interaction during most lab activities focused on procedural issues and not on constructing meaning from the results of the activity. Miss Cornette used the assignment of daily warm-up activities which student completed immediately upon entering the room to help them make connections between the learning of the day before and the new learning that they were about to begin. She did not, however, discuss planning any specific strategies for maintaining coherence between the different units of study that she presented to her students.

The third dilemma that the teacher participants faced was in determining the level of understanding of science content that their students achieved during and as a result of instruction. When lessons were more heavily packed with content information in the elementary classrooms there was evidence that teachers accepted recitation for understanding. For example, my observations revealed students in both the Mrs. Springer's multi-age and Mrs. Fredericks' fifth grade classrooms who memorised and drew or described the parts of an atom as their teachers drew them on the board as evidence of understanding. They also repeated memorised information about electron movement as the cause of electricity. In another series of lessons on the solar system second grade students were witnesses to a demonstration designed to explain the phases of the moon. They were then asked to draw the cause of the phases of

the moon in their journals. In each case, the teacher had added extra content to their lessons that she felt would enable the students to achieve a higher level of understanding of the main objective of the lesson. In assessing understanding these teachers often took answers to knowledge level questions about these phenomena as an indication of achievement of conceptual understanding. When asked to explain concepts that had been included as "extras" students recited memorised words they learned in the book, from the teacher or from an older student.

When lessons were focused on concepts, teachers at the elementary level often used performance assessments to determine the level of student achievement. In spite of the content "extras" included in their electricity units, both Mr. Gorman and Mrs. Fredericks used performance assessments focused on the original objective to determine the level of student understanding achieved at the end of the unit. Mr. Gorman asked his students to wire a model of a house using both series and parallel circuits. Mrs. Fredericks had her students build a circuit board and explain to her how it worked. Mr. Gorman determined the level of understanding of airplane flight that his students achieved by having them construct paper airplanes and analyse why changes in the model resulted in change in flight pattern. Each of the elementary teachers in this study included lessons on food webs and food chains in their science instruction. Each taught these concepts in slightly different ways. Mrs. Springer had her students read about food chains and webs and then choose different ecosystems and make drawings of different food webs. Mrs. Fredericks took her students to the district outdoor education centre and had her students find evidence of food chains in the outdoor setting. Mr. Gorman had his students build miniponds in the classroom and watch the feeding process of several organisms at different ranks in the food chain. In each case the lesson focus was on broad concepts and the assessment of understanding was based on student use of the concepts to analyse different situations.

The teachers in this study brought a broad range of knowledge, including their knowledge of science content and science content pedagogy, as well as a broad range of teaching experience to their science teaching. Each teacher made daily decisions about what content to teach, which instructional strategies to use, what level of student understanding of concepts to expect and how to assess student understanding. As they implemented their lesson plans and taught for understanding, the teachers in this study faced three dilemmas relating to their individual bases of knowledge and experience. One dilemma was maintaining the focus of each lesson as they identified important ideas relevant to each concept and chose instructional strategies that would enable students to achieve understanding of concepts chosen. The second dilemma was determining how to establish coherence within and between lessons on different topics and the third was in differentiating between student memorization of facts and achievement of conceptual understanding. In the case of each of the teacher participants their individual knowledge of science content and science content pedagogy as well as their personal knowledge and experience impacted the instructional and assessment decisions that they made.

Chapter Summary

The general focus of my research was on how teachers developed perceptions about the level of understanding their students achieved. Other related issues were generated by a process of responsive focusing (Guba & Lincoln, 1989) during my observations of and discussions with the teacher participants. It was not my intent to identify and criticise the instructional skills or classroom management practices of these teachers. Issues that I have raised in this section relate to the particular circumstances of these teachers as they were instructing and assessing their students in science. The teachers raised some of these issues and others involve questions I had as I analysed the data. Much that has been written in the literature, regarding teaching for understanding and constructivist learning theory, reinforced my observations.

In this chapter I brought the case studies together and presented an overview of my observations and a brief description of the characteristic elements of each teacher's instruction and assessment practices. I then organised the individual teacher's characteristic elements into groups of related strategies with common themes. The groups are defined by the themes of community, connections, reflection, variety of activities and assessment. I have discussed these themes in relation to the principles of teaching for understanding, constructivist learning theory and the NSES proposals for instruction and assessment. In that discussion I identified similarities between characteristic practices of individual teachers and common strategies they used to develop perceptions of what their students are understanding. I have also discussed the dilemmas that these teachers faced in planning and implementing a focused and coherent curriculum and in recognising student understanding. By comparing and contrasting the practices and ideas of these five teachers, both to each other and to the principles of teaching for understanding, I hope to provide some insight into what they were actually doing and thinking about assessment strategies and how they were responding to the need to assess student achievement in somewhat contradictory ways.

CHAPTER 10 - CONCLUSION AND IMPLICATIONS

I began this study because I was interested in what teachers were thinking about the achievement of their students and how their thoughts developed. In addition I sought to answer questions about how, in the face of two seemingly opposing directives, teachers were actually determining the level of understanding that their students were achieving. What were the assessment strategies that they were using to inform their instruction? How were they balancing the need to teach and assess for understanding and, at the same time, to teach for higher scores on external, standardised, multiple choice tests. As I observed and interviewed the teacher participants a process of responsive focusing (Guba & Lincoln, 1989) directed the focus of my attention to specific issues relating to how teachers develop perceptions of their students' understanding. In the process of developing case studies I have attempted to provide a rich description of the practices of five science teachers, including their own thoughts and beliefs about what they were doing. I used the principles of teaching for understanding, constructivist learning theory and the NSES as referents in the analysis and discussion of my observations. The ideas about instruction and assessment of student achievement posed in this body of literature provided me with a framework for examining the practices of the teachers with whom I worked. I identified several elements both specific to individual teacher's practices and common among several of the teachers. Building a sense of community, making connections in learning, teaching the habit of self reflection, using a variety of activities to teach most concepts and, determining the level of student understanding in several different ways and at several different times during a unit of instruction were practices common to many and in some cases all of these teachers.

In addition to the characteristic elements in the practice of the teacher participants, I have discussed other issues relevant to the perceptions that these teachers developed of their students' achievement. These issues have been reviewed in chapters 4 - 8 and then again in chapter 9 in the overview

and discussion sections. I discuss my main findings in the form of propositions in the conclusion section of this chapter and then suggest implications that those findings may have for the teacher participants, myself as researcher, the district as a whole and educators with an interest in implementing assessment strategies that foster student achievement. Many of my research outcomes reinforce and are reinforced by issues discussed in the literature on teaching science for understanding.

Conclusion

When teaching for understanding, teachers used a variety of strategies to determine student understanding during both instruction and assessment.

The outcomes of this research indicate that the five teacher participants practiced many instructional strategies that have been described in the literature as being effective for teaching for understanding. Between them there was a range of strategies exemplified in the practices they used to inform themselves of student understanding. Each of the strategies described in the case studies, including the processes of creating a sense of community, making connections between new and previous learning, using students' prior knowledge and experiences to help them understand new learning, encouraging students to reflect on their own learning in relation to what they already knew and using a variety of activities to teach for conceptual understanding are supported by constructivist learning theory and the principles of teaching for understanding. They are also identified as appropriate instructional strategies by the NSES (NRC, 1996).

The teachers in this study created a sense of community in their classrooms for either the purpose of providing students with a place where they would feel welcome and comfortable or to orchestrate an environment in which students would be actively engaged in the discussion of ideas. Talbot and McLaughlin (1993) refer to a classroom that has been designed to support teaching for understanding as being a community of learners, characterised by shared goals and standards, an atmosphere of mutual trust, and norms of

behaviour that support students taking risks and making sustained efforts towards serious learning. In each of the classrooms that I observed at least several of these characteristics were present.

Constructivist learning theory was founded on the idea that knowledge is actively built up by the cognising subject and that cognition serves the subject's organisation of the experiential world (von Glaserfeld, 1990). This idea is reiterated in the principles of teaching for understanding as proposed by Talbot and McLaughlin (1993). They describe understanding as "a concept of knowledge constructed by the learner and situated in the context of prior knowledge" (p. 169). A teacher operating from a constructivist point of view understands that knowledge is not transferred from teacher to student but is the product, in Yager's (1991) terms, of "self organisation and reorganisation". It is produced from existing beliefs and understandings and new experiences and ideas. Each of the teachers in this study rejected the role of transmitter of knowledge in favour of being facilitators of learning in their classrooms. They deliberately identified or helped their students identify connections between segments of learning and previous learning and experience; sometimes for fun, sometimes to enhance the relevancy of a subject and sometimes to help support and facilitate new learning.

Four of the teachers spent instructional time on activities designed to encourage their students to reflect on their own learning. That reflection often took the form of journaling but there were other strategies used as well. Students were asked many questions that encouraged self-reflection, they were occasionally assigned essays and, frequently, they were required to engage in self-assessment activities. This process of student self-reflection provided teachers, as well as students, with insight into the level of understanding that students were achieving. The NSES (NRC, 1996), call for teachers to encourage students to take responsibility for their own work by allowing them to take active roles in the assessment of their work. Teachers using these standards as a guideline for their instruction would help students develop their skills in self reflection and provide them opportunities

to assess and reflect on their accomplishments. In the vision presented by the NSES teachers also engage in self-reflective practices. They seek to understand which plans, decisions and actions are effective in helping their students and they explore strategies for improvement. By virtue of their participation in this study, the teacher participants were interested in reflecting on their own professional practices. Two of the teachers, Mr. Gorman and Miss Richardson had been active journalers prior to the beginning of the study. Two of the teachers joined partially because of the need as participants to begin the practice of keeping a journal. Each of the five teachers expressed interest in reflecting on their own understandings of how to teach for understanding.

All of the teachers in this study rejected the idea of transmissionist teaching in favour of roles more congruent to that of a teacher who teaches for understanding. They each planned for and encouraged their students to participate in a wide variety of activities chosen to teach individual concepts in different ways. The NSES (NRC, 1996) state that teachers will "select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities and experiences of students" (p. 30). These teachers spent a great deal of time planning what to teach and how it would best be taught to the many individual students entering their classrooms. Teacher planning addressed the questions of whether whole class or small group instruction would be most appropriate and would students learn best by way of a discussion, a hands-on activity, individual research or perhaps preparation for a presentation.

When teaching for understanding, teachers were confronted with many dilemmas as they planned and implemented instructional and assessment strategies.

The outcomes of this research indicate that each time the teacher participants made a decision, whether it was in creating a classroom environment, planning for focused and coherent lessons, choosing ways to help students make connections between new learning and prior knowledge and

experience, deciding on appropriate activities to include in the instructional plan, or determining how they would assess the level of understanding their students achieved, they faced a dilemma of choices. Each of the elements that were identified as characteristic of the teacher participants' instruction and assessment practices required judgments as to purpose and implementation.

When creating an environment with a sense of community teachers needed to balance the desire to provide a caring environment in which all students felt valued and accepted as advocated by Noddings (1992) and a learning community which provided the intellectual rigor required for scientific inquiry to occur effectively, as advocated by the NSES (NRC, 1996). Four of the teacher participants spoke of their classroom environments as ones where there was trust and respect, nice places to be. Mr. Gorman, however, struggled with understanding his role in creating a "warm fuzzy" feeling in his classroom as opposed to an environment in which there could be an active exchange of ideas.

Much of the literature on teaching for understanding and constructivist learning theory emphasises the importance of teachers' content and pedagogical content knowledge to effective teaching. None of the teachers discussed the use of any one referent which he or she used as a basis for decision making when "teaching for understanding". The elementary teachers in this study were limited in content knowledge and all the teacher participants were limited in pedagogical content knowledge. When teaching science content for understanding, teachers were faced with the challenge of making choices that would affect the focus and coherence of the science lessons they were planning. Information given, assigned activities, questions asked of students and responses to student questions all involved decisions that teachers needed to make. Many of those decisions were made in the planning of lessons but often teachers needed to make these decisions during the instructional process itself. Teachers with a higher degree of science content or science content pedagogical knowledge had fewer struggles in the

process of decision-making. Mrs. Springer's question as to the importance of knowledge of atomic structure to an understanding of how to use electrical appliances safely illustrates the quandary she often found herself in when she strayed from the district prescribed curriculum. Miss Richardson, on the other hand, was very successful in enabling her students to explore many different connections between the learning objectives of one unit, such as the unit on weather, and other subjects that they had studied.

As teachers sought to help their students make connections between segments of learning and life experiences they faced the need to make another set of choices. The need to make learning relevant, meaningful and even fun in order to draw student interest into the desired learning did not necessarily take into account the advantage to student learning of exploring preconceived ideas that students might have brought into the classrooms. Teachers needed to choose between making connections in order to engage their students in learning, as Miss Richardson did when she asked students to imagine the biggest storm they had ever been in and to write how the felt at the time, and making connections in order to facilitate the understanding of new concepts as Mrs. Fredericks did when she helped her students make connections between science, social studies and reading lessons.

Each of the teachers used the discussions involved in making connections between learning experiences to assess the level of student understanding that was achieved at various times during their teaching. They needed to decide when it was appropriate to extend those discussions and allow students to reflect on their own thinking or listen to and discuss critically the thinking of others. Much the same as the choices teachers faced when helping their students make connections between learning, these teachers had to choose between self-reflective activities for their students that would allow students to consider the growth of their understanding, the successes and shortcomings of their work, an interesting life experience that related to the classroom learning or personal goals that would need to be met. Yager (1991) states that learning is the product of self-organisation and

reorganisation. Teachers who are teaching for understanding must decide the purpose for student reflection, self-organisation and reorganisation when they include opportunities for it within their lessons. They also must decide why and how the process of student self-reflection will occur in their classrooms.

Another challenge, created by the desire to teach for understanding and faced by the teacher participants, was that of choosing specific activities for their students that would allow students to achieve the desired learning outcomes. Once these teachers had relinquished the role of transmissionist teaching they stepped into an instructional environment that offered them a myriad of possible activities for their students to complete. A desired gain in low-level knowledge understanding might best be served by a "recipe" type activity. When Mrs. Springer asked her students to decide on the type of substances that were and were not attracted to magnets, they followed a single set of directions and arrived together at knowledge level understanding of a single set of facts. If a teacher desired to have students acquire deeper, conceptual understanding then a more open-ended, problem solving type assignment might have been chosen. Mr. Gorman asked his students to experiment with paper airplanes and try to discover how they might create a plane that was faster, stayed in the air longer, or did stunts. There were no directions for this, just minimum guidelines for solving the problem. In order to provide students with experiences designed to enhance each individual's potential to learn when teaching for understanding, teachers must make decisions about the implementation of strategies with subtle differences in desired outcomes.

Teaching for understanding and the creation of a constructivist culture within a classroom required more than a discrete set of teaching techniques and assessment strategies for these teachers. "Crafting instruction based on constructivism is not as straightforward as it seems" (Windshitl, 1999, p.753). Even though planning instruction is important, constructivism does not dictate specific instructional strategies nor teacher behaviours. Teachers must be able to employ a range of strategies that can be drawn on in response

to the needs of many different situations. If teachers are teaching for understanding they are faced with the daily challenge of planning how best to serve each student who comes into their classrooms.

When teaching for understanding there is a close link between teaching and assessing for understanding.

The outcomes of this research confirm that each of the teachers in the case studies developed their own personal perceptions of their students' understanding by using a number of different assessment strategies. These strategies were embedded in their individual practices of instruction as well as assessment. As a result it was difficult in the data analysis section of the individual teacher chapters to separate their instructional strategies from their assessment strategies. I observed the teacher participants using journaling activities, questioning, group projects, one-on-one interviews, the construction of concept maps, reports on a variety of activities, and individual presentations to determine their students' levels of understanding during the course of instructional units as well as at the end of units of instruction. Teachers frequently used information gained from these sources to adjust their instruction in order to meet their students' needs. Prawat (1989) characterises teaching for understanding by its "highly analytic and diagnostic nature" (p. 324). These teachers had given up the role of transmissionist teaching for one that they perceived to be facilitation. In that new role they used the analysis of student understanding for instructional decision making such as the addition of alternative activities to aid the progress of students with different learning styles. Mr. Gorman did this when he taught his lessons on Bernoulli's principle, as did Mrs. Springer when she added activities to her electricity unit because some of the students were having trouble understanding the concepts she wanted them to learn. Final assessments included performance assessments, project presentations, one-on-one interviews and student-led parent conferences as well as teacher generated paper and pencil tests. During these processes the teachers often inserted instructional comments and Mrs. Fredericks even used one-on-one final assessment interviews to teach students the concepts they were

struggling with. In these instances the focus of assessment was on student understanding of concepts and the processes of reasoning rather than on the production of correct memorised answers.

When teaching for understanding teachers were subjected to conflicting pressures regarding the final assessment of student achievement but were able to disregard assessments that did not provide evidence of student understanding.

Teachers in this study had not accepted the district goal of becoming the "number one school district in the nation as evidenced by standardised test scores" as their own and they hadn't made a personal commitment to it. The science teachers who participated in this research discussed the difficulties in reconciling their preferred instructional and assessment practices and the testing parameters established by the school district. Teachers felt that they were subjected to contradictory direction about how to determine the level of understanding that students were achieving in their classrooms. In each case they felt they were receiving conflicting signals from the district administration in terms of how to adequately evaluate the progress of their students. Teachers were encouraged by the district to participate in workshops and training including several days of training in Madeline Hunter's elements of instruction, multiple intelligences, brain-based learning, multi-age classroom instruction, and the use of performance assessments. The district curriculum had been rewritten shortly before this research began. The teachers involved in the curriculum revision used the NSES as the framework for the revision process. Miss Cornette, the high school chemistry teacher worked with colleagues who had had extensive training in using learning cycles to teach for understanding. Many of those opportunities supported practices recommended by advocates of constructivist teaching. At the same time teachers were being encouraged to develop teaching strategies deliberately focused on raising the standardised test scores. The district goal was to be the number one school district in the nation by the year 2003 as evidenced by test scores, with a benchmark step being to have all students in the district score in the 80th percentile on Stanford 9

Achievement tests and 90% or higher on the district CRM. All teachers in the district were offered incentive pay bonuses if they were able to meet specific short-term goals in order to make progress towards the district goal.

Within their classrooms the teachers planned for science instruction and assessment in light of the contradiction of direction. They fulfilled their responsibilities as they understood them to be in terms of administering the tests but most of the teachers did not seem to place any value in the information that might be gained from the tests results. Mrs. Springer felt that the district CRM test was not appropriate for her multi-age children as it was designed for a single grade setting and had not been adapted to include questions that were appropriate for her students with a wide range of ages. She also dismissed the validity of the SAT 9 tests in determining student understanding and achievement. At the end of this study Mr. Gorman expressed concern about the correlation between district CRM test scores and his own perception of student understanding. However, he was the one teacher of the five teacher participants that was unaware during the study of the use of standardised test scores by the district to determine student achievement. Mr. Gorman acknowledged that these types of tests were here to stay, as people could understand them easily.

Mrs. Fredericks and Miss Richardson both rejected the usefulness of standardised test scores, preferring performance assessments for the final determination of student achievement. Mrs. Fredericks carefully administered the district-mandated tests to her students but did not find the resulting scores useful in her determination of student success. Miss Richardson expressed a willingness to use the test scores as an indicator of student success at some time in the future but was adamant about her lack of trust in the accuracy with which they reflected her student's accomplishments at the time of this study.

Of all the teacher participants in this study Miss Cornette was the one most open to using standardised test scores for the final assessment of her

students' achievement because she understood these tests to be part of the "real world" and felt she should start preparing her students to be successful when taking them. In spite of her willingness to accommodate the district mandate she did not feel that the tests tested what she taught and preferred other assessment strategies. In the end, Miss Cornette was unable to use the standardised test scores that she received due to the manner in which they were reported.

Mr. Gorman and Miss Cornette expressed opinions about the use of standardised tests that acknowledged the reality of the political situation that surrounds them. While, over time, performance assessments might gain public approval, standardised tests are currently viewed by many as reliable and valid measures of student achievement. The only reason either Mr. Gorman or Miss Cornette offered to support their willingness to comply with the district plan was the need to prepare students to be successful on standardised achievement tests that they might have to take in the future. Neither expressed any interest personally in using the test scores to inform their own teaching. At the time of this study the teacher participants gave only cursory attention to any use of standardised test scores, in spite of the fact that administering the tests and increasing student scores on the tests was a district mandate. Each teacher met the district guideline of administering the required tests. However, none of these teachers claimed to use scores obtained from standardised tests to either inform their teaching or determine the level of understanding that their students had achieved.

When teaching for understanding teachers preferred informal information regarding the level of student understanding over that obtained from standardised tests.

The teacher participants in this study assessed student understanding continually during the instruction process and preferred performance type assessments to paper and pencil tests as final assessments. The teachers used assessment strategies at the beginning of lessons to determine what students

already knew about a new subject or what they remembered from previous lessons. They embedded assessment in their instruction to determine if students were understanding as lessons proceeded and used various assessment strategies to determine final achievement of understanding. When two of the teachers had the opportunity to review the results of the district mandated standardised tests and those results didn't support the teachers' own perceptions of student understanding the teachers rejected the standardised test results in favour of their own assessments. All of the teachers expressed concern about the lack of correlation between how student understanding was assessed on standardised tests and the manner in which it was assessed in their classrooms.

Three of the teacher participants deliberately included strategies to determine the initial understanding of students as new lessons began. Mr. Gorman planned and posed questions about the "big ideas" of each new unit to find out what students understood at the beginning of the unit and to generate discussion among the students about the new topic. Both Miss Richardson and Miss Cornette used daily warm-up activities to begin their classes. Students were frequently asked, in Miss Richardson's class, to reflect on previous learning or experience and make connections to the new learning. Miss Cornette asked her students to answer questions directly relating to the lesson taught the day before. Both teachers used the student responses to determine the level of understanding that students had at the beginning of the lessons. They were then able to adjust their instructional plans accordingly.

Each of the teacher participants integrated assessment of student understanding into their instructional strategies. Those practices varied from informal questions during whole class discussions, one-on-one conversations between teachers and students as students were working on individual assignments, discussion of homework assignments, quizzes and reflective writings. Teachers used information gathered from these sources to inform and adjust their instruction in order to provide opportunities for more students to be successful. In their conversations with me both Mr. Gorman

and Mrs. Fredericks described examples of instances when they added specific activities to their planned instruction because feedback from student discussions informed them that students had been struggling with specific concepts. Many of the lessons that I observed in Miss Richardson's class ended with a review of the day's learning. She had the habit of asking her students a series of rapid-fire questions to review many concepts that had been covered in class and to identify specific details that the students would be responsible for knowing. The question and answer sessions served to inform her of how thoroughly her students had understood the material presented in her daily lessons.

All of the teachers told me that they would prefer to interview each student individually in order to assess their final understanding of the concepts taught in class. Mrs. Fredericks was actually able to schedule her classes so that she could have those interviews at the end of several science units. She used the product of performance-type assessments as the focus of those interviews. In the case of the electricity unit she had her students build circuit boards and explain the differences between parallel and series circuits. If they weren't sure of the concepts to be assessed she worked with them in a one-on-one setting until they understood.

Each of the elementary teachers expressed a strong preference for using performance-based assessment in determining the level of student understanding achieved in their classes. Mrs. Springer preferred performance assessments including presentations and projects and believed that students demonstrated understanding when they could apply learning in different situations. In the three units of instruction that I observed in Mr. Gorman's classroom his final assessment of student understanding was embedded in an analysis of a final project. In one case the project involved wiring a model house with series and parallel circuits. Another was constructing and analysing the interrelationships in a freshwater ecosystem and an third was in constructing and flying paper airplanes and explaining how and why variations in design affected the flight of the planes.

The middle and high school teachers also expressed a preference for performance-based assessment but either used or acknowledged the need to use the district mandated criterion and norm referenced multiple-choice tests. Two of the teachers completely denied that there was any value in using them to determine student achievement of understanding. While these teachers each expressed concern that the test did not correspond to either the content taught in the classroom or the level of learning expected of their students, the underlying concern seemed to be that the mandated tests could never accurately test what was learned. There was a clear disconnection between the goals of the teachers in this study in assessing student performance and the district goal of being the number one district in the nation as evidenced by standardised test scores.

During this study the teacher participants implemented assessment strategies that correlated with the suggestions found in the literature on teaching for understanding. The NSES (NRC, 1996) advocate the planning of assessment as an integral part of instruction. According to the NSES, assessments embedded in the curriculum can serve at least three purposes: "to determine the students' initial understanding and abilities, to monitor student progress, and to collect information to grade student achievement" (NRC, p. 87). These teachers used assessment for all three of the NSES identified purposes. They made instructional decisions based on initial diagnosis of student understanding and ongoing analysis of student achievement. The only interest they expressed in the usefulness of standardised achievement tests was in the fact that they understood the need for their students to be able to successfully complete that type of test in the future. "It's a multiple choice world," said Miss Cornette. "But we don't teach that way in our classrooms."

Implications of the Study

This study has provided a description of the thoughts and practices of five teachers of science in the SFSD. These few teachers in this one school district together represent a microcosm of teachers across the nation. They have information to share about what kind of things "work" in a classroom. Each brings his or her own personal sense of connoisseurship to the discussion of how best to instruct for and assess student understanding. The study provides an opportunity to examine the thoughts of teachers as they work to meet their personal commitments to their students in an educational environment that is complex in its nature and contradictory in its direction. The insights and opinions gathered from these teachers help to broaden our understanding of how teachers in general operate in their world of contradictions. The outcomes of this study confirm much of what has been written about teaching for understanding. These outcomes have implications for those who are interested in what teachers are thinking and doing as well as for all teachers who are teaching for understanding. There are specific implications for the teacher participants involved, the district in which this study took place, certainly for me as a principal and supporter of teachers, and, most importantly, for students in science classrooms.

The importance of recognising the impact of political pressures on classroom teachers

Organising a constructivist classroom based on the principles of teaching for understanding and then recognising student understanding when it occurs is problematic at best for teachers at all grade levels. Given the current political climate, which emphasises the importance of student success on high stakes, multiple-choice achievement tests, teachers who are striving to maintain constructivist teaching practices are working in an environment that would seem to be counterproductive to their efforts. Those who are

interested in what teachers are thinking and doing as an important component of efforts towards educational reform and those who are teachers of teachers need to fully understand the dichotomous role that teachers have to fill. The NSES, as well as other standards documents, have provided teachers a guide that supports their concern for and efforts to ensure student understanding at a conceptual level. The instruction and assessment strategies suggested in that document have roots in the principles of teaching for understanding and constructivist learning theory. However many of the state tests, including the required state tests in the location of this study, have taken national standards and used them to develop state standards and accompanying multiple-choice standardised achievement tests. These tests serve as exit exams at various grade levels as students progress through school and, by their nature, compromise the intent of the standards documents.

It would seem likely that science teachers, who are teaching in environments where high stakes tests are held as a critical measure of student achievement, would begin to narrow their curriculum to match what is covered on standardised tests and use instructional practices designed to produce high tests scores as a measure of student achievement (Brooks & Brooks, 1999). However, in spite of political pressure and, in the case of this study, the district incentive pay program, science teachers in this study rejected the use of standardised test scores as an accurate determinant of what their students were achieving. They showed a strong preference for performance and authentic assessments that required students to use upper level thinking skills. Those who are involved with educational research and those who are teachers of teachers should be cognisant of the fact that teachers are showing a preference for teaching for and assessing conceptual understanding in spite of the political pressures. At the time of this study they were giving tacit recognition of the need to administer the district mandated standardised tests but they had not invested personal value or interest in the resulting scores.

As the pressure of high stakes test accountability increases, and it shows no signs of abating, it will become increasingly difficult for teachers to maintain

their focus on student achievement of conceptual understanding without support. Administrators need to come to terms with the discrepancies inherent in the determination of student understanding by use of external standardised achievement tests and by use of more informal teacher generated assessment strategies. Administrators and teachers need to be aware that reliance on information gained from these tests may result in the loss of a more accurate evaluation of conceptual understanding on the part of the student. By recognising the somewhat dichotomous position in which many teachers find themselves, researchers may be able to provide support for teachers' efforts to increase the effectiveness of their assessment practices and to continue to emphasise the importance of assessing conceptual understanding.

The importance of collaboration in systems decision-making

Districts across the nation face the same pressures as the district that was the locus of this study. In this district, the goal of being number 1 in the nation as evidenced by standardised test scores was imposed on the teachers with no time taken to garner teacher support for the stated goal. In spite of the political pressure and district incentive pay plan to encourage teachers to embrace the challenge of raising student scores, teachers in this study seemed to grant little importance to the mandate or to the standardised testing programs. However, they did not as a unified block negate the value to be gained from the district testing program. Only two of the teachers rejected the standardised tests outright. One of the teachers in this study was unaware during most of the study that the mandated standardised tests were looming but said in a discussion that he felt multiple choice tests would "be here for a long time because the general public could understand the results." Two of the teachers expressed interest in giving the tests. Although one of these had had part in writing the district assessments, she didn't trust them but she wasn't opposed to using them. The other actually gave standardised tests as her final exam but, in the end, was unable to use the results. With collaboration between the district teachers and administrative staff, rather

than the imposition of mandates, this district and others may be able to find a solution to the dilemma of meeting both state requirements and research based best practices in assessing student achievement.

Teachers or district administrators have few viable alternatives in states that have implemented clearly defined state standards and strict accountability systems. Operating in defiance of state mandates will be extremely difficult over the next several years. Glickman (2001) offers several options to teachers and their district administrators that involve collaboration and may provide viable solutions for the district described in this study as well as many others. Outright rebellion to externally mandated testing programs, while one of Glickman's suggestions, has obvious disadvantages in that loss of such a battle could mean even more stringent standards being imposed. Working within the state system by proposing variances in the current accountability system and suggesting that certain districts pilot new forms of standards and assessments, accepting the state-mandated testing programs but developing a local assessment system with performance based projects which "integrate what students need to know on the state assessments with a more applicable contribution" (2001, p. 50), accepting the state programs but involve students in finding ways to prepare for them as well as other types of learning, ignore the tests except for crash preparation close to the date of their administration, or resign and find another place to work.

Teachers in this study were working in a district environment that emphasised the necessity of focusing on test scores. The teachers were also provided with specific staff development opportunities which focused on instructional strategies designed to increase student understanding at a conceptual level. The district also had its state mandated but district written CRM program which had the potential for including a performance assessment piece. It would seem, in light of the support for instruction provided by the district and the attitudes of the teachers towards assessment practices, that collaboration between teachers and district administrators might yield a solution similar to Glickman's third option of a local

assessment. This would allow teachers to continue in their classrooms the assessment practices which they understand to be most valuable while the politics of accountability by test scores is played out in a different arena.

The importance of connecting teaching and assessment

Teachers in this study consistently lamented that the state and district mandated multiple choice and standardised tests did not "test what they had taught" or did not "test the way that they had taught" their students to demonstrate their achievement of understanding. In addition, teachers claimed that since standardised tests did not match the manner in which they taught, their students consequently didn't do well on them.

Assessment of student achievement, as a topic of discussion, has become a focus of political rhetoric as well as a concern among science educators. The political push for accountability frequently eclipses the intent of the NSES and the educational practices suggested by constructivist learning theory and the principles of teaching for understanding. While none of the teachers in this study articulated an understanding of constructivist learning theory or the principles of teaching for understanding, they all included in their practices both instructional and assessment strategies that were coherent with these bodies of thought. The result of using strategies related to constructivist beliefs as a basis for making instructional decisions in the classroom may result in quite different understandings being acquired by individual students. It also may result in teachers receiving messages about the level of understanding that their students are achieving which conflict with the information gained from the politically promoted and externally developed standardised achievement tests. Paper and pencil, objective, standardised tests, administered at the completion of a preset interval of learning, in which learners recognise rather than generate answers may provide quantifiable standards of certain types of achievement. However, the results of such tests do not necessarily allow teachers to make accurate

inferences about the level of understanding that has been achieved by individuals in their classrooms.

This study revealed that teachers, as evidenced by their daily practices, are advocates of assessment strategies that allow students to demonstrate what they know and focus on the content that is most important for students to learn. When there is a correlation between and integration of instruction and assessment, teachers feel that they are able to develop a clear perception of the level of understanding that their students are achieving both during the process of learning and at the end during a final assessment of achievement. As a result they can adjust their instruction according to student need and develop evaluation strategies that assess higher order thinking skills. Objective evaluation techniques such as the use of external multiple choice style standardised tests may provide quantifiable standards of achievement but the level of learning that they assess may not be consistent with the depth of conceptual understanding that students have achieved. In addition, results of such tests are often not available to teachers during the instructional process and thus do not serve as a tool to inform instruction of the students that were tested.

Assessment based on constructive practices should represent the instructional goals of the teacher and provide a link between the instruction offered and the students' learning. As such it should optimise students' opportunity to express their learning. Constructive assessment can serve as an exchange of information between teacher, student and other members of the school community and should anticipate action as a result of the knowledge it produces (Clarke, 1997). Assessment, as represented by the state mandated standardised testing programs, does not often provide the same type of information that classroom assessment practices provide. Educators at all levels should be aware of the dichotomy that exists between the information gained from different types of assessments. They need to come to terms with the discrepancies inherent in the determination of student understanding by use of external standardised achievement tests and by use of the more

informal assessment strategies used by practicing teachers. While the national and state political environments, which surround the educational process, are strongly advocating the use of external standardised tests, administrators and teachers need to be aware that reliance on information gained from these tests may result in the loss of a more accurate evaluation of conceptual understanding on the part of the student. In fact, the National Council of Teachers of Mathematics has issued a position statement reiterating their belief that "the movement toward high stakes testing marks a major retreat from fairness, accuracy and educational equity" (2001).

The importance of connecting theory and practice

The pressure to raise student scores on standardised tests is accompanied by lists of curriculum objectives including specific information to be transmitted directly to students' heads and a multitude of available materials designed to increase student test taking abilities. There is an apparent assumption that test scores will rise if teachers will implement instructional strategies designed to lead students along a relatively logical, sequential path towards the required knowledge. Constructivist learning theory and the principles of teaching for understanding do not provide teachers with a set of similar directions to lead the way to student achievement of conceptual understanding. Constructivism addresses how students learn and the principles of teaching for understanding provide an underlying set of beliefs in appropriate approaches that teachers might take in order to enable their students to achieve understanding. There is no clear map provided by constructivism that outlines the route teachers should follow in order to accomplish this goal. Without that clear set of directions the route towards developing a constructivist classroom becomes the more difficult route for teachers to follow. Teachers need to be equipped themselves with the understandings and concurrent abilities to implement instructional and assessment practices which will allow them to meet the mandates of their districts while, at the same time, to maintain classroom practices that are designed to further student understanding as advocated by the NSES. The

teachers in this study did not, in the course of the interview process, discuss any specific referents on which they based their instructional decision making. One way to lend strength to their choices of instruction and assessment practices would be for teachers to be able to articulate a set of beliefs that provide a foundation for those practices. Those involved in education research need to find effective ways to communicate with the classroom teacher.

The importance to teachers of maintaining a safe and connected classroom

When teaching for understanding teachers need to be aware of the impact that each of the instructional strategies that they incorporate into their lessons might have on students' ability to achieve conceptual understanding. The concept of teaching for understanding does not come with a rulebook including right and wrong choices. Teachers balance a complexity of needs in their moment-by-moment decision making processes. For example, the importance to teachers of maintaining safe and connected classrooms has implications for both their abilities to teach for understanding and their students' receptiveness to participation in the process.

The teacher participants in this study had a shared belief in the importance of creating classroom communities based on mutual respect among members of the class and, implicitly, mutual caring. They consciously established respectful and accepting environments within their classrooms. Only one of the teachers sought to deliberately create a learning community in which there was an exchange of ideas. The NSES also call for teachers to develop "communities of learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning" (NRC, 1996, p.45). Teachers must balance the need for maintaining a classroom focused on caring in which all ideas of students are accepted and students receive automatic approval for their individual cognitive efforts and one that provides an intellectual challenge to students by focusing on the rigor of scientific inquiry.

While in the process of establishing a warm and accepting environment teachers need to be cautious of creating an environment that reduces the possibility of developing a sense of intellectual rigor in student discussions and interactions. Prawat (1996) discussed the role of teachers who wish to pursue the goal of fostering a learning community environment within their classrooms. Teachers must first "pay attention to the quality of interaction among participants during community development" and then "encourage participants to rethink or reconceptualise their current position" or challenge them to participate in "meaning-making" through negotiation (p. 106). Teachers need to strike a balance between "honouring each individual's contribution to the group" (Prawat, 1996, p. 108) and moving the group towards disciplinary based ways of viewing specific topics of discussion.

When teachers take specific steps to build a sense of community within their classrooms they may have different purposes for doing so. Their goal may be to create a warm and welcoming place in which students are helped to develop caring relations (Noddings, 1992, p. 18). A community based on trust and respect would be such a place. If teachers are deliberately orchestrating an environment that will increase student understanding of content then they face the challenge of building a sense of community that encourages an exchange of ideas. Such an environment needs to go beyond a community based on trust and respect in which every child is welcomed and supported and their ideas are accepted without examination by others. Students must be provided opportunities to become witnesses to and participate in one another's thinking in order to reflect on the relationship between new learning and their own previous understanding of various phenomena (Windschitl, 1999).

Teachers' choice of the connections they wished to emphasise between new learning and previous student experiences held similar implications for their ability to teach for understanding as their desire to create a safe classroom environment. Teachers in this study took many opportunities to make

connections between classroom learning and relevant experiences and concepts that students had had in other settings. Connections might have been motivational in the sense that they provide interest or fun or they might have drawn on students' previous learning in order to build on it. While in the process of helping students link required new learning and other experiences, these teachers needed to be able to discriminate between reasons for making those connections and understand the impact of their choices.

The importance of teacher knowledge when teaching for understanding.

The NSES professional development standards state, "all teachers of science must have a strong, broad base of scientific knowledge" (NRC, 1996, p. 59). In addition, Prawat (1989) calls for coherence between content knowledge and pedagogical content knowledge. Questions such as which are the most important ideas for students to understand, and how can those be organised to maximise understanding can best be answered by a teacher who brings both content knowledge and pedagogical knowledge to the classroom. Prawat reports that research demonstrates the clear relationship between what teachers know about content and the "depth of understanding they are able to promote in students" (Prawat, 1989, p. 319). The role of a teacher's content knowledge is being examined as the emphasis in instruction has shifted towards achieving conceptual understanding and higher order thinking in students.

Windschitl (1999) reiterates this belief in the importance of teacher knowledge in his expectation that teachers of science have a high degree of subject matter understanding. In this more recent discussion of instruction based on constructivist theory, Windschitl emphasises that constructivist teaching "places high demands on the teacher's subject matter understanding." Teachers must not only be familiar with a topic of study but must also be prepared for a number of ways in which that topic might be explored. Dealing with the correctness of student constructions is an

ongoing concern" and teachers need to develop a critical awareness of disciplinary truths and the viability of various ways of knowing the world" (Windschitl, 1999, p.753).

The teacher participants in this study represented a wide range of knowledge of science content and science content pedagogy. The two of the three elementary teachers had backgrounds in social studies rather than science. The third had a elementary education degree with no special content endorsement. With the limited science content knowledge in three of the teacher participants came a concomitant limit of pedagogical content knowledge. The secondary level teachers each had science endorsements on their certificates and each brought a strong background of science content knowledge to their teaching. However, they were also limited in their understanding of science content pedagogy. Many of the instructional and assessment strategies that these teachers employed in their practices resulted from training they had had in other content pedagogies and or related workshops.

The impact of teacher knowledge of content and content pedagogy was evident in three specific ways in this study. At times these teachers were not able to determine the most important ideas for students to understand within a given district prescribed unit of learning. For example, Mrs. Springer and Mrs. Fredericks struggled with how to develop their units on electricity. The lack of science content knowledge restricted elementary teachers' ability to recognise student understanding. Again, the electricity units provide examples of this dilemma as well. Their were instances when the teachers were limited in their recognition of the potential impact on student understanding of some of the instructional strategies that they were using due to their lack of training in science content pedagogy. The use of learning groups in several of the classrooms would provide illustration of this point. In several instances, groups that might have been structured on the interchange of ideas became small examples of older or more "capable" students simply transmitting knowledge to the other members of their

groups. There was neither negotiation of meaning nor development of thought among the groups as a whole.

Prawat (1989) describes negotiation as "the kind of interaction between teacher and student and between student and student in classrooms where teaching for understanding is the norm" (p. 320). Cobb, Wood, Yackel and McNeal (1992) compare a traditional math classroom to one in which the students were very comfortable challenging each other's interpretations, solutions and answers. The teacher, in their example, actively encouraged her students to make challenges. Exchanges between the students and between the teachers and students illustrated a process by which the teacher used individual constructions to guide her students toward an understanding of mathematical concepts. The atmosphere in the participating teachers' classroom included little student-student interaction and exchange of ideas. Given the opportunity to articulate their ideas to their classmates and analyse the ideas of others these students might have gained a deeper understanding of the material they were assigned to learn.

Windschitl discusses a view of constructivism as a "culture, not a fragmented collection of practices" (1999, p. 752). It cannot make its appearance in a classroom as a discrete set of instructional methods that have been added to a teacher's already existing repertoire of traditional teaching techniques. Many teachers of science received limited training in science content knowledge and content pedagogy prior to entering the classroom. In fact, the teachers of this study did not articulate an understanding of constructivist learning theory or of any related strategies that might be considered appropriate to science content pedagogy. Many of the strategies that they did use came from specific workshops on isolated topics such as "multiple intelligences", "brain-based learning", "multi-age classrooms", etc.

It is easy to advise that in order to accurately recognise what their students understand teachers may need more grounding in their subject matter and content pedagogical methods. Reality is that as new teachers, elementary

level teachers in particular, leave their university training and enter the classroom, they do not bring with them a comprehensive understanding of either science content or science content pedagogy. In rapidly growing districts, such as the one in which this study took place, there is a concurrent rapid growth in the hiring of new teachers to serve the increased student enrolment. Administrators and teachers of teachers need to be aware of the limitations in science training that many teachers have and provide support systems that would enable them to increase the effectiveness of their practices of science instruction and assessment.

The importance of connecting curriculum content and instructional strategies

The district in which this study took place provided its teachers with a prescribed science curriculum guide. It consisted of learning objectives listed by grade level and identified as to the importance of including them in instruction. Both Mrs. Springer and Mrs. Fredericks expressed frustration with the limits to the objectives in the curriculum guide at their respective grade levels. They both felt the need to go beyond it in the scope of material that they presented to their classes but didn't have the knowledge they would have like to have had to adequately plan for extensions of the content they presented. Mr. Gorman lacked awareness of the existence of the curriculum guide until a good way through the year and simply taught what the teacher next door suggested based on the material he had in his classroom. At the secondary level, Miss Richardson used the curriculum guide extensively and relied on her own knowledge of science to determine how to teach the prescribed curriculum. Miss Cornette went beyond the curriculum guide to cover content that her students found difficult but relied on her colleagues for ideas of how to present new learning and help her students understand. There were no district provisions for guidance in how to teach science. One way that districts might support its teachers is to view curriculum as a combination of the guidelines of what to teach and a range of strategies suggested for how that content might be taught.

Final Comments

The significance of this research to the teachers involved has been personal and individual. Each has had an opportunity to reflect on his or her own understanding of effective practices as well as to participate in dialogue on their thoughts during the interview process and with other science teachers during a discussion of the NSES. As they began a joint discussion of the NSES they also began to recognise the need for a set of beliefs to support their choice of classroom practices. Many of these teachers have continued to engage in conversation with me and with each other regarding the district curriculum and district CRM testing program. The contribution of this study to their individual practices would best be determined by continued discussions with them and observations of their instruction and assessment strategies.

An important outcome of this research has been the opening of dialogue between many stakeholders in the science education of the SFSD children. Many of the teacher participants have continued to seek opportunities to share with each other and their colleagues the insights, tensions and richness of experiences that they shared so willingly with me during my research. Prior to the completion of this study there had been changes within the district curriculum and assessment program. These changes are not directly attributable to this research. However, the shared discussions between the research participants and their respective colleagues have possibly had a small ripple effect in moving the change process forward. Teachers, at their request, are taking a leading role in rewriting many of curriculum objectives and the CRM questions. They are also beginning the process of designing a performance assessment portion of those tests. District administrators are making extensive standardised test data available to the teachers and training them in how to use that data to serve individual students. At the same time the state government is extending the required state standardised testing program. It is now necessary that students in the state pass the state tests if

they wish to graduate from the twelfth grade and continue their educations. Both district teachers and administrators are working together to incorporate the new state standards into their current practices without diluting the value of what already exists.

I have continued in my role as principal of a new middle school during the process of writing this thesis. One of my responsibilities in that capacity has been to hire 23 of the 31 teachers on my staff. The majority of these teachers have had three years or less experience. Among them are five science teachers. It was clear during the hiring process that there were few teachers with a background in science who were interested in teaching at the middle school level. As a result, only two of the five teachers that I hired had experience in teaching science prior to joining our staff. Only two had more than a minimal knowledge of science content. Each was highly recommended to me as having instructional skills considerably beyond what might be expected of first year teachers. As a condition of hire, they needed to present me with a written plan outlining how they were going to continue their education and earn the required credits to receive a science endorsement on their certificates. My commitment to them included regularly scheduled dialogue on effective strategies for teaching the district required science objectives as well as continued discussion of science pedagogy. One of the outcomes of this research that has been of significance to me is the personal understanding I have gained about how to support teachers in order for them to develop their skills in both instruction and assessment. While the study focused on science teachers, there are few outcomes that do not have significance for any of the teachers in my school.

As I complete the process of writing, the teachers, themselves, have continued in the development of their skills and careers. Two of the teachers have left the district, one to continue teaching at the university level and the other to a district where she will be able to pursue her interest in varsity coaching. One of the remaining teachers has changed her role in the district and has become the district staff development resource person, responsible

for supporting growth in instructional skills of all district classroom teachers. The district need to find additional science teachers has continued to increase without a parallel increase in candidates. The practicalities of managing an educational system can quickly overshadow the purpose of the system itself. The political interest in accountability for student achievement has continued to increase in the state location of this study. A recent referendum approved by a public vote allows for increases in teachers salaries across the state. However, a large portion of the salary increases is, by law, to be linked to student achievement. Teachers and administrators are collaborating on the design of a plan that the district community as a whole can support. It is my hope that this study will contribute to an understanding of the continuing needs of all teachers, as they remain focused on providing our students with the science education called for by the NSES.

Future Research

The design of this study was intended to be exploratory and descriptive in nature. The purpose of such research can be to investigate and document little understood phenomena and generate hypotheses for future research. Several areas for future research are implied by the outcomes described above. These include the following:

1. What referents do science teachers use when thinking about and making decisions regarding what it means to teach for understanding?
2. To what extent do science teachers use district and/or nationally developed science curriculum guidelines as tools for planning their instruction?
3. What are the tensions that exist between how teachers make sense of teaching science for understanding and how district and or/ national documents address achievement in science learning?

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