CONCEPTUALIZING A "REFLECTIVE PRACTICUM" IN CONSTRUCTIVIST SCIENCE TEACHING

By

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Abstract

This study addresses the problem of conceptualizing the dynamic processes of the practicum in learning how to teach science. It is concerned with the character of the dialogue and relationship between a supervisory teacher and a student teacher, as they inquire into the ways in which pupils conceptualize science concepts and classroom events. Of particular importance is the capacity, or disposition, of a science teacher for appreciating the ways in which pupils make sense of the phenomena that are studied in science classrooms. Thus, the study focuses on the ways in which a student teacher can be encouraged to inquire into the matter of teaching science.

The investigator draws from two perspectives in formulating the theoretical framework for the study. A "constructivist" perspective on the acquisition of knowledge is utilized to inform the events of science teaching. Briefly, this perspective is organized about the variety of ways events can be perceived by different individuals, according to the concepts and conceptual frameworks they use to organize and represent experiences. In science teaching, there is frequently a tension between perceptions derived from the concepts of "ordinary language" and those concepts emanating from "scientific language." A constructivist view of science teaching is developed to characterize this tension, and to point out important implications for science teaching.

The other perspective that has been useful in formulating the theoretical framework for the study is a view of practicum events emanating from Donald Schön's analysis of "reflective teaching." This view focuses on the practicum supervisor's demonstration and description of pedagogical knowledge, as well as
the student teacher's imitation and construction of this knowledge. This view of
the practicum considers how a student teacher learns to "see" the practice
setting as the supervisor does, and how the meaning of the supervisor's model is
derived from the student teacher's experiences in the practice setting.

The combined "Schönean-constructivist" perspective results in the derivation
of an "analytic scheme" used to interpret two case studies of a "reflective
practicum in constructivist science teaching." The database for these case
studies consists of verbatim transcriptions of science lessons and supervisory
conferences collected from the practica of two student teachers--Rosie and
Kevin. Their supervising teachers, Colin and Gary, were experienced science
teachers who subscribed to a constructivist perspective in guiding and making
sense of their own practice. The analysis focusses on Colin and Gary's style of
supervision, specifically in terms of Schön's three "models of coaching reflective
practice." These models are referred to as "Follow Me," "Joint
Experimentation," and "Hall of Mirrors." A set of "clues" for identifying the
attributes of these models is derived from the analysis and illustrated by
examining particularly informative excerpts of their supervisory conferences with
Rosie and Kevin.

The contribution of the study is the analytic scheme and its associated
"clue structure" for identifying patterns of events in a reflective practicum in
which the focus is on constructivist science teaching approaches. The general
conclusion is that the analytic scheme and clue structure for identifying the
three models of coaching reflective practice are both relevant and useful for
thinking about events in a practicum in science teaching.
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Chapter 1

INTRODUCTION

Investigating The Role of Practicum in Learning How to Teach

For years students of education and teacher educators alike have struggled with problems associated with entry into the profession of teaching. Much attention has been focussed on the role of the practicum in the education and socialization of beginning teachers. But while teacher educators agree that student teaching is likely the most influential component of teacher education, researchers who have analysed the empirical literature have, in many cases, characterized the knowledge base on practicum experiences as weak, ambiguous, and contradictory (Davies & Amershek, 1969; Peck & Tucker, 1973; Zeichner, 1980; Feiman-Nemser, 1983; Griffin et al., 1983). There continues to be a great deal of debate about the role that practicum experiences play in teacher education, about ways of conceptualizing and researching the practicum, and about ways of systematically improving it.

This study is concerned with the character of practicum. It is focussed on the experiences of two student teachers of secondary school science—the lessons that they teach, their dialogue with supervisory teachers, their interaction with pupils, and so on—in search of patterns and understandings outlined by Donald Schön's (1987) analysis of a "reflective practicum." In his book Educating the Reflective Practitioner, Schön has put forth ideas about education in the professional schools that seem to promise fresh understandings about the character of practicum. However, the utility of Schön's account of professional education remains untested in the context of teacher education. This study
explores the extent to which Schön's account of professional education—his three "coaching models" in particular—are applicable and appropriate for conceptualizing and investigating science teaching practica.

**Purpose of the Study**

Although there are several meanings associated with "reflective teaching" and "reflective thinking" current in educational literature, this study draws upon only one: the notion that reflection involves the reconstruction of experience—that is, when a practitioner assigns new significance to events, or identifies and attends to features of a practice situation that were previously ignored. Further limitations are placed on the notion of reflection developed in this study by engaging a perspective of science teaching that pays particular attention to how pupils perceive and interpret science classroom events. The two supervisory teachers who have been selected for this study have been involved in a research project at the University of British Columbia investigating the use of this so-called "constructivist perspective" in guiding and interpreting their own practice. This study extends the work of the U.B.C. research project to the arena of teacher education: it is an examination of how two student teachers are inducted into a particular "school" of reflection on practice. Although the study necessarily explicates characteristics of a constructivist perspective on science teaching and learning, its primary focus is on the character of the practicum itself. The broad goal is to generate concepts and understandings of a unique form of science teaching practicum, one that is "reflective" within the boundaries of a constructivist orientation to science teaching. It should be clear at the outset that there are other kinds of reflection than the kind that Schön is referring to, and that within Schön's general account itself, this study attends to certain possibilities of reflection
and ignores others. The purpose of this study is to identify the elements of a "reflective practicum" in the handling of student teachers by two practitioners of constructivism in science teaching. Schön's (1983, 1987) analyses of the nature of professional knowledge, how it is learned, and the qualities of a "reflective practicum" provide an interpretive framework with which two cases of science teaching practicum are examined. The outcome of the study is a set of techniques and competencies required by practicum supervisors for encouraging student teachers of science to become "reflective" about their practice.

The remainder of this chapter is presented in three sections. First, the research problem is presented, together with the specific research questions that guided the study. This section includes a discussion of how the problem is framed, drawing from a brief review of literature pertaining to teacher education research in the areas of early field experience and practicum. The second section presents the statement of the study's significance. Finally, data gathering and analysis procedures are discussed, along with the general methodological stance of the study.

Statement of the Problem and Research Questions

The research problem of this study is to conceptualize and investigate empirically the elements of a reflective practicum in constructivist science teaching. As this task entails the elaboration and clarification of the theoretical framework employed in the study, the theoretical assumptions underlying this work are included. In order to explicate this theoretical framework, the first set of research questions is critical and analytic in character. This set of questions requires a synthesis of a constructivist
perspective on science teaching and learning, and Schön's formulations of professional thinking and practicum in professional education.

1. What are the supportable characteristics of a reflective practicum in constructivist science teaching?
   1.1 What is the constructivist's position about teaching?
      1.1.1 What about the constructivist's position is supportable?
   1.2 What is Schön's position about reflection?
      1.2.1 What about Schön's position is supportable?
   1.3 What is the combined position about reflective teaching?
      1.3.1 What about the "reflective teaching" position is supportable with regard to science teaching?
      1.3.2 What about the "reflective teaching" position is supportable with regard to a teaching practicum?

The second research question is empirical in character; it entails the observation, documentation, and analysis of events in two case studies of science teaching practicum, as these are seen from a Schönean-constructivist perspective.

2. What are the patterns of reflective behaviour that can be seen in the participants' discussions, using the general framework Schön has provided?

Thus, there are two interrelated aspects to this study. First, the characteristics of a reflective practicum in constructivist science teaching are conceptualized, drawing from a critical analysis of two theoretical literatures—one pertaining to a constructivist perspective on science teaching, the other emanating from Schön's formulation of the education of "reflective practitioners." Second, two cases of a science teaching practicum are examined for patterns of reflective behaviour and dialogue.
Framing the Problem

Research reports in the teacher education literature have given rise to a general concern about the knowledge base required to prescribe specific procedures for the practicum. In some cases this concern has to do with the amount of information about practicum that is available, and whether, given more information, it would be possible to derive defensible prescriptions for the organization of practicum. For example, Samson, Borger, Weinstein, and Walberg (1983) came to the following conclusion in their analysis of 38 studies related to the influence of field experiences on the attitudes of education students:

Insufficient information is available about aspects of the subjects and settings, the quality and character of the field experience, the field experience location and other important variables to recommend more specific policies than generally providing early teaching and related experiences in the first few years of college. (Samson et al., 1983, p. 11)

A similar concern was raised by Griffin, Barnes, Hughes, O'Neal, Defino, Edwards and Hukill (1983) in a comprehensive study of the student teaching experience. They concluded from their literature review that, "the current research derived knowledge base appears to be too limited to direct decisions and practices in clinical experiences for prospective teachers" (p. 4). Empirical work with 93 student teachers from two universities led these researchers to the following observation:

Awareness of policies, expectations, purposes and desirable practices was not widespread across participants in the student teaching experience. It was rare that university and school-based teacher educators agreed upon, or could even articulate, the policies and practices which were supposed to guide student teaching. (Griffin et al., 1983, p. 335)

Another kind of concern about the knowledge base on practicum experiences can be found in the literature. This concern has more to do with the type of information that has been collected than with its availability. For
instance, Zeichner (1984) presented a comprehensive meta-analysis of research into early field experiences and student teaching, based on Bronfenbrenner's (1976) conception of the "ecology of education." He argued that there was a need for researchers to attend to contextual features of the practicum by considering three basic elements of the "ecology of field experiences": (1) the structure and content of a field experience program, (2) the characteristics of placement sites, and (3) the relationships between education students and those with whom they interacted.

The particular quality of a field experience cannot be understood solely by its procedures (e.g., length), its organizational structure or even by the curricular intentions and plans of its designers... its influence on teacher development cannot be discerned from the examination of only isolated fragments of its ecology. It is hoped that research on field experiences will give more attention in the future to the complex and multidimensional nature of these experiences and that this ecological approach to the study of field experiences will stimulate discussion and debate over which particular curricular and contextual dimensions of programs will help us more closely realize our goals for teacher development. (Zeichner, 1984, p. 27)

Given the complexity of student teaching experiences, it is not surprising that many research results seem to be ambiguous and conflicting. Popkewitz, Tabachnick and Zeichner (1979), among others, have criticized the wide-spread use of research methodologies that, they say, ignore the quality of particular contexts. For example, Popkewitz et al. (1979) called for a methodology that views teacher education as a "constellation" of dynamic social events.

The events of professional preparation are not independent or freestanding, but are embedded in a social history and in relation to other contemporaneous events. While that embeddedness gives them some stability, dynamic social events are also characterized by their evanescent characters since they are in the process of continually becoming. (Popkewitz et al., 1979, p. 58)

Another example is provided in a recent review of 102 reports investigating Canadian teacher education, in which Wideen and Holborn (1986) reported that they found a "quantitative flavour in which questionnaires and
standardized measures were used to focus on variables isolated from their contexts" (p. 577).

The reductionist nature of the research under such paradigms and the focus on variables taken out of context are unlikely to improve our understanding to any great extent or lead to development of the theory we so critically need. Thus a first methodological priority in research into teacher education is a move toward a more liberal methodological approach. (Wideen & Holborn, 1986, p. 577)

While some teacher education researchers have called for a "more liberal" methodological approach to investigating early field experiences and practicum, there is nothing about "qualitative approaches" that is inherently superior to their "quantitative" counterparts, or vice versa. In the investigator's judgement, the expectation that progressive teacher education research rests on a particular methodological orientation is misguided. What the teacher education literature does indicate, however, is that there is a need for new ways of conceptualizing the practicum.

Certainly, understandings of the character of practicum are needed. This study seeks to conceptualize, and describe in context, qualitative characteristics of two science teaching practica. The study is framed as a conceptual and exploratory analysis of practicum events, the aim of which is to generate new understandings of a science teaching practicum.

Significance of the Study

One of the possibilities that Wideen and Holborn (1986) discuss as a means of conceptualizing practicum phenomena advocates a position presented by Russell (1984), in which he argued for a model of teacher education based on "reflective" action by teachers. Russell's position has at the centre of teacher education the development of prospective teachers' "reflections" on their own teaching. He examined Schön's (1983) perspective in terms of the significance
of reflection in learning a practice, and considered its implications for teacher education.

Finally, we have the beginnings of a way out of what I regard as one of the basic dilemmas of teacher education--the relationship between the university, where teachers are "trained" and "retrained," and the schools, where most teachers practice their profession. If the daily work of teachers and student teachers can be removed from its present inferior status, we may find that much of our current work in teacher education can be redirected to exploring the meanings of "reflection-in-action" and, in time, coming to understand the stages through which a teacher moves in learning to reflect-in-action. (Russell, 1984, p. 28)

Not only is there a need to develop new understandings of the character of practicum, there is also a need to conceptualize the nature of reflective thinking that occurs in the context of teacher education. There is a plethora of teacher education literature dealing with the term reflection, due in part to the popularity of Schön's work. Yet this literature contains numerous meanings associated with the sloganized term, and nowhere have Schön's ideas about reflection and the education of reflective practitioners been thoroughly worked through in the context of teacher education. Nor has the concept of reflection been associated systematically with any particular view of subject matter, as this study sets about. This investigator embraces Russell's position by conceptualizing and investigating empirically the character of a reflective practicum in constructivist science teaching. The intent of this study is to show the central importance of the concept of reflection to science teaching, and hence to a science teaching practicum.

Data Gathering and Analysis

As noted above, two teachers were selected for this study from a research group at the University of British Columbia. Both teachers hold a Masters Degree in science education from U.B.C., and both have investigated the use of a constructivist perspective on science teaching to guide and examine their own
practice (at the time of this study, the teachers were in their third year of involvement with the aforementioned research project). In this document the teachers are referred to with the pseudonyms "Colin" and "Gary." Colin was in his nineteenth year of teaching, while Gary was a veteran of twelve years in science teaching at the time of the study.

Two student teachers enrolled in a B.Ed. program in science education at U.B.C. were invited to take part in the study. Their anonymity has been maintained in this document by using the pseudonyms, "Rosie" and "Kevin." Rosie and Kevin were selected for the study on the basis of recommendations made by their science methods instructor (who also served as their University Practicum Advisor), and in consultation with the Director of Student Teaching. They accepted the invitation to take part in the study quite enthusiastically.

Rosie and Kevin both held a Bachelor Degree in Engineering Science and had decided to major in secondary school physics teaching during their B.Ed. program. However, data for this study were restricted to the "general science" courses to which they were assigned in practicum. (The term "general science" means that there is no one main disciplinary focus in the course; in British Columbia the separation of science courses into disciplines, e.g., chemistry, physics, etc., takes place at the Grade Eleven level.) Colin and Gary were asked to select one class in which Rosie and Kevin, respectively, would be observed and recorded by the investigator. In Rosie's practicum, this was a Grade 10 class of twenty-seven pupils; in Kevin's practicum, it was a Grade 9 class of twenty-eight pupils. In both cases, the investigator spent at least two periods in the classroom as a "visitor" so that Rosie, Kevin, and the science pupils could get to know him a little bit before data collection began.

Case studies of the practicum experiences of Rosie and Kevin were developed as the practicum proceeded. The practicum was 12 weeks in
duration, beginning in January, 1988. Data sources included video and audio recordings of lessons taught by the student teachers and supervising teachers, as well as their supervisory conferences. In addition, video and audio recordings were made of interviews with small groups of science pupils that were conducted by the supervising teachers, the student teachers, or, in one case, the investigator.

Over the duration of the practicum, the investigator divided his time equally between the two schools. He alternated from one school to the other, typically spending one week at a time with Colin and Rosie, the following week with Gary and Kevin, etc. In total, the database for the study consists of 16 lessons, 14 supervisory conferences, and four interviews with science pupils. Video tapes of the lessons and the interviews with pupils were discussed by the participants in the supervisory conferences. These video tapes served as a record of what happened during the lessons, and were used in conjunction with transcriptions made from the audio tapes. Usually, the conference about a lesson would be held one or two days following the lesson, after the transcription of the lesson had been prepared. While the investigator was preparing the transcriptions, the student teacher and, in few cases, the supervising teacher would take the video tape of the lesson home to view.

Audio recordings of the supervisory conferences were transcribed and analysed by the investigator. These transcriptions comprised the primary data base for developing a set of criteria for identifying characteristics of a reflective practicum—patterns of reflective behaviour that can be seen in the supervisory dialogue. In other words, these data were used to examine research question 2 in light of the conceptual analysis derived in answering research question 1.
Methodological Stance

Data were analysed in light of the Schönean-constructivist framework of a science teaching practicum for patterns of the participants' reflective behaviour, together with the conditions about which reflection seemed to occur. The research methodology can be thought of in terms of two parts: (1) the supportable characteristics of a reflective practicum in constructivist science teaching were derived theoretically from a critical analysis of the literature pertaining to constructivism, as well as Schön's general formulation of reflection; and (2) the context of a science teaching practicum was added in order to see what the theoretically derived characteristics (from part 1) looked like in reality—these theoretically derived characteristics of a reflective practicum were thus refined and enriched by the analysis of the data. The patterns emerging from the analysis resulted from an "interdependence" between the conceptual framework developed in response to research question 1, and the data collected from the two case studies. The general methodological stance drew from conceptual analysis to examine practice, though it is recognized that the conceptual framework itself was illuminated by the practice context.

A Preview of the Study

This study is exploratory in nature. It requires the development of a scheme for detecting characteristics of supervisory practice in science teacher education that lead to the reflective analysis of teaching by student teachers. It seeks to determine how contextually related experiences and practices might be seen to influence these characteristics. The challenge for the study is that it should provide greater understanding of the dynamic processes of the practicum in teacher education, and, particularly, the significant role of reflection in learning how to teach science.
This document is presented in seven chapters. The present introductory chapter is followed by a review of teacher education literature pertaining to the concept of reflection. Chapter Three elaborates on the research methodology of the study, outlining the research stance as well as the research activities of the investigator. Chapter Four deals with "constructivism" as a general perspective about teaching and reviews an empirical literature pertaining to "children's science." In addition, Chapter Four develops a diagramatic representation of a "constructivist view of science teaching," illustrating this view by analysing a dialogue among Grade Nine students who were interviewed after studying a unit about heat. Chapter Four concludes with a discussion and illustration of the central importance of reflection in science teaching.

Chapter Five develops an analytic scheme for identifying the broad characteristics of a reflective practicum in constructivist science teaching, beginning with a critical review of Schönh's analysis of reflective practice. The chapter includes a review of various critiques of Schönh's writings, and determines which of Schönh's ideas stand up to analysis. Chapter Six extends the analytic scheme developed in Chapter Five, by analysing verbatim transcriptions of lessons and supervisory conferences taken from the case studies of Rosie and Kevin's practica. The result is a clue structure for indentifying Schon's three coaching models--"follow me," "joint experimentation," and "hall of mirrors." Finally, the main argument of the thesis is reviewed in Chapter Seven, and the conclusions, limitations, and implications of the study are discussed.
Chapter 2

A REVIEW OF RESEARCH ON REFLECTION IN TEACHER EDUCATION

In educational literature of the nineteen eighties the word "reflection" has been used extensively. One only has to look briefly into current research articles pertinent to almost any domain of teacher education to find the term used in a variety of different ways. The purposes of this chapter are to develop an historical context for thinking about reflection, to characterize the meanings that current educational researchers seem to attach to the term, and to establish the uniqueness of the problem that the present study addresses.

First, an historical perspective on the development of thought about reflection in this century is presented. The chapter begins with a short review of two of John Dewey's books in order that Schön's intellectual "roots" can be established for the discussion of his work in subsequent chapters of this document. Further, there is a brief review of Harold Rugg's work, as well as that of H. Gordon Hullfish and Philip Smith, representing thought in the nineteen forties through to the sixties, respectively, that followed the tradition of Dewey.

The second part of this chapter is devoted to characterizing various conceptions of reflection that can be discerned from current teacher education literature. In particular, the review focusses on papers presented at two international meetings of educators held in 1987: the Houston Conference on Reflective Inquiry, sponsored by the U.S. Office of Educational Research and Improvement, and the annual meeting of the American Educational Research Association. A scheme for categorizing and representing various conceptions of reflection used by researchers is developed along the way.
An Historical Perspective

It is no coincidence that Dewey's work provides a useful beginning point for talking about reflection, for establishing Schön's intellectual roots, and, ultimately, for understanding the development of thought about reflective teaching in this century. It is convenient to start with one of the underlying themes running throughout discourse about reflection: the possibility of a relationship between a "science" of education and the "art" of teaching.

In his book, The Sources of a Science of Education, Dewey (1929) asked two questions: Is there a science of education? and, Can there be a science of education? The very phrasing of these questions raises many difficulties because of the variety of senses in which we use the word science. As Dewey noted, the term might suggest to some minds activities such as mathematics and physics, excluding the ordinary activities belonging to disciplines such as biology or psychology, for example, on the grounds that the latter are relatively descriptive, inexact, or lacking in rigorous methods of demonstration. Dewey rephrased the questions as follows:

What are the ways by means of which the function of education in all its branches and phases . . . can be conducted with systematic increase of intelligent control and understanding? What are the materials on which we may--and should--draw in order that educational activities may become in less degree products of routine tradition, accident and transitory accidental influences? (Dewey, 1929, p. 9)

Dewey viewed disciplines such as psychology, sociology, or biology, as sources of a science of education. According to Dewey, these sources provided "intellectual instrumentalities" for widening our range of attention to particular detail in practice situations; they were not to be viewed as sources of "rules of practice." Dewey was well aware of the hazardous intellectual connections from theory, to middleman interpreter, to practitioner, to instruction itself. He preferred to think that educational science "had no content of its own," that is,
there were no "recipes" for the art of teaching. Rather, Dewey chose to think of educational science residing in the inquiries of the practitioner.

It is often assumed, in effect if not in words, that classroom teachers have not themselves the training which will enable them to give effective intelligent cooperation [to disciplined inquiry in practice]. The objection proves too much, so much so that it is almost fatal to the idea of a workable scientific content in education. For these teachers are the ones through whom the results of scientific findings finally reach students. They are the channels through which the consequences of educational theory come into the lives of those at school. I suspect that if these teachers are mainly channels of reception and transmission, the conclusions of science will be badly deflected and distorted before they get into the minds of pupils. I am inclined to believe that this state of affairs is a chief cause for the tendency . . . to convert scientific findings into recipes to be followed. The human desire to be an "authority" and to control the activities of others does not, alas, disappear when a man becomes a scientist. (Dewey, 1929, p. 47)

Dewey thought that a discipline of education can never exceed the quality of the parent disciplines from which it must draw. Further, there were the limitations of translation, interpretation and communication, leading to his conclusion that "the final reality of educational science is not found in books, nor in experimental laboratories, nor in the classrooms where it is taught, but in the minds of those engaged in directing educational activities" (Dewey, 1929, p. 32).

Thus, Dewey's ideal was that the "intellectual tools" afforded by science could be used, if they were to be used at all, by teachers as inquirers, investigators in their own practices. To provide the substantive features of this type of "inquiry in practice," Dewey turned to the notion of reflection.

In his 1933 book titled, How We Think, Dewey distinguished reflective thinking from other forms of thought by two characteristics: (1) a state of doubt or hesitation in which thinking originates in the practice situation and, (2) an act of inquiring to find material that will resolve the doubt and dispose of the perplexity. These features were seen by Dewey to arise in the course of practice much like the occasional fork in the path we travel:
In the suspense of uncertainty, we metaphorically climb a tree, we try to find some standpoint from which we may survey additional facts and, getting a more commanding view of the situation, decide how the facts stand related to one another. . . . Thinking is not a case of spontaneous combustion; it does not occur just on "general principles." There is something that occasions or evokes it. (Dewey, 1933, pp. 14-15)

As reflection arises from a directly experienced situation that puzzles or surprised us, so it leads to a situation that is clear, coherent, settled, harmonious. However, the conclusion arrived at is tentative and subject to further examination by

the active, persistent, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the further conclusions to which it tends . . . . once begun, it includes a conscious and voluntary effort to establish belief upon a firm basis of evidence and rationality. (Dewey, 1933, p. 9)

Dewey noted that the data at hand in a situation of doubt or perplexity cannot, in any straightforward manner, supply the solution to the practical problem at hand; they can only suggest it. "What, then," he asked, "are the sources of the suggestion?"

Clearly, past experience and a fund of relevant knowledge at one's command. If the person has had some acquaintance with similar situations, if he has dealt with material of the same sort before, suggestions more or less apt and helpful will arise. But unless there has been some analogous experience, confusion remains mere confusion. (Dewey, 1933, pp. 15-16)

In summary, Dewey put forth the idea that the basic intellectual content for teacher education should come from established sciences outside of the family of educational research disciplines. He pointed to physiology, biology, psychology and sociology as likely sources, and proposed that "conceptualists" would translate these to primary concepts for educational application. But the application would take the form of "reflective inquiry," with the tools of the intellect enabling the broadening of perception, rather than "recipe-style" direction of practice. Grounded in the practitioner's knowledge and experience, reflective thinking originates in directly experienced situations that are puzzling
and uncertain, and proceeds through observation, inference, suggestion, intellectualization, and the formulation, reasoning, and testing of hypotheses in the practice situation.

Dewey's view led to the "Foundations of Education" movement, beginning in the nineteen thirties and forties, in which the focus of teacher education was on the fundamental ideas, concepts, scholarship, and theory essential for understanding and improving practice and techniques. Harold Rugg's (1947) book, *Foundations for American Education*, was in agreement with Dewey about the nature of the outside sources for the intellectual content of educational thought, though Rugg included aesthetics and morality as sources from which a science might be developed. The foundations of education shifted from the established sciences to the psychological, social, aesthetic, and ethical foundations of civilization and education. And, like Dewey, Rugg looked on education as a subject of study that would naturally emerge from the intellectual interest and concern of practitioners. For Rugg, this meant that teacher education institutions would have to move away from their traditional "trade school temper" and, by means of the foundations program, become centres for the synthesis of information and creative expression pertinent to the invention of a sound theory of society, of the nature, behaviour, and expression of man.

Rugg operationalized his "foundations" view much like Dewey's "reflective thinking," though Rugg used the name "problem solving":

First: We recognize the problem; we confront it directly. Dewey calls it the "felt-difficulty" . . . the "forked-road situation." It has become a problem--impulsive, habitual behavior will no longer serve. We confront alternatives; hence we must choose. The situation is tense; we must confront it directly in head-on-collision.

Second: We meet it in a rapid process of calling up suggestions . . . ways of behaving . . . from our past experience. In imagination we bring to consciousness things that we might do, find factors that may fit the situation.
Third: We try them, comparing and appraising, rejecting one or other.

Fourth: We accept one and act upon it.

In this analysis the process has been broken down into a series of enumerated steps. Actually they are fairly concurrent, flashing up in swift succession, shot through with the mood, feeling, and emotion of the moment, tangled with meanings, desires, or fears. (Rugg, 1947, pp. 114-115)

Though Rugg departed from Dewey in terms of the "foundations," or "sources" on which educational thought should rest, his portrayal of reflective thinking remained largely unchanged. In the main, reflection was seen as a conscious, deliberative move away from habitual ways of responding to situations in practice.

Hullfish and Smith (1961) offered a somewhat different analysis of reflection in their book titled, Reflective Thinking: The Method of Education, though they began with a similar set of "phases" for reflective activity:

1. The presence (and recognition) of a problem situation.
2. Clarification of the problem.
3. Hypotheses formed, tested, and modified. Hypotheses, which may also be called hunches, guesses, ideas, or insights, lead us to cast predictive statements in the form of "if-then" propositions. Such hypothetical propositions account for or explain the facts already observed or stumbled upon and, in addition, serve to direct further observation or fact finding.
4. Action taken on the basis of the best-supported hypothesis. (Hullfish & Smith, 1961, pp. 43-44)

Hullfish and Smith began to speak of reflection as the "reconstruction of experience"—somewhat different from Dewey's notion of reflection as "practical deliberation" in a situation. The idea of "reconstruction" entails more than broadening one's range of attention to particular detail; as the term "reconstruction" connotes, it is a complete restructuring of the situation, precipitated by a "new development" (comparable to Dewey's "uncertainty," or "perplexity").
This new development doesn't fit the basic structure of patterns already accepted. Consequently, there is a feeling of incongruency. This feeling frequently occurs with immediacy, apart from reflection, and thus may precede by a considerable time any intellectualization of the difficulty. This lack of coherence, of course, makes further reflective activity necessary; and, at this point, the patterns of knowledge held must be reconstructed if the new experience is to be accounted for. (Hullfish & Smith, 1961, p. 54)

The view of reflection as the reconstruction of experience is enabled, in part, by the idea that knowledge is never a matter of direct disclosure. According to this view, we can never "know" the world as it is independent of our ways of "apprehending it." As Hullfish and Smith noted,

One does not see and hear, in terms of pure sentiency, the glowing embers and the crackling and hissing of green wood as it burns in the fireplace. At the very most, the raw data of experience are light and heat of a certain intensity and sound of a particular kind. The overtones of memory and imagination convert or interpret the light and sound into glowing embers and crackling fire. The latter, not the raw data of sentiency, are the objects of knowing. Knowledge is always mediated (interpreted sensa), never immediate (raw sensa). . . . When it is said that knowledge is mediated, never immediate, reference is thus made to the necessary role of meaning or cues. . . . So long as activity goes forward in terms of recognition . . . there is no need to exercise conscious control over it. No problems are confronted. But when recognition fails, even momentarily, the situation calls forth feelings of uncertainty and doubt. This is the ground from which reflective activity (often designated in a more limited and limiting way as "problem solving") arises. And it is a ground, we should note, which intermingles emotional involvement and reflective activity. Thinking is not the work of an impersonal logical machine. (Hullfish & Smith, 1961, pp. 34-35)

The development of the concept of reflection in this century has focussed on the matter of breaking habitual ways of recognizing and dealing with situations. Thought about reflection has grown out of the problematic distinction between "science" and "art," "theory" and "practice," the "general" and the "particular." Having their roots in Dewey's classic works, modern ideas about reflective thinking have moved to the notion that reflection involves the reconstruction of experience. In the course of this development, the familiar theory/practice dichotomy has been relaxed for the most part. Yet, as the following survey of current research on reflection in teacher education suggests,
there remain numerous conceptions of reflection, and the word may have become more of a slogan than a well articulated position about the nature of inquiry in practice.

**Review of Current Literature**

Scholars who have written about the idea of reflection in teacher education and reviewed the related empirical research have drawn upon disparate conceptions of reflection, and in few cases do articles include any explication of the conception being proposed. However, particular conceptions of reflection can be discerned from this literature and classified loosely into three categories, varying in their degree of conformity to the traditional concept of reflection developed by Dewey, among others. The conceptions of reflection that can be identified in this literature are the following: reflection as mediating action, reflection as deliberating among competing views of teaching, and reflection as reconstructing experience. These categories will be described and illustrated as the review proceeds. While this review is not exhaustive, it serves to represent the variety of thinking and empirical work that has been carried out and reported in a vast literature. Nor is the scheme itself to be taken as definitive—that is, it is one among many possibilities for sorting and making sense of this literature. This scheme is utilized here to represent the work that has been conducted in the area of reflection in teacher education. It has been derived inductively from the literature reviewed for the purposes of locating this dissertation in a class of studies that conceive of reflection as reconstructing experience in action situations. At the same time, this review of related literature demonstrates the uniqueness of the problem that this study addresses.
Reflection as Mediating Action

This first group of papers and journal articles are presented to represent a conception of reflection as being a process that leads to thoughtful, mediated action, usually involving the implementation of research findings and theoretical formulations of education into practice.

Simmons and Sparks (1987) argued for the need of a new model of teacher supervision and evaluation that identifies reflection as an explicit goal of teacher education programs. In their attempt to synthesize literature on teacher reflection, they identified several premises on which teacher education experiences could be designed to enhance reflection. Beginning with the notion that reflection requires the ability to bridge the gap existing between theory and practice, they noted that the act of reflection involves the integrated use of teacher pedagogical knowledge, attitudes and beliefs, and performance; it involves the cyclical and holistic use of the teacher's cognitive processes including problem setting, factor naming, analysis, synthesis and evaluative decision-making leading to action and, in turn, further reflection. They noted that while the teacher's own individual levels of metacognition and "professional self-efficacy" contribute to both the quality and quantity of reflection occurring, teacher education programs could nurture and enhance teacher reflection through appropriate research methodologies and instructional strategies. Such strategies would include cognitive mapping, oral and written "think aloud" exercises, journaling, and structured interviewing about events observed and enacted. But while Simmons and Sparks charged that the goals of teacher reflection and the evaluative criteria for assessing these goals were typically "fuzzy concepts, somewhat inaccurate in content, and implicitly held in teacher educators' minds" (Simmons & Sparks, 1987, p. 2), they included little, if any, in their paper to clarify what they take to be reflection, beyond the idea that it mediates action,
and that it is somehow characterized by the infusion of theory into practice.

Denton and Peters (1987) reported on a 15-month intern program designed to prepare "thinking, analytic teachers who apply the principles of pedagogy to resolve practical problems in the classroom" (Denton & Peters, 1987, p. 2). Typically, according to Denton and Peters, teaching candidates are trained to apply algorithms for planning and implementing instructional plans because of the limited time afforded to pedagogical studies. Their intern program was conceived to foster the development of "students of teaching"; that is, teaching candidates who would "exhibit self-monitoring behaviors, be willing to address problem solving challenges and [who] would readily form hypotheses regarding issues associated with teaching and learning" (Denton & Peters, 1987, p. 1). The teaching candidates were said to exhibit reflective thinking when they interpreted classroom events using organizational theory, school context, teacher effectiveness literature and teacher decision making literature.

Only when the interns viewed video taped episodes of their own teaching in class and were challenged to explain what they were doing in terms of the instructional and management principles encountered during summer school . . . was there any discussion which could be described as "reflective." (Denton & Peters, 1987, p. 4)

By "reflection," Denton and Peters seem to mean a conscious, deliberate effort to bring educational theory and research to bear on practice.

A similar conception of reflection was espoused by Hall (1987) in the context of researching intervention behaviours of school principals. His work focussed on examining the role and style of principals in facilitating teachers' implementation of educational innovations. Hall's criteria for detecting "reflective principals" included their tendency to analyse and monitor their acts and deeds, and project the next steps they would take. Again, the notion of reflection being put forth is one of mediating action.
Volker (1987) produced a paper outlining methods for fostering education students' "reflective analyses" of research on teaching, in which he portrayed a similar conception of reflection--one which involves analysing the nature of teaching behaviours, the conditions under which they are performed, and the consequences of carrying them out. As the following quote illustrates, Volker's conception of reflection is likely more limited to a technical mechanism of incorporating research findings into practice.

[Teaching] consists of psychomotor skills such as questioning techniques or classroom management. Reflective analysis might be expected to accompany the practice of the skills, as teachers premeditate their actions, consider alternatives, and incorporate a knowledge base from research. . . . Competency-based teacher education programs, the use of microteaching, and the lengthening of student teaching may appear to have an action orientation, dealing more with practice than with theory. But by reflecting on the reasons for the action, and using underlying research findings to do so, students avoid an "if-then" point of view; if this is your objective, then use that technique. Together, reflection and action can avert simple classical conditioning in which students are trained to act in predetermined ways as they choose a specific behavior to fit a standard classroom contingency. (Volker, 1987, pp. 1-2)

Cruickshank (1985) wrote about reflective teaching as a form of laboratory experience similar to micro-teaching, suitable for use not only in preservice teacher education, but also in inservice training, graduate education, and research on teaching.

Reflective Teaching is used in introductory courses in preservice teacher education to introduce novices to the role of the teacher and to the tasks of teaching. It is used even more generally in methods course, which focus on helping prospective teachers to gain knowledge of theory and then to learn to apply this knowledge under controlled, laboratory conditions. For example, educational psychologists teach novice teachers about motivation or human learning and then use Reflective Teaching to see how well students can apply this knowledge in the act of teaching. (Cruickshank, 1985, p. 705)

This form of "laboratory exercise" begins with a micro-teaching session, after which small groups of peers observe and discuss the video-taped lessons, the performance of the teachers, and pupil learning. Drawing from Cruickshank's work, Peters (1985) investigated the outcomes of the Reflective Teaching model,
and claimed, among other things, that, "students will identify [a] greater number and wider variety of variables present during the act of teaching" (Peters, 1985, p. 61).

In summary, these papers and journal articles expose a conception of reflection as thoughtfulness about action—contemplation that leads to conscious, deliberate moves, usually taken to "apply" research findings or educational theory in practice. The use of the word "apply" is significant here, for after reading these papers one gets an impression that their authors subscribe to an associated view of educational theory and research findings about teaching that is technical, perhaps even mechanistic, in character. It is a view of knowledge with which one could expect the knower to direct, or control practice. Among all of the papers presented in this chapter, this group is perhaps the most optimistic about the ease with which reflection can be accomplished in teacher education, although in some cases the author would mention technical limitations such as the lack of time afforded in the program to reading research journals. Perhaps another distinguishing feature of papers that fall into this category is their tendency to view "new information" as coming primarily from "authorities" who publish in journals—never from the practice situation itself.

Reflection as Deliberating Among Competing Views of Teaching

A second group of papers presented at the Houston Conference proposed conceptions of reflection as deliberation and choice among competing versions of "good teaching." This deliberation entails a consideration of educational events in context and anticipation of the consequences following from different lines of action, taken from these competing versions of good teaching.

Valli and Tom (1987) proposed a set of criteria for a framework that would help prospective teachers bring knowledge to bear on practice,
particularly in terms of evaluating, or mediating, conflicting conceptions of the knowledge base required for competent teaching. They argued that an adequate knowledge base would necessarily comprise the content, forms, and sources of that knowledge; that it would be goal-oriented, drawing upon all relevant scholarly traditions in presenting competing views of teaching; and it would show the relationship between technical and normative knowledge. Such a framework, they proposed, would encourage reflective practice. Reflectivity about school practices then, according to Valli and Tom, implies thoughtful deliberation and wise judgement in using "craft and research knowledge":

This can be done by comparing competing visions of good teaching and by emphasizing that questions of values and goals cannot be adjudicated through empirical knowledge, that there is a fundamental difference between "what is" and "what ought to be." . . . the primary problem within teacher education is not applying knowledge to practice but, rather, embedding a professional mode of thinking within practice. (Valli & Tom, 1987, p. 5)

Moore, Mintz and Biermann (1987) put forth a conception of reflection in teaching that emphasizes the personal definition of a problem to be solved and taking the responsibility for the consequences of its solution. According to these authors, reflective teachers must first know how to process information, how to make decisions given alternative views and lines of action, and believe that they can make ethical choices for their classrooms. Accordingly, their vision of a reflective teacher education program,

requires that all contributing areas of academic and professional study and clinical experience provide for the practice of inquiry skills. . . . The teacher who practices disciplined inquiry . . . is a skilled decision-maker capable of choosing, modelling and applying alternative instructional strategies selected from differing traditions in teaching. (Moore et al., 1987, p. 5)

Galluzzo (1987) defined reflection as the ability of the practitioner to look back upon an event and consider it in relationship to its context; in this manner he or she achieves an accurate portrayal of the event.
The reflective person is one who encounters a situation, studies it in its context, and acts upon this situation in a manner that is consistent with foundational knowledge for teaching. In using the context of an event one can examine the true meaning of that event. (Galluzzo, 1987, p. 1)

Similarly, Valli and Taylor (1987) argued that reflection involves thinking critically and contextually about practices and goals of education for the purposes of a more consciously driven mode of professional activity, as contrasted with action based on habit, tradition, or impulse. They proposed a model of inquiry in teacher education that encourages a continuous dialectical relationship between common-sense notions and theories/research derived from all modes of scholarly inquiry. Specific activities in this model allow prospective teachers to explore multiple ways of viewing problems, consider why these problems are worthy of being addressed, and examine the role of the teacher, the learner, the subject matter, and the context in both the problem and potential solutions. Students are asked to consider how their thinking changed during the process, and to relate their approach to their educational philosophies and beliefs about the design of instruction, the control of learning environments, and the purposes of schooling.

Papers that have been placed in this category are distinguished by their attention to the context of educational events, and the idea that in reflecting about particular events and situations, one deliberates among competing views of teaching and examines each in light of the consequences of the action it entails. Thus, there is a tendency for authors of these papers to subscribe to a relativistic, or eclectic view of knowledge. The test of this knowledge is in the benefit of its consequences for students. The associated expectation placed on the reflective practitioner is to **inform** practice through deliberating upon competing views of good teaching.
Reflection as Reconstructing Experience

The third broad category of literature on reflection in teacher education includes conceptions of reflection as the reorganization, or reconstruction of experience that is primarily aimed at one of the following: (1) new understandings of action situations, (2) new understandings of self-as-teacher by examining the cultural milieu of teaching, or (3) new understandings of taken-for-granted assumptions about teaching by using analytical techniques from a "critical-theoretical" tradition. Each of these three areas is dealt with below in a sub-category under the general heading of the third broad category--reflection as reconstructing experience.

Reconstructing Action Situations. The common feature of articles in this sub-category is the degree to which the act of problem setting in an action situation is made problematic itself. Here, reflection is seen as a mechanism by which a teacher can either attend to features of the situation that were previously ignored, or assign new significance to features that were identified previously. In either case, reflection involves recasting situations in light of clarifying questions, reconsidering the assumptions on which previous understandings of the situation were based, and beginning to rethink the range of potential responses that are available to the teacher.

Pugach and Johnson (1987) argued that the goal of developing reflective teachers may be enhanced substantially by drawing on existing research in the field of metacognition. Their "Peer Collaboration Project" incorporated the components of a metacognitive training model, utilizing a four-step dialogue. In the first step, teachers engage in explicit self-questioning and responding to clarify the situation of concern.

The purpose of this step is to identify a range of factors that might be contributing to the situation or that might be appropriate in developing
response or solution. The process of self-questioning also provides the opportunity for teachers to access potentially relevant but formerly inert information. Examples of question formats might include: "What other activities are taking place when the problem occurs?" or "In what areas is the student able to do well?" or "How is the teacher responding to the situation now?". . . . Clarification, then, broadens how teachers conceptualize teaching-learning situations and sources of difficulty that may arise. (Pugach & Johnson, 1987, p. 6)

In the second step, the collaborating teachers summarize the situation following a specified format. The summary includes the identification of a pattern of student action, the teacher's affective response to the situation, and the identification of relevant variables under the teacher's control.

Summarization provides teachers with the opportunity to recast the situation in light of the clarifying questions, to recognize that things are not always as they first appear, to reconsider the assumptions upon which their previous understandings of the situation were based, and to begin to rethink the range of potential responses based upon relevant classroom and teacher variables. (Pugach & Johnson, 1987, p. 7)

The third step of the process requires the teachers to develop at least three response patterns for use in the classroom, to predict the outcomes of each, and to select one for actual implementation. This step is designed to promote flexibility and creativity in developing responses, to practice thinking through plans before their implementation, and to develop the understanding that one's first idea may not be one's best. The final step in Peer Collaboration requires the development of a plan to evaluate the response or intervention selected for implementation.

Preliminary results of the Peer Collaboration Project indicate that "teachers are able to move from global, non-analytic and often judgemental descriptions of classroom situations to summaries characterized by greater understanding of the situation in terms of the student's view and the teacher's range of choices in responding" (Pugach & Johnson, 1987, p. 10).

In the context of describing the "Teachers for Rural Alaska" (TRA) program at the University of Alaska, Noordhoff and Kleinfeld (1987) put forth
ideas about reflection in teacher education that draw upon the notion that reflection involves the reconstruction of experience. To begin, they noted that preparation for "effective teaching" means much more than learning to apply technical, research-based knowledge to the classroom, much more than becoming a subject matter specialist, knowledgeable about the conceptual foundations of a subject and able to represent subject matter flexibly. According to Noordhoff and Kleinfeld, teachers must be prepared both cognitively and emotionally to understand and deal with complex and ambiguous educational situations through the use of a reflective heuristic. However, in their judgement, common sense connotations of the term reflection make it vague and ambiguous, meaning little more to students in their program than "thinking about" the business of teaching.

Noordhoff and Kleinfeld described in their paper what they take to be a more useful heuristic than "reflection," or "reflective inquiry"--the concept of "design":

What skillful and experienced practitioners actually do in attempting to change present situations into more desirable future ones is to impose a design on a problematic situation, work out the implications of this design, judge the fit between their design and what they want to accomplish, and then revise their design. (Noordhoff & Kleinfeld, 1987, p. 12)

According to these researchers, the "language of design has become the operational definition of reflective inquiry" (p. 13), encompassing five activities: naming and framing situational problems, appraising the worth of goals, sorting images and selecting strategies, spinning out consequences, and re-viewing and revising. Following the work of Schön (1983, 1987), Noordhoff and Kleinfeld emphasize the central importance of problem setting and reframing in constructing representations of practice situations.

We want to foster in our TRA students the disposition and capacity to think of the mismatches between expectations and experience as riches to be mined, not disappointments. We want to explore the idea that
prospective teachers might be "surprised" into re-framing problems and, thereby, increase their flexibility in problem setting from different perspectives. . . . we are further attempting to assist our students in 1.) coming to know the perspectives they bring to bear in understanding contexts and 2.) coming to see more features of situations, and thus, alternate ways of framing contexts. (Noordhoff & Kleinfeld, 1987, p. 19)

Practitioners recursively reframe and revise designs. In order to do so, they must be able to "see" the situation with "new eyes" and reshape their definition of the problem. (p. 24)

Yinger (1987) presented comparable ideas about reflection, drawing from Dewey's notion that reflective thought proceeds by a hypothesis testing mode of problem solving. In following Dewey's thinking, Yinger proposed that reflection is the means by which the success of planning and action are tracked and assessed, providing the link between past action and future action by supplying information about operations and outcomes. However, Yinger proposed that the "rational" model implied by the "language of planning, implementation and reflection" is restrictive in the sense of the immediacy demanded of practitioners to respond to situations in action. Yinger put forth the "language of improvisation and contemplation."

The intelligence of practice is based on an ability to fit tool and method to specific needs and problems with specific people and places. The essence of practice is work-in-place. The conversation of practice is made possible by improvisation and contemplation. . . . Improvisation is skilled performance that is especially sensitive to moment and place. The impromptu, responsive nature has generated connotations of being unprepared and off guard. The reality of improvisational performance is quite different. It is highly patterned, intelligently composed, and quite complex to learn. (Yinger, 1987, pp. 13-15)

Yinger generated several propositions about improvisation that are roughly parallel to Noordhoff and Kleinfeld's (1987) notion of design. In particular, Yinger seems to be referring to the construction and reconstruction of elements of practice situations:

Skillful improvisation is based on the incorporation of patterns and pathways in a way that is continually responsive to changing exigencies and purposes. Patterns are continually being monitored for "fit" and "workability." Changes in the situation lead to an extension (embellishment) of current patterns or, if extreme, to the activation of new patterns that
fit better. Particular mistakes are usually handled by "constructive repair" (Garfinkle, 1967) from within the performance. A "bad note" or a "false start" is picked up, built upon, and woven into the melody until it becomes a part of the theme and no longer out of place. (Yinger, 1987, p. 16)

Ross (1987) reviewed a considerable body of literature about reflection in teacher education and attempted to develop a synthesis of the various meanings that the term reflection holds for different scholars. Her synthesis included meanings that ranged from views of reflection as a general way of thinking about educational matters, to the ability to make rational choices and to assume responsibility for one's choices. In that sense, certain statements made in Ross's paper would fall into the first two categories of this review: reflection as mediating action, and reflection as deliberating among competing views of teaching. However, Ross eventually moved to what she refers to as "an expanded view" of reflection which focusses on aspects of problem setting and reframing (Schön, 1983, 1987). The information stimulating reflection, according to this view, is, in part, the "back talk" of the situation.

In discussing monitoring the effects of actions, Schön (1983) repeatedly stressed the importance of attending to the intended and unintended effects of one's action by "listening while the situation talks back." . . . Schön's discussion is important . . . in helping us to remember that the focus must be on assessing one's effects by attending to the situation as opposed to applying predetermined criteria to evaluate the effects of one's actions. (Ross, 1987, p. 6)

Ross also explored the area of cognitive psychology in an effort to develop an operational framework for the definition of reflective judgement. One aspect of her review that is particularly interesting is her reference to Kitchener (1977) and King (1977), who proposed a seven-step model of the development of reflective judgement. According to this model, the reflective judgement of adults becomes increasingly complex over time by progressing through seven stages,

which vary on such criteria as one's view of the nature of knowledge, one's view of the nature and use of convincing evidence, one's willingness to accept responsibility for one's decisions, and one's openness to new
evidence once a decision has been made. In early stages, the world is viewed as simple, knowledge is seen as absolute, and authorities are seen as the sources of all knowledge. In the middle stages (3 and 4) one is able to acknowledge that differences in viewpoint exist, and knowledge is viewed as relative with varying positions seen as equally right or equally wrong. One develops a beginning ability to evaluate and interpret evidence but unsupported personal belief (whim) is used as frequently as evidence in making decisions. During later stages (5 through 7) one sees knowledge as contextually based, recognizes that an integrated perspective can be evaluated as more or less likely to be true, and develops the ability to integrate evidence into a coherent point of view. Additionally, by stage 7, one is able to make objective judgements based on reasoning and evidence and is able to modify decisions and judgements based on new evidence if necessary. (Ross, 1987, p. 8)

Ross noted that many of the empirical studies that drew upon this conceptualization concluded that the majority of college students fall between stages 2 and 4 of the scheme. Appropriately, she mused over whether teacher educators are being realistic in calling for strategies designed to foster reflectivity among students of education.

As the culmination of her review Ross proposed three broad categories of strategies that may be important to faculty who wish to teach education students to be more reflective. These are based upon the following general commitments: an awareness that knowledge is socially constructed, the role and importance of modelling reflection, and the value of providing guided practice in reflective thinking and teaching.

In similar studies, Grimmett (1984) and Grimmett and Crehan (1987) found that the potential reflective process embedded within instructional supervision only became realized when both supervisor and teacher were capable of functioning conceptually at a "highly complex level." Where one or the other supervision participants' conceptual level was low, reflection and the derivation of insight through the framing and reframing of classroom events rarely occurred. By analysing the content of conference dialogues, Grimmett explored the questioning strategies that accompanied instances of teacher reflection and insight. Four types of questions were identified as stimulating the reflective
process: so-called "open-ended," "apprising," "focussing," and "task-orienting" questions. The criterion on which Grimmett judged conference dialogue as reflective was whether it brought new insights to bear on the teacher's lesson.

The underlying knowledge base of teachers is the focus of studies carried out at Stanford into how student teachers reconstruct their "pedagogical content knowledge" (Shulman, 1987). Richert's (in progress) study attempts to map out a variety of methods for developing among teachers the disposition and analytical knowledge required to engage in reflection, which is defined as,

what a teacher does when he or she looks back at the teaching and learning that has occurred, and reconstructs, reenacts, and/or recaptures the events, the emotions, and the accomplishments. It is that set of processes through which a professional learns from experience. It can be done alone or in concert, with the help of recording devices or solely through memory. . . . Central to this process will be a review of the teaching in comparison to the ends that were sought. (Shulman, 1987, p. 132)

The reconstruction of practice situations that occurred in student teachers is the focus of a case study by LaBoskey and Wilson (1987), which investigated the potential effects that becoming a "researcher in the practice context" (Schön, 1983, p. 63) had on the student teachers' development of reflection. Student teachers were presented with opportunities to do case study research on themselves as teachers. They were asked to spend a period of three weeks looking carefully at their teaching in order to identify and explore an issue of interest. To aid in the process, they kept a journal and were observed and "debriefed" by their supervisor and a peer. The cases produced by the student teachers fell into three general categories: descriptive, problem-setting, and problem-solving. Twenty-three of the 45 cases analysed had problem setting characteristics--they identified, scrutinized and clarified a problem that the student teachers had encountered, and were essentially exemplars of student teachers' "framing and reframing the problematic situation."
Two types of cases fell into the problem setting category. One type consisted of the framing of a problem around "self-in-a-situation," while the other type consisted of framing a problem around a concept, such as humour, continuity, risk-taking, flexibility, and accountability. In the latter cases, LaBoskey and Wilson argued that the student teachers had focussed their discussion on an issue emanating from their practice, and in doing so, they had begun to frame a problem in such a way that precipitated new insights.

The sort of experience that Laboskey and Wilson recounted on the part of the student teachers in their program seems to be what Garman (1986) had in mind when she wrote about reflection as the heart of clinical supervision, indeed the primary process of inquiry within the teacher's practice. Garman discussed techniques designed to encourage practitioners to understand their own frames of reference through "theorizing in the context of practice"—understanding and depicting meaningful human action for the purpose of guiding practice. A procedural representation of the process included (1) involvement in a scenario, (2) a record of the scenario, (3) making sense of the records, (4) making an "educational construal"—an abbreviated, manageable (conceptual) form of events and meanings for future use; an insight, a concept, principle, significant incident, portrait, or conceptual framework could be construed, the essence of reality being construed from one form to another, and (5) a confirmation—a way to determine whether the construal has meaning to other practitioners.

As noted in the introduction to this section, articles included in this category are common in their focus on problem setting in an action situation. Reflection is seen as a means by which teachers attend to features of situations that were previously ignored, or begin to assign new significance to identified features, recasting situations in light of clarifying questions, reconsidering the
assumptions on which previous understandings of the situation were based, and rethinking the range of potential responses that are available. In short, these authors subscribe to a view of reflection as a general means by which the knower appreciates, or apprehends practice situations.

Reconstructing Self-as-Teacher. Literature reviewed in this sub-category presents conceptions of reflection as the reconstruction of experience, the focus of which is the individual's view either of himself or herself as a teacher. Much of the work is phenomenological or hermeneutic in orientation, aimed at providing interpretive accounts of the way teachers structure their knowledge and "worlds of practice," often taking into account the complex socio-cultural milieu in which they operate.

Drawing extensively on the German and Dutch scholars whose work has come to be known as Geisteswissenschaftliche Pedagogik (Human Science Pedagogy), Van Manen (1987) articulated a conception of pedagogy that includes as one of its principles, the principle of "self-reflection of life." He described three ways in which the idea of life's reflectivity has been used in hermeneutic pedagogy: self-reflection as an ontological phenomenon, self-reflection as a life philosophy, and self-reflection as a methodological concept. As an ontological phenomenon, self-reflection is concerned with ways of being in the world. It is concerned with the nature of being human and how we come to understand our own existence; human beings acquire an understanding of themselves through self-reflection, and it is only through life that one can understand life. In using the concepts of self-reflection as a life philosophy and self-reflection as a methodology, Van Manen seeks to gain insights into the actions of teachers, not only as educators but also as adults who share a lived reality with children. To be self-reflective in this sense is to be attentive to the relationship between
theory and action, or praxis:

Methodologically speaking, pedagogy's task is to practise an active self-reflection (a thoughtfulness) on the reality in which adults live with children in order to be able to offer those adults (parents, teachers, and other educators) insights or understandings that minister to their pedagogical praxis. Theory has thus a peculiar relation to praxis. First there is the praxis of life, then there is the theoretical or reflective moment. Theory formation does not function as a solution to the problems of praxis--theory cannot be the source of praxis. Rather praxis is the source of theory--theory always reflects on (holds a mirror to) praxis in order to provide praxis with a more thoughtful understanding of its own active suppositions. (Van Manen, 1987, p. 13)

Hultgren (1987a) drew, in part, upon Van Manen's work in a phenomenological study of student teachers' experiences. Her interest in this work was to understand what it means to be a student teacher, what it is like to experience student teaching. The following excerpt from Hultgren's course syllabus is telling of the conception of reflection in which she sought to engage her students:

Reflective teaching will be the instructional goal and process used to help engage you in reflection about teaching and learning which you experience in this course and in the natural laboratory of your student teaching setting. ... From the point of view of this course, the quality of that experience can be enhanced when you as student teachers, personally and autonomously, come to understand your own lifeworlds and how these are connected with taking action in the everyday lifeworld of teaching. This will necessarily entail a personal search, a search for meaning wherein a central question for you will be--What, in my existence as a person, in my relations with others, in my work as a teacher, is of real concern to me and what sense can I make of it? (Hultgren, 1987a, pp. 37-38)

Elbaz (1981, 1983) presented a case study of one teacher's practical knowledge in which she described the influences that setting and personal history had on this teacher's practice. She argued that although decisions are unique to their circumstances, the means by which they are achieved involves a process of deliberation involving the use of "rules of practice," "practical principles," and "images." Elbaz's concept of image is of interest here, as this is the focus for the constructed representation of self-as-teacher:
On this level, the teacher's feelings, values, needs, and beliefs combine as she formulates brief metaphoric statements of how teaching should be and marshals experience, theoretical knowledge, and school folklore to give substance to these images. Images serve to guide the teacher's thinking and to organize knowledge in the relevant area. The image is generally imbued with a judgement of value and constitutes a guide to the intuitive realization of the teacher's purposes. (Elbaz, 1981, p. 61)

Following the work of Elbaz, Connelly and Clandinin (1984) and Clandinin (1987) put forth the notion of "narrative unity" as a means by which teachers' constructions of self-as-teacher could be examined.

Narrative unity is a continuum within a person's experience which renders life experiences meaningful through the unity they achieve for the person. What we mean by unity is the union in a particular person in a particular time and place of all that he has been and undergone in the past and of the tradition which helped to shape him. (Connelly & Clandinin, 1984, p. 147)

Using Schön's (1983) conceptions of the role of metaphor and "seeing-as" in practical action, Munby (1987a, 1987b) examined metaphors in teachers' language of practice and the role that metaphors may play in teachers' professional actions. Through his analyses of teachers' linguistic patterns, he investigated the way in which teachers construct their professional realities, documenting how metaphors evolve through time and influence the development of practical knowledge. Munby commented thus on some of the assumptions that appear to separate and confound the realities of actual practice and the realities of teacher education programs:

As the study moves forward, we are increasingly aware of the extent to which we are involved in trying to document and analyze developments in professional knowledge that have been masked or obscured by the assumptions that dominate existing teacher education programs. These assumptions cover a broad range, from believing that propositional knowledge can be applied directly to practice, to believing that the value of practice teaching lies in unreflective practice—a practice that is unmediated by language. We expect "metaphor" to become a powerful concept in the process of identifying assumptions that we may be quite unaware of. (Munby, 1987a, p. 9)

A similar theoretical focus guided the work of Russell (1987) in his examination of teachers' views of the relationship between theory and practice.
Interested in the ways that teachers' perspectives on their work were reconstructed over time, Russell interviewed 15 teachers with varying teaching experience. He noted a disparity between the way in which experienced, and inexperienced teachers viewed theory and practice.

The picture that emerges [from the data] suggests that learning to teach is not a two-step process of (1) learning theory and (2) putting theory into practice. Yet our culture in general and our universities in particular use the phrase "theory into practice" so easily and freely that it would be surprising if those electing programs of teacher education did not see their own learning as a two-step process. (Russell, 1987, p. 9)

In summary, the main idea put forth by the authors who have been grouped into this sub-category is that experience, including one's past and present teaching practices and one's personal biography, is shaped by reflection. Reflection, in turn, is the process by which a teacher structures and restructures personal, practical knowledge.

Reconstructing Taken-for-Granted Assumptions about Teaching. This final category of literature on reflection in teacher education consists of scholarly works that put forth conceptions of reflection as reconstructing taken-for-granted assumptions about teaching. Reflection, according to this literature, is a means by which critical theory (Habermas, 1973) can be practised with an emancipatory interest—that is, it allows a practitioner to articulate, and ultimately to address, the social, political, and cultural conditions that frustrate and constrain self-understanding. Critical reflection, then, begins with such questions as, "To what ends, and in whose interest is knowledge being used?"

Drawing upon the critical social theory of Habermas, the early Van Manen (1977) argued that within the notion of self-reflection there can be different levels of reflectivity. These levels of reflectivity correspond to three forms of knowledge and their associated "cognitive interests" that Habermas distinguished
among: the empirical-analytic, the hermeneutic-phenomenological, and the critical-theoretical. The empirical-analytic level of reflectivity is concerned with ends-means questions and the relationships between theory and practice. At the hermeneutic-phenomenological level, reflective concerns focus on the nature of lived experience and understanding the life-worlds of those with which one interacts. Van Manen distinguished these two levels from the critical-theoretical level thus:

Critical theory utilizes a method of reflectivity differing from those of the empirical-analytic and the hermeneutic-phenomenological paradigms in that it employs an emancipatory concept of truth. Truth is recognized in the deliberative rationality of formulating norms, roles, and knowledge about possible ways of life undistorted by repressive forms of authority, privilege and the vested interests of exploitation. Truth as social wisdom acquires the meaning of justice, the possibility for happiness, and the undistorted life forms in the practical art of living. (Van Manen, 1977, p. 222)

Smyth (1986) and Carr and Kemmis (1983) have been major proponents of the view of reflection that draws on a critical-theoretical perspective. These researchers draw explicitly from Habermas and Van Manen with the notion that critical reflection,

endorses the self-reflective stance of the "practical" in explicating the aims and values of adopted moral positions in education and schooling. But it goes further. What is unique about critical reflection is its concern about the way in which educational goals and practices become systematically and ideologically distorted by structural forces and constraints at work in educational settings. (Smyth, 1986, p. 18)

There has been considerable empirical research conducted in the critical reflection paradigm. Drawing upon Van Manen's "levels of reflectivity," Goodman (1986) developed a social studies methods course that taught students to develop and implement curricula from a critical perspective. An early field experience program that took place in conjunction with this course was designed to help methods students to become reflective, empowered teachers, the intention being to engage them in reflection at the second and third levels.
In choosing a topic for study, students were asked to reflect upon their own interests and upon what knowledge was worth exploring with the pupils in their practicum sites. They were asked not only to consider skills and talents necessary for adulthood (e.g., reading, writing, speaking) but also topics that would enrich children's lives. As representative examples the following units were developed... (a) "Super views of the news"—a critical examination of our mass media and the role it plays in our society (grade 6); (b) "The fifties: a decade of fun and fear"—a study of what life was like in America during the 1950s with particular reference to the forms of entertainment, McCarthyism and the civil rights movement (grade 5); and (c) "Human beings: what are we?"—an exploration of the physical, emotional and intellectual aspects of being human both as an individual and as part of a community (grade 1). (Goodman, 1986, p. 114)

Ross and Hannay (1986) also argued in favour of adopting a critical-reflective stance in preservice social studies teacher education. They advocated the cooperation among teacher educators, institutions, and classroom teachers in integrating the ideal of critical thinking and reflective inquiry into the everyday world of teaching and teacher education.

Preservice students must be encouraged to reflect on the knowledge and skills overtly and covertly perpetuated through such taken-for-granted facets of everyday school life as textbooks, school organization, student tasks, or interaction patterns. (Ross & Hannay, 1986, p. 12)

Cinnamond and Zimpher (1987) put forth a conception of reflection that pays particular attention to the issue of socialization of teachers. Their notion is that reflection is embedded in social processes and, as such, is a function of particular communities. While reflective thinking is seen to occur when taken-for-granted assumptions and beliefs inherent in particular social communities have been questioned, it is not to be thought of, according to these authors, as a separate action to be used instrumentally.

[Reflection] can not be a skill taught for use in certain instances, but is an ongoing process of the every day life world that needs to be emphasized explicitly through dialogue. (Cinnamond & Zimpher, 1987, p. 14)

Accordingly, Cinnamond and Zimpher call for a view of reflection in teacher education that focusses on dialogue with all the social groups in the school as a part of the reflective process, rather than the idea that reflection be limited to
the "individuated student teacher" (Cinnamond & Zimpher, 1987, p. 16).

Other researchers, such as Parsons (1983) and Kitchener (1983), have argued for the importance of fostering critical-reflective skills among school children and conceiving of curriculum as a dynamic, enabling process that would provide the means to personal liberation and individual development, largely through the reexamination of current assumptions.

Literature on teacher reflection included in this third broad category has included conceptions of reflection as the reconstruction of experience, that is, a process by which a practitioner achieves a "new view" of practice. This conception of reflection has an associated view of knowledge as being individually or socially constructed. Drawing from a repertoire of constructed concepts and principles, reflection is seen as a means by which a practitioner appreciates, or apprehends practice.

In order to account for some disparity in the theoretical and empirical work that has been done in this third broad category, three sub-categories were derived. In the first sub-category the focus of reflection is on the action situation itself--reflection is seen as the reconstruction of action situations, allowing a practitioner either to attend to features of a situation that were previously ignored, or to assign new significance to features of the situation that were identified previously. The second sub-category, included work that has been conducted around the idea that reflection involves reconstructing the self-as-teacher, much of the work being phenomenological or hermeneutic in orientation, aimed at providing interpretive accounts of the way teachers structure their knowledge and "worlds of practice." The third sub-category included literature that has put forth ideas about reflection as reconstructing taken-for-granted assumptions about teaching. In this latter group, authors have advocated "critical reflectivity," the focus of which is on power structures of
society and the organization of social life; reflection is seen as a means to develop understanding of the socio-structural constraints in which teachers teach and students learn.

Summary

Current literature related to "reflection" in teacher education has been presented in three broad categories that correspond to three distinct conceptions of reflection on teaching: (1) conceptions of reflection as mediating action, (2) reflection as deliberating among competing views of teaching, and (3) reflection as reconstructing experience. The conception of reflection as mediating action has an associated technical view of knowledge about teaching, and writings espousing this view tended to present reflection as a means by which research on teaching could be "applied" to practice in a technical, instrumental fashion; the reflective practitioner, according to this conception of reflection, is someone who directs, or controls practice.

Papers presenting a conception of reflection as deliberating among competing views of teaching (group two) tended to outline the importance of considering events in context, anticipating the consequences of actions that follow from the competing versions of good teaching. In most cases, though not all, papers in this second category imparted a view of knowledge that is relativistic, or eclectic in character; the reflective practitioner, in this sense, is someone who informs practice.

Literature classified in the third group included works that put forth varieties of the conception of reflection as reconstructing experience, the end of which is the identification of a new possibility for action. In brief, according to papers in this third category, reflection involves recasting situations in light of clarifying questions, puzzles, or surprises, reconsidering the
assumptions on which previous understandings of the situation were based, and rethinking the range of responses that are available. In many cases, this literature drew explicitly on a social constructivist view of knowledge; reflection is seen as a means by which a practitioner appreciates, or apprehends practice.

The purpose of this chapter has been to review a literature that pertains to the idea of "reflection" in teacher education. Specifically, the intent has been three-fold: (1) to provide an historical perspective of the development of the concept of reflection; (2) to present a representative sample of the variety of current thinking in the field; and (2) to locate the present study within a body of theoretical and empirical work that conceives of reflection as the reconstruction of experience in action situations (category 3a). Much of the work presented in this section drew from Schön's (1983) theoretical formulation of reflective practice, but nowhere have his ideas regarding a "reflective practicum" (Schön, 1987) been applied to the context of teacher education. Nor has Schön's notion of reflection been thoroughly applied in the investigation of science teaching.

The present study aims to show the potential utility of Schön's conception of reflection as the reconstruction of experience in action situations for examining supervisory practice in a practicum in science teaching. The following chapter discusses the research methodology that has been engaged in order to bring this about.
Chapter 3

RESEARCH METHODOLOGY

Shulman (1986) pointed out that the knowledge produced through the inquiries of educational researchers is a "function of the kinds of questions asked, problems posed, and issues framed" (p. 3). In turn, the conduct of researchers is influenced substantially by their conceptions about proper questions, methods, techniques, and forms of explanation. The interpretation and evaluation of the results of any research study, therefore, require some appreciation of the conceptual and methodological approaches taken in framing the problem and conducting the research.

As outlined in Chapter One, the research problem of this study is to conceptualize and investigate empirically the elements of a reflective practicum in constructivist science teaching. In response to a general concern expressed in the teacher education literature about the knowledge base required to prescribe specific procedures for practicum, the problem was framed as a conceptual and exploratory analysis of the character of practicum, the aim of which is to generate new understandings of practicum events in the context of science teaching. Chapter One also included a brief discussion of the methodological stance taken in this study as one drawing from conceptual analysis to examine science teaching practice and practicum.

The purpose of this chapter is to discuss in general terms the research methodology used in this study and the reasons for its use. The chapter includes two sections, the first of which focusses on the "research stance" that has been taken in the study. The second section presents a detailed account of the investigator's research activities.
Research Stance

On the nature of educational research, Soltis (1984) argued that pedagogy, as a basic and universal human activity, "requires empirical, interpretive, and normative approaches for its proper study . . ." (p. 6). He went on to ask,

But how should it be studied? No doubt pedagogy is a human activity in the world that has effects on individuals in that world. As such, it can and should be studied empirically, its causal and correlational regularities charted, and its successes and failures measured. But our experiences of teaching and learning are not all of pushes and pulls, causal or correlational as important as that is; they are also filled with meaning and meaningfulness for both teachers and learners. (Emphasis added, Soltis, 1984, p. 7)

Because pedagogy is an intersubjectively shared activity with meaning, Soltis argued that it is possible to have, "more or less successful philosophical analyses of its generic features, of the different meanings of the terms we use to talk about it, and of the conditions that signal its occurrence" (Soltis, 1984, p. 7). Talk of the intersubjective understanding of concepts related to pedagogy does not, according to Soltis, preclude the use of a rational and public mode of inquiry,

that can be considered to be objective in the sense that we are examining a publicly constructed concept and that we appeal to the evidence of its accepted common usage to make our claim public and challengeable . . . . First there is the intersubjectively shared meaning of the concept of pedagogy that I view to be objectively studied via philosophical analysis, and then there are the actual meanings offered and the understandings acquired in the pedagogical event itself. (Soltis, 1984, p. 7)

The research stance taken in this study is succinctly summarized in Soltis's argument. First, the study draws on critical, conceptual analyses of (1) a view of knowledge known as "constructivism," and (2) a view of professional thinking and education in professional schools encapsulated in a rather specific use of the term "reflection." These are regarded as systematic theoretical perspectives from disciplined work that are plausibly linked to important science education phenomena. The first task for the study is to show what is defensible about
these theoretical perspectives and how their combination in an "analytic scheme" is useful for regarding science teaching practicum. The analytic scheme, then, is a set of categories representing a systematic perspective that is both warranted theoretically and practically relevant.

The second task for the study involves the application of the analytic scheme to "the pedagogical event itself" by examining verbatim transcriptions of lessons and supervisory dialogue taken from the practicum setting. The task requires that the theoretically derived analytic scheme be "translated" to the context of science teaching practicum by developing a "clue structure," or set of criteria for identifying instances of events. The test of both analytic scheme and clue structure, then, is a matter of successful detection of instances which fit the categories of the scheme. In the process of testing, the clue structure is refined and enriched for "goodness of fit" to the pedagogical event.

The research design outlined above was put forth by Roberts and Russell (1975) as an alternative to the quantitative research approaches that predominated science education at the time. The approach is specifically designed, Roberts and Russell pointed out, to produce systematically examined phenomena of science education practice with a three-fold payoff:

The research findings are significant in their own right, they establish a solidly conceptualized basis for empirical studies, and they constitute a useful tool for science teacher education. The major point to be emphasized is that the significance of what is accomplished in this approach to science education research depends upon the relevance to practice of the theoretical perspective developed from whatever source. (Roberts & Russell, 1975, p. 115)

The Roberts and Russell research design is particularly appropriate for achieving the objectives of the present study. The broad goal of the study is to generate concepts and understandings of a unique form of science teaching practicum, and to identify these elements of a "reflective practicum" in the
handling of student teachers by two practitioners of constructivism in science teaching. To that end, an analytic scheme and "clue structure" are developed for detecting and analysing the logical features of such a practicum. The theoretical basis for asserting that a reflective practicum in constructivist science teaching indeed has logical features is, of course, to be found in the theoretical perspectives selected as the sources of categories for the analytic scheme. The practical utility of the scheme has increased potential if it is shown to be capable of addressing the actual events and demands of science teaching practicum itself.

Identifying Events

The matter of identifying events that "fit" the categories of an analytic scheme warrants further consideration. Research of the kind utilized in this study is afflicted by a struggle to make something of "the data." These polymorphous bodies of stirring and shifting things that will eventually be said to have particular shapes and regularities--indeed, to count for something, to represent particular significances--seem at one glance to require identification, and, at another, fabrication.

Verbatim transcriptions of interviews and teaching episodes, gathered by the educational researcher are not meaningful data until they are seen in light of a conceptual framework; they do not speak for themselves, and yet they have the potential to stand for many things. In order to become meaningful, data must first be given conceptual shape and said to represent a pattern or fall into a category--to count as an instance of something else. A pattern could be a particular brand of behaviour, a unit of discourse that has characterizing features, a regularity of voice inflection, or any number of things. Similarly, a category could be anything from a socio-economic group to
an "apprising question"; from a philosophical position implicit in a teacher's behaviour, to a state of anxiety among students. It seems right to say that once a generic phenomenon becomes a datum, say a pattern or an "identified event," it must be said to belong to a class of things that count as something else—something with a particular cognitive significance.

Where do patterns come from? Do they arise from concepts or from the transcripts themselves? Put another way, are patterns "pre-conceived," or are they "emergent"? Surely, the answer must be neither. There is a danger in relying on one or the other as an ultimate source. In the case of relying too heavily on fixed, apriori associated conceptual frameworks, there is the danger of "seeing" in generic phenomena things that simply are not there, the danger of being charged with "reading into the data." On the other hand, without the guidance of a carefully articulated conceptual framework, or analytic scheme, as it is referred to in this study, there is the danger of waffling about among transcripts with the unwarranted expectation that what is "identifiable" is waiting there to be "discovered," or unwittingly believing, in the end, that the identified patterns were "really there" all along without acknowledging the role of a conceptual framework in their identification. Ultimately, both problems represent a form of rigidity that excludes the possibilities of learning something new and making it public, the two things that research is all about.

To account satisfactorily for the source of patterns and identifiable events that are sought in research of this type, we might think in terms of an interdependence—even a tension—that is played out between conceptualizations and generic phenomena of practice. Yet, this spirit of research is somehow lost in the language with which we describe it. We speak about "research findings," "uncovering understandings," or "identifying events," for instance. It may be more appropriate to speak about recognizing, that is, becoming cognizant of
them, although this term is not totally satisfactory either.

It may be helpful to say that the analytic scheme and clue structure resulting from analysis reside in the mind, enabling our apprehension and articulation of important features of educational events for specific educative purposes. That is, the patterns of events that we make of the world of teaching are embodied with value and our purpose to understand that world "in a new light," and, whether it is a part of our research program or not, to do something eventually with that understanding. In the end, the clue structure that emerges from transcript analysis must do just that: it must shed new light on significant problems of practice, and, at the same time, point out a direction of action in situations that are characterized by such problems. All of these components--significant problems of practice; their associated research problems, purposes, and questions; the analytic scheme derived from conceptual analysis; collection and analysis of transcripts; the clue structure that emerges from transcript analysis; as well as understandings and possibilities for action in the practice setting--are part and parcel of a coherent, mindful system, comparable to what Smith (1978) referred to as a "bounded system," which he used in discussing ethnographic research.

The coherence of this system is brought to bear on the justification of the validity of the clue structure, together with judgements about whether other members of the educational research community can "see" the events that the researcher has identified in the transcripts. In short, the clue structure must be valid in terms of its consistency with both the conceptual and the empirical end of the research study, as well as the normative claims that are made, or can be made, to follow from the research.
Research Activities

The research activities undertaken in the present study reflect the Roberts and Russell design. An account of these activities is set out here to provide an overview of the study and thus foreshadow the details of the next four chapters.

The Roberts and Russell design is predicated on identification of an important issue related to everyday science education practice. This study was initiated as a result of the investigator's involvement with science teacher education as a university methods instructor and practicum advisor over a period spanning six years. Further, the investigator has been involved with science education at the public school level as a teacher or researcher for the past ten years. The relevance of the two theoretical perspectives drawn upon for this study was intuitively obvious to the investigator at the time of its design, given his familiarity with problems associated with science teaching practice, as well as science teacher education. On one hand, a constructivist perspective on science teaching and learning was seen to be particularly illuminating in terms of conceptualizing some of the problems pupils encounter in learning science. On the other hand, Schön's analysis of reflection in professional practice and the education of "reflective practitioners" was seen to be a useful way of thinking about science teacher education, especially in terms of the dynamics of practicum. As discussed above, the challenge for the study is to show the significance, theoretically and practically, of the combined "Schônean-constructivist" perspective on science teaching practicum.

The first comment to be made on specific research activities has to do with the selection of the participants for the study. The investigator deliberately chose two teachers who were well familiar with a constructivist
perspective on teaching and learning science, and who were also familiar with educational research. The investigator had worked with both of these teachers as a researcher in their classrooms throughout the year preceding the present study, so they were well known by him, as he was by them. Moreover, both teachers were interested in the "dissemination" of a constructivist perspective to other science teachers, and both were keenly interested in the practicum experience. In short, the teachers were chosen as "ideal" candidates for the study. As mentioned in Chapter One, the two teachers are referred to in this document as "Colin" and "Gary."

The two student teachers who were invited to take part in the study were chosen with similar care. The criteria for their selection included: (1) a strong background in the subject matter of science; (2) an interest and aptitude for a constructivist perspective on teaching and learning, demonstrated in their science methods course; (3) an ability to listen carefully, with interest, in the course of informal conversations with the investigator and other education students in social gatherings; (4) prior experience with children in a leadership role; and (5) an enthusiastic outlook on the prospect of becoming a teacher. Both of the student teachers selected for the study met these criteria. They both held degrees in Engineering Science and showed an interest in a constructivist approach to science teaching; they were regarded by their methods instructor as top students. The investigator met Rosie at a social gathering for science education students in September, 1987, where he was impressed with her skill at conversing with fellow students. Although Kevin was not present for that event, the investigator was similarly impressed by his conversational skill when introduced to him two weeks later by Kevin's methods instructor as a potential candidate for the study. Rosie had worked in the past as a summer camp counsellor, while Kevin had been a youth leader in his
church, so both met the criterion of having previous experience leading groups of children. Finally, both Rosie and Kevin were very enthusiastic about their professional year in the Faculty of Education, as well as the prospect of taking part in this study.

An initial meeting with Rosie, Kevin, their methods instructor, the investigator and his supervisor was held in early October, 1987 during which the purposes of the study and the involvement of the participants were discussed. Rosie and Kevin were asked if they would mind some of their lessons and discussions with supervising teachers being video taped. Not only did they have no objections to this, but suggested that it might be worthwhile showing the tapes to other students in the program. Indeed, after the practicum had concluded in the following spring, Rosie and Kevin asked the investigator if they could use some of the video tapes for a presentation they were giving to their peers.

The reader will likely have the impression by now that the investigator attempted to establish optimal conditions for the study by his choice of participants. Indeed, this was done quite deliberately in order to achieve, as near as possible, an "ideal" practicum situation. Since the study was to be exploratory in nature, the investigator's idea was to find out what was possible in terms of a "reflective practicum," thus enabling its systematic examination.

With the cooperation of the Director of Student Teaching, Rosie and Kevin were assigned to the schools of Colin and Gary, respectively. They met with each other for the first time in November, on a day when Colin and Gary came to the university as guest speakers in the methods course. Though the practicum did not begin until mid-January, Rosie and Kevin spent a two-week period in December, just before Christmas break, observing lessons in their respective schools.
When practicum began, the investigator allowed a two-week period to elapse before he began visiting the two schools. The intent was to allow Rosie and Kevin to settle into the routines of their school and get to know their pupils, as well as experience the role of the teacher before the investigator began video taping their lessons. In early February the investigator started visiting the schools, spending at least one week at a time in each school, alternating weeks from one to the other. At first he would simply sit and watch lessons, without the video and audio recorders present, and without taking notes. He socialized with the pupils before and after class, as well as during laboratory activities in order to establish a relationship such that pupils would "trust" him, once he was behind the video camera. When this rapport was established, the investigator began video taping some of the lessons, usually one or two per week.

The same "gradual" approach was taken with regard to the investigator's presence for the supervisory conferences. At first, he simply sat in a corner and listened to the discussion between student teacher and supervising teacher. Once he felt his presence for these discussions was accepted as routine, he began video and audio recording them.

The following strategy evolved for "synchronizing" the recorded lessons with the supervisory conferences: the supervising teacher would make suggestions about which lessons would be worthwhile recording; the lesson would be recorded and the video tape given to either the student teacher or the supervising teacher for their independent viewing at home; the investigator would prepare a verbatim transcription of the lesson from the audio recording; and the transcription would be used for the supervisory conference, usually held one or two days after the lesson. Both supervising teacher and student teacher would generally have an opportunity to view at least part of the video tape before the
conference, and sometimes pertinent parts of the video tape would be selected by the supervising teacher for viewing during the conference.

As the study proceeded, the benefit of video taping became more apparent to the supervising teachers and they began to explore other avenues of its use. Colin used a video tape of his own teaching to "model" particular features of his practice for Rosie. On other occasions he requested that the investigator video tape groups of pupils working on various problems pertaining to electricity so that he and Rosie could later view and discuss their strategies for solving the problems and their conceptions of electric current. Similarly, Gary used a video tape of his own teaching that was made the previous year to discuss with Kevin some aspects of questioning techniques. A video tape of Kevin interviewing pupils about a test question pertaining to heat was made in order to explore pupils' conceptions of heat and temperature. The ways in which these video tapes were used in the practicum will become apparent in the remaining chapters, but the point to be made here is that the use of video tape, though originally conceived as a means of collecting the "investigator's data," soon became a source of data for the participants' inquiries as well.

Throughout the study, the investigator maintained a close rapport with the participants. His role in the practicum became one of "participant-observer," as he began to take part in planning various activities and discussing various events with the participants. Often, he would have long discussions with the participants on the telephone in the evenings. He would also discuss his research with them, pointing out the significance he "saw" in particular occurrences or strategies used by the supervising teachers. In a very strong sense, this study became one of so-called "collaborative action research," as the research agenda began to include the prerogatives of the participants themselves.
Summary

While this study took on some features of "participant-observation," or "action research," it is, nevertheless, mainly regarded in terms of the Roberts and Russell design as drawing from philosophical analysis to examine practice. The design requires that the researcher first develop an "analytic scheme," drawing from systematic theoretical perspectives of disciplined work that are plausibly linked to important science education phenomena. The analytic scheme developed for this study draws upon a "constructivist perspective on science teaching and learning," as well as Schön's theoretical formulation of a "reflective practicum" in the education of practitioners. The conceptual task for the study, then, is to show how these perspectives combine in a scheme that is both warranted theoretically and practically relevant to science teaching practicum.

The second task for the study involves the "application" of the analytic scheme to transcripts of science lessons and supervisory discussions. The purpose of this step is to develop a "clue structure," or set of criteria for identifying instances of events that fit the categories of the scheme. Through repeated "application" to the transcripts, the analytic scheme and clue structure become refined and enriched by the practice context; the test of both is a matter of successful detection of instances that fit the categories of the scheme.

This chapter has provided elaboration on the conceptual and methodological approaches taken in the study in order that the reader have some appreciation of these for interpreting and evaluating the results of this study. Next, Chapter Four begins with the development of the analytic scheme by examining a literature on constructivism.
Chapter 4

A CONSTRUCTIVIST VIEW
OF SCIENCE TEACHING

The purpose of this chapter is to put forth the main ideas of a perspective on teaching and learning known as constructivism. The intent is to demonstrate the utility of this constructivist perspective for conceptualizing science teaching events. Sections of the chapter focus on the specialized role of scientific language in experiencing phenomena according to particular conventions. Frequently, scientific language enables different "perceptions" than those perceptions enabled by "ordinary language." This difference in ways of perceiving phenomena is seen to be a crucial problem in science teaching. The purpose of this chapter is to develop a coherent view of science teaching that provides a useful way of thinking about problems of perception and cognition in science classrooms.

This "constructivist view of science teaching" is then illustrated by examining a dialogue of Grade Nine pupils who were interviewed after studying a unit about heat and temperature. The dialogue is examined in terms of two different uses of the term heat—one within the realm of ordinary language, the other within the domain of scientific language. It is argued that the pupils experienced difficulty in understanding the scientific use of the term heat, partly because of their ordinary use of the term in making sense of the phenomenon under consideration. Finally, the central role of "reflection" as the reconstruction of a natural phenomenon or a classroom event from a pupil's point of view is discussed.
Constructivism

Those who hold a constructivist orientation to teaching and learning believe that all understanding and all communication are a matter of interpretive construction on the part of the experiencing subject. As von Glasersfeld (in press) stated, a constructivist perspective can be summarized by two main principles:

[Constructivism] asserts two main principles whose application has far-reaching consequences for the study of cognitive development and learning as well as for the practice of teaching, psychotherapy, and interpersonal management in general. The two principles are: (1) knowledge is not passively received but actively built up by the cognizing subject; (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. To accept only the first principle is considered trivial Constructivism by those who accept both, because that principle has been known since Socrates and, without the help of the second, runs into all the perennial problems of Western epistemology. (Glasersfeld, in press, p. 1)

These two principles of constructivism require some analysis and illustration in order to understand what they are claiming. The first principle begins by stating that knowledge is not passively received. The following vignette is employed to unpack what this idea means.

A physics teacher began class one day by asking his students the question, "What was Newton's third law of motion?" Several hands shot eagerly into the air.

Beth was selected to give the answer—"The law of inertia," she replied.

"And what does the law of inertia say?" asked the teacher.

"An object in motion has a tendency to stay in motion unless acted upon by an opposite and unequal force," Beth elaborated.

"That's . . . the main idea," said the teacher, hesitating slightly. Then, he reached into his desk drawer and pulled out a small white object, which he waved high above his head for all to see.

"Here, I have an egg," he declared, "which behaves in a rather odd fashion." The class was silent as the demonstration began. He placed the egg on the counter top and spun it around with a snap of his fingers. As it turned, he put his palm on the egg to stop it, and immediately lifted his hand from the shell. The egg began to spin again, making three or
four turns before it came to rest.

The teacher looked up at the class and smiled. "Now, Beth, is this a raw egg, or is it hard-boiled?" he asked.

All too often, students are able to state the laws of science, yet they are unable to apply them in making sense of particular situations. In the example above, it would not be unfamiliar to find Beth confused as to whether the egg was raw or hard-boiled, in spite of the fact that the words she produced for the third law of motion could be "applied" to solve the problem. In effect, it is quite possible for an individual to be able to recite Newton's third law and not understand it or be able to apply it to novel situations. In other words, it seems that it is possible to be able to state something and not "know" it, or at least know how it might apply in a particular context.

This is likely what is meant by the phrase, "knowledge is not passively received." It could be suggested that Beth had "passively received" the law of inertia and could reproduce it on request. Yet, she might be unable to apply the law and deduce that the egg must be raw since its liquid interior kept spinning after the shell was stopped. But, as the vignette continues below, the matter is not at all this simple.

After a short pause, Beth said, "The egg is raw."

"Good," came the reply from the teacher, "and can you tell us why it's raw?"

"It didn't spin very fast when you snapped your fingers," Beth explained.

Beth focussed her attention on a different aspect of the demonstration--the initial letting-go of the egg. She noticed that it wobbled slightly as it slowly seemed to gain momentum. She "felt" the liquid interior by what she could "see" of the shell's behaviour. This feeling interacted with what she had experienced in her handling of eggs--holding them in her hand, cracking them open, balancing them, and so on. She "constructed" an image of
the liquid interior and an understanding of its behaviour long before she would ever produce an explanation invoking Newton's third law. In fact, to produce the explanation would involve further thinking, and, perhaps, an entirely different set of mental operations than those intuitive operations by which she so naturally "felt" that the egg was raw. In short, Beth's knowledge of the egg was constructed, not by "passive reception" from the teacher, but by an active and vivid interplay between her perception of the egg's motion and her experiential "feel" for eggs. In further support of this claim, consider the following conclusion to the vignette.

"So you're saying that the egg spun slowly," began the teacher.

"Yes, I guess the yolk was at rest to begin with, or, at least relatively motionless."

"Go on," said the teacher.

"Then when you spun the shell," Beth continued, "the yolk had to slowly pick up speed because it was rubbing against the inside of the shell. As the yolk picked up speed, the egg gained momentum, and its wobble evened out."

With that explanation, the teacher was quite happy, of course. It demonstrated, reasonably correctly, an application of the law of inertia to the phenomenon at hand. But it wasn't the one that the teacher had in mind to begin with. He expected the application of the law to take place in the context of the egg resuming its spin after the shell was stopped, the shell being set in motion again by the spinning liquid interior. In fact, the whole demonstration was set up to highlight that occurrence. Beth constructed her understanding of the demonstration in a very different way to that which the teacher initially had in mind.

The second principle of a constructivist perspective on teaching and learning states that the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality.
This means that we represent events in certain ways because we "put them together" in those ways. It may not be the case that a particular event will carry the same meaning for one person as it does for another. Individuals construct different representations of events because of the differences in their ways of thinking, the variation in their past experiences and ways of representing them, the differences in their particular interests and purposes, and so on. A student of biology will typically see an air bubble under the microscope "as a cell" because she has certain expectations surrounding her use of the word "cell." She knows that it has an inside and an outside, and there must be a definite wall that separates one from the other. For the student, these attributes hold true for the air bubble. She is mistaken only in the extent to which she does not know how to recognize the attributes of a cell according to the conventions of biology. True, her perceptions will increase in conformity within her growing experience in "doing" biology and talking about it with her teacher and fellow students. However, the "ontological reality" of "cell" for the biologist consists in conventional uses of concepts that form the language of biology, just as an air bubble can be recognized as a cell according to the conventions of ordinary usage of the word.

This means that we do not experience the world directly. A cell does not identify itself as a cell. Rather, a cell is a concept used to organize the experiential world. In biology there are particular reasons and purposes for using the term, and, until one appreciates these, one cannot make the required "perceptions" or interpretations of the "raw data of sense experience." Indeed, if one accepts a constructivist perspective, there is a very fuzzy border between "data" as distinct from the conceptual devices (concepts and their interconnecting theories and logic) that give rise to their identification. The familiar dichotomy between theory and fact becomes much more problematic to
the constructivist. To make a scientific perception is to use scientific language to interpret the experiential world according to convention.

Scientific knowledge is seen to be individually and socially constructed, tested against standards and criteria of judgement, which are also socially constructed. These constructions include concepts, principles, laws, theories, and models used in representing and explaining phenomena. In the context of science teaching, a central premise to this perspective is the notion that a learner continually constructs meaning of new information and events as a result of the interaction of that individual's prior knowledge and experiences with his or her current observations. As Magoon (1977) put it,

The constructivist perspective holds as a chief assumption about much complex behavior that the "subjects" being studied must at a minimum be considered knowing beings, and that this knowledge they possess has important consequences for how behavior or actions are interpreted. (Magoon, 1977, pp. 651-652)

Another premise in constructivist literature pertaining to science teaching is the idea that learners are "purposive" beings, that is, the locus of control over cognition and intelligent behaviour resides within the subjects themselves.

Much complex behavior like teaching and learning might best be understood as being constructed purposively by the subjects (both teachers and students) themselves, and cannot adequately be studied without accounting for meaning and purposes. (Magoon, 1977, p. 652)

Thus, a constructivist account of learning is concerned with the "intents, beliefs and emotions of individuals as well as their conceptualizations, and recognizes the influence that prior experience has on the way phenomena are perceived and interpreted" (Driver & Oldham, 1985, p. 2). As Osborne and Wittrock (1983) argue,

Considerable emphasis in research, curriculum design, and teaching at all levels needs to be placed on the nature and detail of children's views of the world and meanings for words used in science. Teaching needs to take more fully into account pupil perceptions and viewpoints and, where appropriate, to attempt to modify and build on, but certainly not ignore children's ideas. (Osborne & Wittrock, 1983, p. 492)
Traditionally, the role of the teacher has been to impart knowledge to students. In science teaching, where the subject matter consists in ways of representing and explaining natural phenomena, there is a long-standing ritual engaging students in the laboratory—a custom that endeavors to provide "first-hand" experience with these phenomena. In addition, natural phenomena are brought to the science classroom via textbooks, films, or accounts of out-of-school experiences. Thus, students gain access to something on which they are to hang that domain of our intellectual heritage called "science." In turn, the teacher uses the laboratory, a text, a film, or an account, to provide "scientific experience" with which he or she can impart scientific knowledge to the student. This rather simplistic view of science teaching is represented by Figure 1.

Figure 1. A Simplistic View of Science Teaching
Though this simplified model of teaching may sometimes exist in the ways in which we talk about science education, at least from a curricular point of view, there are several reasons why it cannot exist in practice. The first set of reasons has to do with what constitutes a "scientific experience," and the role of a specialized language in mediating such experience. The second set of reasons has to do with a more familiar type of experience for students, that of "ordinary experience," and the role of ordinary language in its mediation.

Language and Experience

In science, as is the case with other disciplines, there are rather well defined ways of ordering perceptions of natural phenomena. For a long time now, philosophers have argued that phenomena do not speak for themselves; information about the world is not simply "handed" to the knower. Rather, phenomena are apprehended, or taken from the world. As Charles Brauner put it,

Perception is not a matter of simply seeing what is out there much as a camera loaded with sensitive film will take a picture of anything in its field of focus. For the most part it is a matter of being directed to take notice of certain things and not others. (Brauner, 1987, p. 10)

Thus, we have the notion that perception itself is "theory-laden" (Hanson, 1958). In order to make a scientific perception, or to have a scientific experience, we depend upon public formulae that tell us two things: what to look for, and what significance to attach to it. These public formulae consist in the concepts, principles, models, purposes, and criteria for judging claims--all of which are inherent in scientific languages and theories. As Osborne, Bell and Gilbert put it,

In developing views of the world, scientists have found it necessary to develop a technical language where words have specific meanings and quantities have unambiguous definitions. . . . Unfortunately, many of the words used in science have everyday meanings which are subtly different from their scientific meaning, e.g., work, force, power, friction, energy,
animal and plant. This creates great problems for children learning about scientists' viewpoints. (Osborne, Bell & Gilbert, 1983, p. 3)

The role of scientific languages and theories in ordering experience is represented diagramatically by a two-way arrow between the teacher and the domain of natural phenomena; as depicted below in Figure 2.

![Diagram showing the role of language in mediating experience]

T - Teacher
S - Student
NP - Natural Phenomena

**Figure 2. The Role of Language in Mediating Experience**

Turning now to the student, there are similar things that can be said about the role of language in ordering perception and experience. Though the provision has been made for the student to gain access to the realm of natural phenomena under consideration in science, he or she, by definition, is not equipped to perceive these phenomena in a manner consistent with the scientific community. Rather, there is a much more extensive realm of experience with the natural world that the student has acquired through the use of ordinary language.
Like scientific language, ordinary language consists of concepts and rules which function as "public formulae for focussing attention on a limited number of characteristics of the entity under consideration" (Brauner, 1987, p. 13). Depending on the nature of those characteristics, "the concept puts the thing under consideration into a number of categories that limit what can be reasonably attributed to that entity" (Brauner, 1987, p. 13). By virtue of the fact that the student of science is a learner of a specialized language, the primary mode of perception and experience, at least initially, is that of ordinary language. Thus, the student's principal access to the realm of natural phenomena in the science class is that of ordinary experience, as represented in Figure 2 by the two-way arrow between the student and the domain of natural phenomena.

What becomes problematic for students and teachers alike is that ordinary perception and experience are very different in character from scientific perception and experience, even though the same words are often employed in both languages. In ordinary language, for example, it is quite appropriate to say, "I can feel the cold entering the kitchen from the refrigerator." Or, to use one of Brauner's favourite examples, "I see the sun going down over the horizon." It is a very different accomplishment to "perceive" thermal energy being exchanged in the room by the refrigerator, or the earth rotating easterly on its axis, thus hiding the sun from view, as a scientist could perceive these phenomena.

By attending to the different ways of experiencing natural phenomena that derive from these different language communities, we have some elucidation of the sorts of problems facing science educators, as documented in a rather extensive literature pertaining to "children's science." The following section presents the main ideas derived from this literature.
Children's Science

Over the past decade there has been a great deal of science education research dealing with the ways in which children make sense of natural phenomena (Driver & Erickson, 1983; Driver, Guesne & Tiberghien, 1985; Erickson, 1979; Gilbert & Watts, 1983; Osborne & Wittrock, 1983; Osborne & Freyberg, 1985). It is generally accepted that children form their own ideas about natural phenomena long before they arrive in the science classroom, and that their ideas may be quite different from currently accepted scientific views. The term "children's science" has evolved in the literature that investigates the ideas that children hold about natural phenomena (Osborne & Freyberg, 1985). Osborne, Bell and Gilbert (1983), who were, in part, responsible for coining the term children's science, noted its similarities to science and recognized that it is a natural and perfectly legitimate form of inquiry.

Children, like scientists, use similarities and differences to organize facts and phenomena and, in the observation of facts and phenomena, search for elements and relationships among elements, to build structures of relationships. In addition, children, like scientists, gather facts and build models to explain known facts and make predictions. (Osborne, Bell & Gilbert, 1983, p. 2)

However, Osborne et al. also recognized that some of the concepts and ideas inherent in children's science are quite different from those found in science:

This [children's science] knowledge may have a number of characteristics that differentiate it from notions found in formal science, and it can be amazingly tenacious and resistant to change. (Osborne, Bell & Gilbert, 1983, p. 1)

These "alternative conceptions," or "alternative frameworks," as they have been referred to by various researchers, may lead children to interpretations of science classroom events that are unintended by the teacher. Further, several researchers have documented that children's science often remains uninfluenced, or is influenced in unanticipated ways by science teaching (Erickson, 1983;

Not only does children's science differ from orthodox science in terms of its inherent concepts and ideas, it also very often differs in terms of its methods and standards of inquiry. As Osborne et al. argue,

Children bring to science lessons not only their views of the world and their meanings of words, but also their own methods of investigation, their own ideas about what constitutes adequate explanations, and their own outlook on science. All these profoundly influence learning, including the motivation to find out how and why things behave as they do. (Osborne, Bell & Gilbert, 1983, p. 5)

Pedagogical Principles

Three pedagogical principles follow from this perspective on science teaching (Erickson, 1988). If we subscribe to the notion that experience is mediated by language, and, further, that learning to "see" phenomena as a scientist does entails learning the specialized language of science, then we ought to be concerned with the concepts employed in that language and, particularly, the ideas that students have regarding these concepts. Thus, teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts, as these are derived through the use of ordinary language and manifest in the way students perceive and interpret phenomena. Second, these ideas must then be taken into account in the instructional program in order to provide a foundation for extending concepts, or constructing new concepts and the meanings derived from them. This means that, as teachers, we would listen very closely to what our students have to say about phenomena under consideration in our science courses. We would strive to understand what our students understand--to "see" phenomena as they see them. Third, students should be actively engaged in the learning situation and become more aware of the purposes that lie behind
The matter of teaching, if we take this perspective seriously, appears much more in the form of bi-directional communication, as depicted in Figure 3 by the two-way arrow between teacher and student. The term "Children's Science" is used in Figure 3 to refer to the knowledge and ways of dealing with experience that students "bring" to the classroom.

![Diagram of a "Constructivist" View of Science Teaching]

T - Teacher  
S - Student  
NP - Natural Phenomena

Figure 3. A "Constructivist" View of Science Teaching

The "constructivist" model of science teaching, represented as it is in Figure 3, is not unlike the "Trialogue Style" of teaching, proposed by Roberts and Silva (1968) in response to the inquiry teaching movement of the nineteen-sixties. Similarly, the triangular arrangement of the model is very much in accordance with what David Hawkins wrote about in his essay titled, I, Thou, and It (Hawkins, 1974, pp. 40-65). The point is that these ideas about science teaching are not entirely new; many researchers have focussed their thinking about science teaching on the various ways pupils and teachers perceive
and communicate about phenomena.

From a constructivist perspective, much learning in science involves children coming to hold new and more powerful ways of conceiving scientific events and concepts—ways that are consistent with our intellectual heritage of scientific inquiry. Yet, the learning of these "orthodox" scientific concepts may be extremely difficult, since "children's science" works so well for them in the realm of ordinary experience with natural phenomena. Indeed, to children, the "alternative frameworks" are likely orthodox scientific views. As a result, some educational theoreticians who have adopted a constructivist perspective have begun to speak of learning in terms of conceptual change, a general model of which is briefly presented in the following section.

Conceptual Change

Posner, Strike, Hewson and Gertzog (1982) and Hewson (1981) have proposed a general model of conceptual change, which formulates the conditions required for a particular set of ideas to be replaced by another more powerful one. According to this model, the conditions required for conceptual change to occur are the following: (1) there must be a dissatisfaction with existing conceptions, that is, the learner must have a store of anomalies or puzzles that cannot be resolved with his or her current conceptual repertoire; (2) a new conception must be "intelligible," that is, the learner must be able to make sense of it; (3) the new conception must be "plausible"—it must be reconcilable with other existing concepts, and it must be believable; and (4) the new conception must be "fruitful" in that it solves a previously unsolved problem, or it opens up new territory for inquiry.

Hewson and Hewson (1984) have suggested a number of teaching strategies that might be derived from the conceptual change model. The main categories
of strategies include "diagnosis"—the gathering of information about pupils' existing knowledge regarding a particular conception or phenomenon; "integration"—the linking of a new conception to existing conceptions when they are reconcilable; and "exchange"—the superseding of an existing conception with a new, irreconcilable conception. This latter strategy normally entails creating conflict among the pupil's existing conceptions, then resolving the conflict with the new conception. The immediate difficulty in attempting to create "conflict" among pupils' existing conceptions, though, is that they often do not regard evidence in the way teachers do.

But the main problem with the conceptual change model is that it may lead us to unwittingly devalue students' thinking; the model may direct us toward continually showing pupils where their thinking is wrong. In this investigator's opinion, the important issue is not so much that pupils' conceptions are "wrong" and need to be changed, but that pupils need to understand when it is appropriate to use a particular concept for a particular purpose in making a particular interpretation or perception of an event.

Another way of regarding learning in science is to put less emphasis on "conceptual change" and think more in terms of providing students with opportunities to broaden their experiential bases. If we were to organize curriculum around the variety of ways in which phenomena can be perceived, such as Brauner (1988) has advocated in a philosophy of education he named "Perceptivism," we might adopt a radically different way of regarding concept-acquisition in science: we might be concerned with the perceptions pupils make of events, the concepts used in making these perceptions, as well as what children understand of these concepts. Of course, it may well be that a pupil needs to learn a new conception of a term, in which case it may be appropriate to speak of a conceptual change required by the pupil. However,
the concept should not be thought of as though it could be separated from its use in context. Nor should a pupil's "new conception" be thought of as something that will be exchanged with the old. Rather, the new conception should be regarded as something that develops, perhaps only gradually, in the context of the pupil's increasing understanding of the uses of scientific language.

As noted in the introduction, the purposes of this chapter are to set forth the main ideas of constructivism and to show their importance for conceptualizing and researching science teaching. Before moving on to an empirical illustration of this constructivist view of science teaching, it will be well to summarize these ideas. As a perspective on teaching and learning, constructivism asserts two main principles: "(1) knowledge is not passively received, but actively built up by the cognizing subject; and (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (Glasersfeld, in press, p. 1). In the context of science education, these two principles have been discussed and illustrated to some extent, and three pedagogical principles have been derived: (1) teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts; (2) these ideas must then be taken into account in the instructional program in order to provide a foundation for extending concepts, or constructing new concepts and the meanings derived from them; and (3) as learners are seen to be "purposive beings," students should be actively engaged in the learning situation and should become more aware of the purposes that lie behind instruction.

The following section illustrates some of these ideas by examining a dialogue among Grade Nine pupils who were interviewed after studying a unit about heat. In particular, their dialogue shows that they have difficulty sorting
out two different concepts associated with the word heat: one concept belonging to the language of science, the other derived from ordinary language.

Illustrative Analysis

The following excerpts are taken from an interview between four pupils and Kevin (the student teacher) at the end of a unit dealing with heat. Much of the interview concerned the following question from the unit test:

If you have a large ice cube and a small ice cube in water, the small ice cube will melt first.

1. Are both ice cubes at the same temperature? Yes / No
2. Why do you think the small ice cube melts first?
3. Do you think both ice cubes need the same amount of heat to melt them? Explain your answer.

The four pupils were selected for an interview with Kevin on the basis of their answers to the "ice cubes" question (the selection criteria are explained below). All four pupils circled "Yes" for the first part of the question: they all thought the ice cubes were at the same temperature. Their answers to the second part of the question, "Why do you think the small ice cube melts first?" were the following. (Parenthetical comments were made in the students' original work; additions in the square brackets are made by the investigator as points of clarification.)

Kate: I think [the small ice cube] melts first because not as much heat is needed to melt it.

Mary: Because it has less mass and the latent heat of fusion says that water needs a certain amount of Joules of energy/kg to melt.

Lucy: Because there is less matter and therefore it will melt faster.
Sara: Probably because of its mass (in size). The bigger one is bigger and takes longer. The small is smaller and will not.

The answers to the third part of the question, "Do you think the ice cubes need the same amount of heat to melt them?" have been sorted below into two groups. Kate and Mary's answers were the following:

Kate: No, I don't think they [the ice cubes] need the same amount of heat because the larger cube has more room for heat to be transferred into it.

Mary: The larger ice cube needs more heat because it has a greater mass (latent heat of fusion).

Here, Kate and Mary are using a conception of heat that is more-or-less consistent with scientific language, "heat" being the amount of thermal energy transferred from one body to another. Thus, the larger ice cube requires more heat to melt because it has a greater mass than the small ice cube. Going further, we could infer from Kate's response that she conceives of heat as a substance that moves into the ice cube ("... the larger ice cube has more room for heat to be transferred into it.") If this inference were correct, Kate's conception of heat is similar to that proposed by "Caloric Theory" and, therefore would not be consistent with the "Kinetic Molecular Theory" that was taught in the unit, specifically about the idea that heat is molecular motion rather than an indetectable fluid. But regardless of the underlying theory of heat, both girls are using the term in the correct "scientific" sense by saying that the ice cubes require different amounts of heat to melt. In this respect, their thinking is consistent with either theory.

Turning to the responses given by Lucy and Sara to the third part of the question, we see a very different use of the term "heat":

Lucy: Yes [both ice cubes need the same amount of heat to melt them] because they are both at the same temperature. The
smaller cube will just melt faster because there is less mass.

Sara: Yes, but the big ice cube will take longer to melt because of its mass.

Lucy and Sara's responses invoke a concept associated with the word "heat" that derives from one of its uses in ordinary language. This concept of heat is roughly equivalent to the concept of temperature in that it refers to a "level" of hotness. For example, we say that we can only stand so much heat before seeking out a shady area. The word heat, in this context, refers to a particular air temperature that is just tolerable. We could also say that we can only stand so much heat before getting out of the sauna, in which case we would usually be referring to the amount of time spent in the sauna, rather than its temperature. Similarly, for Lucy and Sara, the two ice cubes require the same amount (level) of heat to melt, but one will require a longer time. Their answers to the third part of the question make sense in the terms of ordinary language, yet they answered the question incorrectly because they failed to use the term "heat" in its proper scientific sense. In other words, Lucy and Sara did not know the "rules of the game," despite the fact that they had just finished studying a unit on heat.

As mentioned above, these four girls were selected for an interview with Kevin on the basis of their answers to the "ice cubes" question. Kate and Mary were chosen because they seemed to understand the scientific concept of heat, while Lucy and Sara were selected because their answers suggested they did not. Kevin planned to investigate further the girls' understanding of heat and, in collaboration with the investigator, set out a strategy that would guide the interview. It was decided that the four girls would be interviewed together in the hopes that they would discuss their answers quite spontaneously among themselves. Therefore, a protocol was not formulated in terms of setting the
actual interview questions in advance. The girls were given their test papers so they could see what they had written for the "ice cubes" question, after which they were invited to comment on why they wrote the answers they did. (The supervising teacher had several meetings during the week of the interview and was unable to attend during the noon-hour when the interview was conducted. However, he and Kevin viewed and discussed a video tape of the interview on the following day.)

The following excerpt of the interview shows further evidence that two different concepts associated with the word "heat" were being used by the girls. The excerpt also shows that this was not a trivial problem: it seemed to be almost impossible for Lucy and Sara to "see" that the ice cubes required "different amounts of heat" to melt.

Kevin: Okay, what about the second question? Why do you think the small ice cube melts first? Lucy, what did you put?

Lucy: Because there's less mass in the small one. Like there's less of it so it'll melt quicker.

Sara: And it's sort of like it has a head start because it's smaller.

Lucy: Yeah.

Sara: So it'll melt faster.

Kevin: (to Kate) What did you put?

Kate: I put the same.

Kevin: So what did you say?

Kate: I said the small one will melt first.

Kevin: Because . . .

Sara: This could be a trick question.

Mary: I put that the small one melted faster because the bigger one will need more heat because of the latent heat of fusion. And you need a certain amount of Joules of energy to melt each kilogram?
Kevin: Okay. I see where you're coming from there. Okay, what about the last question . . . do you think both ice cubes need the same amount of heat to melt? What did you put, Lucy?

Lucy: Yeah.

Kevin: Okay, and explain why.

Lucy: Well, because they're . . . they're the same. Uhm, they're the same temperatures, so this one will just melt before.

Kevin: Okay . . . what did you put, Sara?

Sara: Uhm, I put that it would . . . uhm, because the smaller one uhm, because its mass is already smaller and it would melt, like, faster?

Kevin: So, does it require the same amount of heat?

Sara: Uh, yeah.

Kevin: Okay.

Sara's comment about the possibility of the question being a trick is interesting, suggesting that she may be searching for the purpose of the question, or a clue as to which direction she should take in thinking about it. From her point of view, the question may well be a trick. (The importance of knowing the "context of a question" is discussed later in this chapter.)

This portion of the girls' dialogue is convenient for pointing out the two different concepts associated with the word "heat" that are being used by the girls because these concepts lead to opposite answers. Mary says that the ice cubes require different amounts of heat to melt because she is conceiving of heat as energy. Lucy and Sara say that the ice cubes require the same amount of heat to melt because they are conceiving of heat as something like temperature. As the dialogue continues below, notice that this shift in language seems to be the cause of the girls' failure to communicate effectively with each other.

Mary: I put that the larger heat [sic] needs more because it has a greater mass.
Kevin: The larger heat?

Mary: The larger ice cube.

Kate: That was the same as mine.

Kevin: Is that what you guys put? Okay, so what . . . I guess I'm trying to . . . what . . . what is that asking? Could you rephrase that question for me? Lucy or Sara? Do you think both ice cubes need the same amount of heat to melt? And you said yes, but it just takes longer.

Lucy: Yeah, it just takes longer to melt the bigger one.

Kevin: Okay. (to Sara) And that's what you were thinking?

Sara: Yeah.

Lucy: Well, cause they're at the same temperature.

Kevin: I agree it probably takes longer. Well . . . we . . . why do you think the small ice cube melts first? And we both agreed that the small one would melt first. Uhm, I'm just wondering . . . okay, if I were to ask, "Do you think both ice cubes . . . uhm, melt at the same temperature . . . or need the same temperature to melt?" Is that the same question, Lucy?

Lucy: Uhm, yeah. (embarrassed) Don't look at me. (laughs)

Kevin: I'm sorry . . . I'm just trying to get at . . . uhm, what you felt the question was asking here in terms of . . . uh, is it the same amount of heat to melt. Because you said yes, they need the same amount. And then you went on to say that one would require longer to melt. And, like, we all agree that it would require longer to melt. What did you put, Mary?

Mary: I put the larger ice cube needs more heat because it has a greater mass . . . because of the latent heat of fusion.

Kevin: Okay . . . (to Kate) how does that . . .?

Kate: That's about the same as I had.

Kevin: Okay, could you rephrase that . . . like how did you answer that one?

Kate: I just said that they don't need the same amount of heat because the larger ice cube has more mass that the heat can be transferred into.

Kevin: Okay. How . . . uhm, the answers are a bit different here. And I'm just wondering why they're different . . . or what you think about the difference.
Lucy: What I think . . . oh, uhm . . .

Kevin: Do you see any hang ups?

Lucy: No.

Kevin: Okay, they said no . . . and you said yes.

Lucy: Well, I mean if you wanted to, you could do it both ways.

Kevin: Why could you do it both ways?

Lucy: 'Cause I mean you can melt it at the same temperature, but you can also . . . do it at different temperatures. If you want it done at the same time.

Kevin: Okay.

Lucy: You know?

Kevin: But how does temperature relate to heat then? 'Cause was the question asked about temperature or was it asked about heat?

Lucy: Heat.

At this stage in the dialogue a couple of points need to be made. First, it is quite clear that there is an impasse in communication brought about by the fact that Kate and Mary are using the "scientific language" concept of heat, whereas Lucy and Sara are using a concept of heat derived from ordinary language. According to the former, "heat" refers to the amount of thermal energy transferred from one body to another, while "heat," according to the latter, means roughly the same thing as temperature, that is, the amount of "hotness" of a substance. Both parties are having a great deal of difficulty moving beyond the impasse, so as to enable Sara and Lucy's understanding of the scientific concept of heat. The very idea that different amounts of heat are required to melt the two ice cubes is interpreted by Sara and Lucy as if to say, "Sure, this can be done if you want to melt the two ice cubes in the same period of time." Again, they are "thinking" about temperature; at least what they mean by heat is equivalent to what is meant in science by temperature.
As the dialogue continues we see that Sara and Lucy eventually seem to "understand" the scientific concept of heat, allowing them to reinterpret the question, and reformulate their answers.

Kevin: I'm not evaluating you in any way. You know, actually to be honest . . . uh . . . a lot . . . most people answered the question . . . they gave the correct reasoning . . . yet I'm not sure about your answers. Like your "yes," I'm not sure if yes is the right answer. But your reasoning is right. And so I'm just wondering where our hang up is here. Do you see? (to Mary) Can you maybe explain something?

Mary: I don't know . . . I don't know what her answer is.

Kevin: Okay, see what the answer was. And Kate, here see what Sara put. 'Cause your reasoning I like. But I'm not sure why you think . . . why you think . . .

Mary: I think that what she has there is . . . uh, the temperature. Like, like . . . they need the same temperature of heat going into them, but they need more heat going into them. Like the bigger one will need more heat to go into it to melt it than the little one.

Kevin: You mean the same temperature for a longer time.

Mary: Yeah, the same . . . yeah, yeah.

Kevin: What do you think, Kate, about that?

Kate: I don't know . . . uh . . .

Kevin: (to Lucy) What do you think?

Lucy: About that?

Kevin: Yeah.

Lucy: Or that?

Kevin: Or . . .

Lucy: Well that's right, because it's yes and no.

Kevin: Why is it yes and no?

Lucy: Uhm . . .

Kevin: I'm just a first year teacher . . . I don't understand this.
Up to this point in the dialogue, the girls have been evenly split in their thinking about the ice cube problem: Mary and Kate have been using the scientific conception of heat as the amount of thermal energy transferred from one object to another; Lucy and Sara have been using the ordinary conception of heat "as temperature." But as the dialogue continues, Sara begins to use the scientific conception of heat, as all of a sudden she seems to "see" that the two ice cubes require different amounts of heat to melt. Lucy's reaction to this is rather interesting: the amount of pressure on her at the time of losing her ally must have been considerable. Her question to Sara at that point is seen by this investigator to be earnest, perhaps desperate. (The investigator is identified as the speaker by "Allan.")

Lucy: Well, I mean . . . you could do it either way, right? You could use the same amount of heat or you could use different amounts of heat.

Kevin: Could you?

Sara: Oh yeah.

Lucy: Yeah, because if you wanted them both melting at the same time then . . .

Sara: Yeah, actually the larger one does need more heat though. Because it's bigger.

Lucy: It could do the same heat for a longer time, though, because . . . couldn't it?

Sara: It's because the larger one's bigger, but the smaller one's already had a head start so it wouldn't need as much heat to melt it?

Kevin: Like when you say the same heat for a longer period of time, are you talking about the same temperature for the longer time?

Lucy: Oh yeah.

Allan: I think part of the problem is that heat sort of has two meanings. It has a meaning in science, and it has a meaning in everyday life. In everyday life heat has the same meaning as temperature.

Kevin: Yeah, like how hot is it outside? What's the heat? Well, it's 32
degrees... or even that's the heat. But in science what is our definition of heat?

Students: (in chorus) The amount of energy that's transferred from one object to another.

As the dialogue about the "ice cubes" question concludes, it appears as though the four girls have resolved their difficulty in agreeing about the amount of "heat" required to melt the two ice cubes. Though the evidence is certainly not conclusive, the resolution of their difficulty may be due to (1) their realization that the use of the word "heat" is different in science from its use in "everyday" language, and (2) their recognition that the context of the "ice cubes" question makes it appropriate to use the scientific concept of heat in formulating an answer.

Shifting the Context

The context of a question is important in determining the correct usage of language as well as appropriate ways of thinking about the question. This is a very important idea: in the investigator's judgement, much of what pupils must do in the way of "seeing" situations in their schooling, and so determining appropriate ways of responding in those situations, is of this form. That is, much of being successful in school has to do with being able to "see" situations appropriately. In the dialogue above, Mary and Kate show that they are able to see the situation correctly--they "know" what the intent of the question is. Mary is particularly good at "reading" context; she was able to recognize, for example, that Lucy was using the word "heat" to mean temperature. In order to do so she must have been able to understand the context in which Lucy was interpreting the question. Sara, on the other hand, wondered if the question was a trick--even if we take her jokingly, we can conclude that she is searching to understand the context and intent of the question.
This section explores further the matter of context in determining appropriate ways of dealing with phenomena. The analysis focusses on Mary, who has thus far demonstrated in the test and the interview that she is a competent science student. The remainder of the interview dealt with a second question, in which the context was shifted considerably. First, the person who carried the dialogue with the girls shifted from Kevin to Allan. Second, the context of the question shifted from school science to "everyday life." The idea was that the girls were to help Allan prepare his lunch by spreading butter on a filet of frozen fish. When they noticed that the butter became stiff, it was hoped that they would discuss the phenomenon quite "freely."

The significance of shifting the "interviewer" from Kevin to Allan is that the latter was known by the girls as a camera man, not as a teacher. Though they likely had the sense that Allan had something to do with Kevin's student teaching, they were not obliged to respond to him in the "school science" way that they were obliged to respond to Kevin, even though Kevin was present. At least, this is what we might expect, until the girls are able to "read" the situation as a school science one. As the following excerpt illustrates, this is precisely what happened with Mary, as she shifted from speaking of cold moving from the fish into the butter, to saying that heat was being taken from the butter for the phase change of the fish. The dialogue begins with Mary spreading the butter:

Allan: Actually, the way you're doing it . . . it almost looks hard.
Mary: It is.
Allan: It's nice and soft butter too.
Mary: I'm not very good at it. Does it have to be even, or is this good enough?
Allan: That looks great to me. Actually, I like a little bit more butter.
Lucy: Is something going to happen? (laughs)
Allan: Kate, would you like to put a little bit more on?
Mary: That knife is bending, and it doesn't . . .
Allan: Uh huh.
Lucy: This is a waste of food.
Allan: Actually, I am going to have it.
Mary: Oh do it nicely.
Kate: This is quite gross I must say.
Allan: Is it easy to spread?
Kate: It's hardening.
Mary: No because it's having a heat transfer from this to that . . . it gets harder.
Allan: From what to what?
Mary: From the fish.
Sara: (touches fish and butter) Oh, it's so cold.
Mary: It's frozen and so it's transferring . . . to the . . .
Lucy: It makes the butter cold . . . the margarine a little bit colder.
Kate: Heat is being released.
Sara: (-touches the butter dish) Hey, this is warm.
Kate: No, heat is being taken.

It is tempting to say that Mary's thinking about heat has shifted with the context of the question. Using the "ordinary language" concepts of heat and cold she quite reasonably seems to be close to saying that there is cold moving from the fish into the butter, and therefore the butter gets harder. What is interesting in this second part of the interview is that Mary seems to have abandoned the scientific concept of heat, even though she was using it quite comfortably just minutes before in the context of one of the test questions.
Kate, on the other hand, "reads" the situation in a different way, recognizing that the "right" way to think about the fish and butter is in terms of heat being "taken" from the butter by the fish. She is rather timid about saying so, and never really completes her sentence by saying, "heat is being released (taken) from the butter." It is as though Kate is trying out her answer to the problem to see how it will stand up in the dialogue.

Allan: Heat is being released?
Mary: This is the same butter dish as I have at home you know.
Allan: Is it? I've got two of those.
Mary: One goes on top of the other.
Sara: I want to get one.
Allan: Now, did you say that the cold goes from the fish to the butter?
Mary: Yep.
Students: Yeah.
Sara: I agree with that.
Mary: It's taking . . . no, it's taking heat away from the butter.
Allan: Oh, I see.
Mary: So it can use it for it's phase change.
Allan: It's a phase change?
Lucy/Sara: No.

One can point to the place in the dialogue where Mary's language shifted back to the language of science: it happened when she said, "It's taking . . . no, it's taking heat away from the butter." At that point, it is argued, she realized the possibility for dealing with the phenomenon in the context of school science, and resumed working with the scientific concept of heat. Going further, Mary could then "see" that heat was required for the phase change of the fish.
Lucy and Sara's response (in unison) to Allan's question at the end of the excerpt, "It's a phase change?" is also very interesting in terms of context. The investigator's interpretation is that Lucy and Sara cannot "see" the phenomenon in terms of the context of school science, and they must search for the appropriate way to respond. They take Allan's question as challenging Mary's idea, and they "try out" the only other possible answer to his question. Lucy and Sara's response is seen as an example of the all too familiar pattern of pupils reading the clues of the situation without knowing the context of the question, or without knowing how to regard the subject matter in the appropriate manner.

The dialogue about the "hardening butter" continues below, with Mary explaining to Lucy and Sara what is going on from a scientific point of view. Allan, in the meantime, tries to establish the reasonableness of thinking about cold moving from the fish to the butter:

Mary: It's trying to. It's trying to melt.
Kate: It's trying to come back to life.
Allan: It's getting stiffer isn't it?
Mary: The butter is, but the fish is trying to melt.
Allan: I see. Okay, I see. Well, when my daughter tried that... and my daughter is nine... and she said that the cold is going from the fish into the butter. Does that make sense?
Sara: The cold going into the butter?
Mary: No... cause it's not cold transfer... it's heat transfer.
Sara: No, but it's cold.
Lucy: The cold's going into the butter.
Mary: The fish is taking away the heat from the butter.
Kevin: Why is the cold going into the butter?
Lucy: Because the butter's hard now ... well, kind of.
Sara: That was warm ... and then ...
Mary: Yeah, but the fish takes it away.
Sara: It was warm ...
Lucy: It was that (points to soft butter) and then it went to that (hard butter on fish).

It should be clear from the dialogue that the girls are using two different ways of regarding the phenomenon of the butter getting harder. Mary and Kate are using the scientific concept of heat to say that heat is being transferred from the butter to the fish; it is required for the phase change of the fish. Lucy and Sara are using the "ordinary language" concept of cold to say that the cold is being transferred from the fish to the butter. Again, the difficulty of communication can be thought of in terms of two different language uses at work in the girls' thinking. As the dialogue continues, Allan tries to clarify the problem for the girls by pointing out the two different ways of thinking about the phenomenon:

Allan: I think my daughter was sort of thinking that. And that's sort of the way we think in the everyday world, isn't it? We think about cold being moved here and there as well as heat being moved here and there. But, Mary, what you were saying is that in science we don't think about cold moving ...

Mary: We think about heat moving, yeah.
Kate: Heat transfer.
Allan: What do you think about that, Lucy?
Lucy: I don't know. Uhm, well I guess she's right. 'Cause well this is melting kind of.
Kate: It's getting nice and soft.
Allan: It might even be getting soft. You probably don't want to touch because your hands will smell fishy ... but (puts wrap around the fish) you can feel it's getting a little soft on the bottom if you touch the wrap. Can you feel it?
Mary: Yeah. That's from the desk.

Allan: Uhm.

Sara: The desk's warm . . .

Mary: Warmer anyways.

Sara: It's at room temperature, sort of.

Allan: (touches the spot of the desk that the fish was resting on) Is it warm there?

Sara: No . . . it's freezing.

Kate: 'Cause the heat's been taken away from the desk by the fish.

Kevin: Why is heat being taken away from the desk by the fish?

Kate: 'Cause the fish is trying to melt.

Kevin: Like it doesn't . . . I mean . . . how would you explain that in terms of energy . . . or whatever? Can you explain it?

Kate: The fish is taking energy.

Allan: It's starting to smell . . . I'll put it away so it doesn't smell the room up. That would be pretty gross. Okay, (to Kevin) What were . . .

Kevin: I was just wondering why the fish would draw the heat away from the butter or the desk.

Lucy: 'Cause it's warmer than the fish.

Sara: The desk?

Lucy: Yeah, the desk and the butter's warmer than the . . .

Kevin: And so why would it go from the . . .

Kate: 'Cause the fish needs heat . . .

Lucy: 'Cause it's trying to melt . . .

Kate: It's defrosting.

Allan: Okay, well, great. Thank you very much. I'm going to enjoy my lunch. Thanks for doing all the work.
It is not clear in the dialogue that Lucy and Sara can "see" the hardening butter phenomenon in terms of "heat being removed by the thawing fish." Even Kate's thinking is difficult to comment about when she used an anthropomorphic explanation (the fish is trying to melt) in response to Kevin's question about why the heat from the desk was being taken by the fish. What is quite intriguing, though, is the clarity with which Mary's "ah ha" experience appears when we are prepared to notice the shift in her use of language, together with the change in the way she "perceived" the hardening butter.

Summary

This chapter began with an examination of the two main principles underlying a "constructivist" perspective on teaching and learning. These two principals are (1) knowledge is not passively transmitted and received, but actively built up by the cognizing subject; and (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. These principles of constructivism have been applied to the matter of science teaching, and an analytic scheme has been derived for representing a "constructivist view of science teaching." This scheme has been presented in two parts: a diagrammatic representation presented in Figure 3 with accompanying elaboration in the text; and a set of "pedagogical principles." Figure 3 is shown again below for the reader's convenience.

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

\[ \text{Scientific Knowledge} \]

\[ \text{"Children's Science"} \]

\[ \text{Ordinary Language} \]

\[ \text{Ordinary Experience} \]

\[ \text{Scientific Experience} \]

\[ \text{Scientific Language} \]

T - Teacher
S - Student
NP - Natural Phenomena

\textbf{Figure 3. A "Constructivist" View of Science Teaching}

From this analytic scheme it follows that a constructivist science teacher will recognize that students continually construct meaning of classroom events based on their prior understandings and experiences, and that their experiences in science courses will derive, at least initially, from their use of ordinary language. Further, a constructivist science teacher will have a disposition for attempting to "see" science classroom phenomena from students' perspectives in order to accommodate these in the instructional program. As illustrated in the dialogue concerning heat among Grade Nine students, this disposition to "see" phenomena from students' perspectives is fundamental to their learning about the appropriateness of particular conceptions to particular contexts. In other words, the disposition and ability to "see" from students' points of view is
fundamental to sorting out what is "right" about their thinking, rather than simply what is wrong about it.

To "see" a phenomenon from a student's point of view requires "reconstruction" on the part of the teacher. That is, the phenomenon in question must be seen in a "new light," much as Kevin was able to "see" how two ice cubes of different masses require the same "heat" (temperature, in scientific language) to melt, or Allan was able to "see" why three of the four students spoke initially about "cold" moving from the frozen fish into the hardening butter. In the investigator's judgement, the ability to "see" from the student's perspective is absolutely necessary before the student can be taught about science.

The conjecture that is being made here is that this process of "reconstructing situations of practice" might be enhanced by creating a "reflective practicum" for student teachers. The following chapter begins to conceptualize such a practicum.
Chapter Four concluded by noting the central importance of a teacher being able to "see" classroom events from pupils' points of view. This is especially important in science teaching where the words used in describing and explaining phenomena may have a variety of uses and meanings, determined in part by the contexts for using scientific language as opposed to ordinary language. A view of the sort of teaching that inquires into the possible meanings that students bring to classroom events is developed in this chapter under the construct of "reflective practice," as it is discussed by Donald Schön.

The purpose of this chapter is to develop a scheme for identifying the broad characteristics of a reflective practicum in constructivist science teaching. The chapter begins with a critical review of Schön's (1983, 1987) analysis of reflective practice by examining the main ideas put forth in his two recent books, as well as some of the arguments that have been advanced by his critics. The analysis focusses on "technical rationality," "problem setting," the distinction between "knowing how" and "knowing that," "reframing," and the distinction between "reflection-in-action" and "reflection-on-action," all of which are central to Schön's analysis of reflective practice.

The ideas that are seen to be appropriate are then fashioned into an analytic scheme for identifying the characteristics of a "reflective practicum" in constructivist science teaching. Thus, the chapter concludes with a synthesis of the ideas presented in Chapter Four regarding a constructivist view of science teaching, and ideas put forth in the present chapter regarding "reflective practice" and a "reflective practicum."
Reflective Practice

By way of an introduction to Schon's ideas about education for "reflective practice," it will be useful to draw upon an analogy he has constructed to point to a dilemma he claims exists in schools of the professions. Schon (1983) has referred to this dilemma as one of "rigor or relevance" (p. 42). The topography of professional practice, as the analogy goes, consists of a hard, high ground overlooking a swamp. The hard, high ground is seen to be comprised of well-formed theoretical problems that can be solved by applying the "methods of science." In the swamp below there are the important, but messy and difficult problems of practice--problems, according to Schon, that require a form of artistry for both their definition and solution.

In the varied topography of professional practice, there is a high, hard ground where practitioners can make effective use of research-based theory or technique, and there is a swampy lowland where situations are confusing "messes" incapable of technical solution. The difficulty is that the problems of the high ground, however great their technical interest, are often relatively unimportant to clients or to the larger society, while in the swamp are the problems of greatest human concern. (Schon, 1983, p. 42)

To deal with the dilemma that this topography suggests, Schon has proposed two courses of action. Shall one remain on the hard, high ground where it is possible to be rigorous in solving problems, but where the problems are relatively unimportant to practice? Or shall one descend into the swamp below where the problems are relevant, but where one cannot be rigorous in any way that he or she can describe? At first glance, the problems inherent in the dilemma of rigor or relevance in professional practice seem to be insurmountable. And, since much of Schon's analysis begins with the relationship between thought and action encompassed by his analogy, it is essential to "unpack" this idea of the "varied topography of practice," together with the dilemma of rigor or relevance that is so central to his thinking.
Technical Rationality

The problems associated with the "varied topography of practice" are not inherent in the nature of practice itself, at least, not in the main. Rather, they exist, as Schön pointed out, in a particular view of professional practice he referred to as "technical rationality," together with a corresponding view of professional education grounded in the belief that the teaching of technical, propositional knowledge should precede the development of skills in its application.

According to the model of Technical Rationality—the view of professional knowledge which has most powerfully shaped both our thinking about the professions and the institutional relations of research, education and practice--professional activity consists in instrumental problem solving made rigorous by the application of scientific theory and technique. Although all occupations are concerned, on this view, with the instrumental adjustment of means to ends, only the professions practice rigorously technical problem solving based on specialized scientific knowledge. (Emphasis added, Schön, 1983, pp. 21-22)

It is worth illustrating what Schön means by technical rationality by looking briefly at the matter of teacher education. As a case in point, there has been a tendency in faculties of education (in methods courses, at the very least) to characterize teaching in terms of methodologies and techniques that have been shown to correlate positively with student achievement, often drawing on the so-called "effective teaching" research literature. Thus, students of education are taught about the "principles of teaching." For instance, they learn about the concept of "wait-time"--the time elapsing between a question and its answer. They are told that student achievement is optimized when a teacher waits three to five seconds after asking a question. The idea is that students need some time to think about what the question means before formulating their answers. As a guide for teaching, the concept of wait-time has merit; no doubt, it will serve to prevent some beginning teachers from moving too quickly from one student to another in search of the right answer.
And, it is not as though these beginning teachers would operate much like machines in the course of using the construct of wait-time. But two aspects of the standard treatment of this concept make it an "element" of technical rationality: first, it is tested rigorously under experimental conditions in order to make a technical claim--"optimal wait-time" falls within the three to five second range. Second, having achieved the status of a "scientific finding," the three to five seconds become a "rule of thumb" for practice. This is a case in point of a general tendency to divide the activity of teaching into technical components, to deliver these components as a teacher education curriculum that frequently takes the form of "what research says" to the teacher, to expect that the meaning of these components can then be taken from words in lieu of experience in the practice setting, and, finally, to expect students of education to construct their practice from these words that are supposed to describe the technical building blocks of teaching. In short, technical rationality is the view that the principles of teaching can be "delivered" during the on-campus component of a teacher education program, and then applied by candidates in their practice teaching.

Schön went on to say that technical rationality is the heritage of positivism, which he defined as "the powerful philosophical doctrine that grew up in the nineteenth century as an account of the rise of science and technology and as a social movement aimed at applying the achievements of science and technology to the well-being of mankind" (Schön, 1983, p. 31). Schön argued that a technical description of practice cannot account for the "craft" and "artistry" sometimes displayed in the work of practitioners.

Among philosophers of science, no one wants any longer to be called a Positivist, and there is a rebirth of interest in the ancient topics of craft, artistry and myth--topics whose fate Positivism once claimed to have sealed. It seems clear, however, that the dilemma which afflicts the professions hinges not on science per se but on the Positivist view of
science. From this perspective, we tend to see science, after the fact, as a body of established propositions derived from research. When we recognize their limited utility in practice, we experience the dilemma of rigor or relevance. But we may also consider science before the fact as a process in which scientists grapple with uncertainties and display arts of inquiry akin to the ... arts of practice. (Schön, 1983, pp. 48-49)

The "varied topography of practice" that Schön attributed to the professions warrants careful examination. He has not proposed that we are unable to be rigorous in thinking about what we do. Nor has Schön proposed that professional practice is unlike science. Technical rationality, together with the dilemma of rigor or relevance, exists only in the way we tend to think about practice, especially in the way we sometimes construct "programs" in professional schools and in the rhetoric surrounding these programs.

Schön's main interest is how some people are very good at dealing with the "swampy, uncertain problems of practice," and this has led to an illuminating formulation of "reflective practice." But the dichotomy suggested by the "varied topography of practice" is quite problematic. For in practice the high ground of any profession cannot be separated from the lowlands as the bifurcation of, say, "intuition" and "rationality" suggests, even in the case of science. For instance, Einstein (1949), on the discovery of natural laws wrote, "There are no logical paths to these ... laws. They can only be reached by intuition, based on something like an intellectual love (Einfühlung) of the objects of experience" (p. 125). Similarly, Popper (1959) wrote, "there is no such thing as a logical method of having new ideas. ... every discovery contains an 'irrational element' or a creative intuition" (p. 32).

The "context of discovery" is not readily amenable to rational analysis, as many philosophers of science have pointed out. Similarly, in the context of framing situations of practice, intuition plays a prominent role. In most professional situations practitioners are never called upon to operate formally in the "context of justification" where a formal language, rules of inference and
deduction, etc., must be brought to bear on their activities. This seems to be Schöln's point in talking about the "dilemma of rigor or relevance," or "technical rationality."

Fenstermacher (1988) has criticized Schöln's dichotomous separation of the "topography of practice," contending that "there is a bridge between 'the hard, high ground' and the 'swampy lowland'" (p. 44):

I believe that Schöln has offered us an either-or description of a situation that is actually a both-and. I can detect no bifurcation between science (even, to an extent, positivist science) and practice, such that the two are incapable of contributing productively to one another. The results of scientific inquiry can be and have been of great help in the indeterminate zones of practice. . . . it seems a more accurate description of the science-practice relationship to say that scientific research can and does bear on practice, including those aspects of practice that are in the swampy lowlands. (Fenstermacher, 1988, pp. 44-45)

Shulman (1988) has also criticized the sorts of dichotomies suggested by some of Schöln's terms, including

the dichotomy between school knowledge and reflection-in-action, between teaching and coaching, between technical rationality and artistry, between the determinate and indeterminate. . . . We are told that the perspectives of school knowledge or technical rationality "leave no room" for certain more reflective, artistic, or responsive processes. In practice, such assertions will simply not hold up. While the extreme form of [a] routinized teacher can surely be contrasted sharply with a responsive and sensitive progressive educator, most of the teaching world does not parse so readily into extreme groups. (Shulman, 1988, p. 33)

Indeed, one can appropriately ask where the separation of "technical rationality" and "reflective practice" leads. Schöln says that technical rationality is built into the normative curricula of professional schools. The tradition of these curricula, he says, is to first instruct students in the propositional knowledge pertaining to their field, and then follow it with a practicum. Certainly, problems arise when there is disagreement about the character and expectations placed on the various kinds of knowledge that are thought to be required for professional work. Further problems may arise, as Schöln suggests, when students of the professions learn that a technical knowledge base seems to
be insufficient for identifying and bringing under control some problems of practice. It may well be the case that what has been neglected in schools of the professions, including faculties of education, is the importance of providing experience in learning a practice, together with opportunities for developing the disposition and capacity to reflect about that experience. At the heart of this form of inquiry in practice is what Schön refers to as "problem setting."

**Problem Setting**

Uncertain situations of practice that lead to inquiry do not come to the practitioner as "givens." Schön is right in saying that problems of practice must be constructed from the "materials" of the situation according to the "frames" available from past experience. There is no objection to this idea among Schön's critics. Some go so far as to grant Schön the importance of the "tacit knowledge" that may be at work in making problems, though it is not without some contention. For example, Shulman wrote,

> There is great importance in Schön's reminding us of the importance of tacit knowledge, of that which cannot be spoken, of that which cannot be articulated, lying close to the heart of many kinds of artistic expertise and even professional judgement. But I am not sanguine about the sufficiency of tacit knowledge when we speak of educating the professional educator. (Shulman, 1988, p. 32-33)

The process by which one gets to a well-formed problem is not in itself a technical problem, although the problem could certainly be illuminated, as Fenstermacher reminds us, by a "technical" perspective, just as it could by any other. How we transform situations of practice into problems of practice is highly inferential in that we construct not only our understandings of practice but the very ways we present it to ourselves. Of course in one sense we need a "high ground" in order to do that. In the course of professional practice, we may draw on several different theoretical perspectives at once when we formulate and, especially, articulate problems in terms of concepts, languages
and standards with which we describe and prescribe practice.

What seems to interest Schön in particular is how some practitioners seem to have a tendency to construct and reconstruct their practice world in search of "better" understandings, rather than settling for "first construals" of events. Schön's idea is that this tendency to construct and reconstruct ways of seeing phenomena of practice lies at the heart of competence in the professions, and it can be characterized by his analysis of "reflective practice."

Schön says he approaches the matter of professional education from a "new" perspective—a new "epistemology of practice." He asks not how we can apply science to the problems of practice, but how we can discover in the work of practitioners what it is that they know when they are being competent.

Let us ... reconsider the question of professional knowledge; let us stand the question on its head. If the model of Technical Rationality is incomplete, in that it fails to account for practical competence in "divergent" situations, so much the worse for the model. Let us search, instead, for an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict. (Schön, 1983, p. 49).

The crux of Schön's analysis has to do with the kind of knowledge that a competent practitioner displays in action and the "non-logical" processes that are manifest in recognition of patterns and making sense of complexity. Here, Schön draws extensively from Polanyi (1962) and Ryle (1949) with the notion of tacit knowledge and the distinction between "knowing how" and "knowing that," respectively. He develops the concept of knowing-in-action to refer to the spontaneous, intuitive awareness that practitioners bring to their work. The phenomenon of carrying out a sequence of actions, apparently without having to think about them is of central importance. The following section explores the distinction between "knowing how" and "knowing that," as this is a central aspect of Schön's analysis.
"Knowing How" and "Knowing That"

In reconsidering the nature of professional knowledge, Schön honors the competence of practitioners in so-called "divergent" situations, focusing on the "intuitive performance" of the actions of everyday life:

When we go about the spontaneous, intuitive performance of the actions of everyday life, we show ourselves to be knowledgeable in a special way. Often we cannot say what it is that we know. When we try to describe it, we find ourselves at a loss, or we produce descriptions that are obviously inappropriate. Our knowing is ordinarily tacit, implicit in our patterns of action and in our feel for the stuff with which we are dealing. It seems right to say that our knowing is in our action. (Schön, 1983, p. 49)

Drawing from Ryle (1949), Schön goes on to say that there is nothing in common sense to purport that know-how consists in rules or plans which we entertain in the mind prior to actions:

What distinguishes sensible from silly operations is not their parentage but their procedure, and this holds no less for intellectual than for practical performances. "Intelligent" cannot be defined in terms of "intellectual" or "know how" in terms of "knowing that"; "thinking about what I am doing" does not connote "both thinking what to do and doing it." When I do something intelligently, I am doing one thing, not two. My performance has a special procedure or manner, not special antecedents. (Ryle, 1949, p. 32; Schön, 1983, p. 51)

The assertion that intelligent performance does not necessarily depend upon the consideration of a prior set of procedures is crucial to Schön's analysis. However, this is not to say that thinking in advance about a procedure has no bearing on its execution. As Ryle elaborated,

Certainly we often do not only reflect before we act but reflect in order to act properly. The chess-player may require some time in which to plan his moves before he makes them. Yet the general assertion that all intelligent performance requires to be prefaced by the consideration of appropriate propositions rings unplausibly, even when it is apologetically conceded that the required consideration is often very swift and may go quite unmarked by the agent. I shall argue that the intellectualist legend is false and that when we describe a performance as intelligent, this does not entail the double operation of considering and executing. (Ryle, 1949, pp. 29-30)

Ryle's example of the "wit" provides a good illustration:
The wit, when challenged to cite the maxims, or canons by which he constructs and appreciates jokes, is unable to answer. He knows how to make good jokes and how to detect bad ones, but he cannot tell us or himself any recipes for them. So the practice of humour is not a client of its theory. (Ryle, 1949, p. 30)

For Ryle, and for Schön, the existence and importance of "knowing how" is central to the matter of learning a practice. This is not to say that "learning by doing" without analysis is a substitute for "learning by doing" with a theory. Rather, it is to say that "learning by doing" mitigates some of the difficulties that arise when a practitioner is unable to articulate and analyse competent performance. Certainly, intuitive actions are subject to thoughtful consideration and further articulation and understanding. The point is, however, that the reverse is not the case: intelligent performance does not follow automatically from knowing a set of procedures or maxims that govern it. As Ryle put it,

Efficient practice precedes the theory of it; methodologies presuppose the application of the methods, of the critical investigation of which they are the products. It was because Aristotle found himself and others reasoning now intelligently and now stupidly and it was because Izaak Walton found himself and others angling sometimes effectively and sometimes ineffectively that both were able to give their pupils the maxims and prescriptions of their arts. It is therefore plausible for people intelligently to perform some sorts of operations when they are not yet able to consider any propositions enjoining how they should be performed. Some intelligent performances are not controlled by any anterior acknowledgments of the principles applied in them. (Ryle, 1949, p. 30)

This investigator believes that while teaching is subject to rational inspection both conceptually and empirically, there may be something quite important in the idea that intelligent performance may not be controlled by any anterior acknowledgement of the principles and standards applied to it. Returning to Ryle's distinction between "knowing how" and "knowing that," it seems right to say that the meaning of "that" unfolds to the beginning practitioner only gradually, and usually in the context of doing, and then thinking about doing "that."
Reframing

One's ability to carry out a sequence of actions may not depend, according to Schön, on the description of the sequence. Rather, one's ability to recognize patterns in situations of uncertainty and uniqueness, and to act efficaciously in those situations, depends on one's capacity to frame problems. In doing so one is drawing upon a repertoire of past experience and ways of apprehending that experience, both of which lead to an ability to reframe problems in the light of the information obtained from the practice setting. Schön refers to these processes as "reflection-in/on-action," that is, he likens them to a "reflective conversation" that takes place between the practitioner and the uncertain situation. Reflection-in/on-action is the mechanism which permits practitioners to continue to develop a rich repertoire of strategies and ways of making sense of experiences that, ultimately, accounts for their competence in dealing with the "messy" problems of practice.

Reflection-in/on-action consists of problem setting and problem solving. These activities may take place consciously (reflection-on-action), or tacitly in a situation of practice (reflection-in-action). The distinction between reflection-in-action and reflection-on-action is extended shortly. In either case, however, the central feature of reflection is problem "setting," that is, the framing and reframing of "indeterminate" practice situations.

Problems do not present themselves to the practitioner as givens. They must be constructed from the materials or the problematic situations that are puzzling, troubling and uncertain. When we set the problem we select what we will treat as the 'things' of the situation, we set the boundaries of our attention to it, and we impose upon it a coherence which allows us to say what is wrong and in what directions the situation needs to be changed. Problem setting is a process in which, interactively, we name the things to which we will attend and frame the context in which we will attend to them. (Schön, 1983, p. 40)

Reframing occurs when the practitioner reconstructs the problem, assigning new significance to certain features of the practice situation, or bringing to
attention other features that appear to be relevant. Reframing involves a "new way of seeing" a phenomenon. The point that Schöhn is making is that problem setting, framing, and reframing are activities that are highly inferential in character—they involve the mind in its active construction and reconstruction of representations and explanations of practice situations, and in its consideration and reconsideration of implications for future practice that follow from these representations and explanations.

In order to see what can be made to follow from this reframing of the situation, each practitioner tries to adapt the situation to the frame. This he does through a web of moves. Within the larger web, individual moves yield phenomena to be understood, problems to be solved, or opportunities to be exploited. (Schöhn, 1983, p. 131)

Following Schöhn's account, problem setting and problem solving are incumbent on each other; a particular line of action taken to solve a problem that is identified in practice follows from the frame that has been engaged to set the problem.

... the practitioner's effort to solve the reframed problem yields new discoveries which call for new reflection-in-action. The process spirals through stages of appreciation, action and reappreciation. The unique and uncertain situation comes to be understood through the attempt to change it, and changed through the attempt to understand it. (Schöhn, 1983, p. 132)

When a practitioner sees a new situation as some element of his repertoire, he gets a new way of seeing it and a new possibility for action in it, but the adequacy and utility of this new view must still be discovered in action. (Emphasis added, p. 141)

Schöhn's account is particularly useful for pointing out the complex and important character of "setting a problem" in practice. Let us return now to the distinction between reflection-on-action and reflection-in-action, as this seems to be at the heart of the relationship between the conscious and deliberate attempt to understand and improve intuitive performance.
Reflection-in-action

Reflection-in-action is a construct Schöhn has developed to refer to conscious, verbal problem setting and solving as well as such non-intellectual, non-verbal processes as a jazz musician's on-line improvisations. Reflection-in-action often happens intuitively and engages processes that are manifest in making-sense of complexity at a subconscious level. It involves making on-the-spot-adjustments in action, and, though it is greatly influenced by articulated and consciously deliberated knowledge, it is, nevertheless, not easily reduced to this knowledge base. Of course, it may be examined, in part, through description, but its "locus of control" is in the action itself. Hence, it is possible to produce a description of an action that is obviously inappropriate, or which fails to include a "salient feature" of a performance.

It is true . . . that there is always a gap between such descriptions and the reality to which they refer. When a practitioner displays artistry, his intuitive knowing is always richer in information than any description of it. Further, the internal strategy of representation, embodied in the practitioner's feel for artistic performance, is frequently incongruent with the strategies used to construct external descriptions of it. Because of this incongruity, for example, people who do things well often give what appear to be good descriptions of their procedures which others cannot follow. (Schön, 1983, p. 276)

Schön acknowledged counter arguments to reflection-in-action, citing the story of a baseball player who claimed never to think about his pitching in a game, and the standard story of the centipede that was paralyzed when asked to think about its movement. Four possible reasons may support this line of thought:

1. There is no time to reflect when we are on the firing line; if we stop to think we may be dead.

2. When we think about what we are doing, we surface complexity, which interferes with the smooth flow of action. The complexity that we manage unconsciously paralyzes us when we bring it to consciousness.
3. If we begin to reflect-in-action, we may trigger an infinite regress of reflection-on-action, then on our reflection-on-action, and so on ad infinitum.

4. The stance appropriate to reflection is incompatible with the stance appropriate to action. (Schön, 1983, pp. 277-278)

But Schön goes on to say that if one accepts the distinction between thought and action, reflection-in-action appears to be a contradiction in terms. Clearly, Schön wants to argue that reflection-in-action is not a contradiction in terms if one rejects the myth:

These arguments admit the possibility of reflecting on action (even the pitcher who never thinks during the game is happy to review films of the game in the privacy and safety of the locker room), but they point to the dangers of reflection in action. They contain grains of truth, but they depend on a mistaken view of the relationship between thought and action. Fused together in conventional wisdom, they have become a myth that reinforces the ever-present tendency to mystify the art of practice. (Schön, 1983, p. 278)

Like Schön, this investigator believes that we display much of our knowledge in what we do, and that we are guided in practice by our intuitive "reflection-in-action." Further, it seems right to suggest that our spontaneous actions in practice situations can be influenced by those times when we contemplate about what we have done in a situation, or when we consciously think about what we are doing as we are doing it. The term that Schön uses for this conscious, deliberate form of reflection is "reflect-on-action."

**Reflection-on-action**

Reflection-on-action involves a conscious reconstruction of a practice situation. According to Schön, most situations of practice do not dismiss the possibility of "thinking" what one is doing while doing it:

There are indeed times when it is dangerous to stop and think. On the firing line, in the midst of traffic, even on the playing field, there is a need for immediate, on-line response, and the failure to deliver it can have serious consequences. But not all practice situations are of this sort. The action-present (the period of time in which we remain in the "same situation") varies greatly from case to case, and in many cases
there is time to think what we are doing. Consider, for example, a physician's management of a patient's disease, a lawyer's preparation of a brief, a teacher's handling of a difficult student. (Schön, 1983, p. 278)

Court (1988) questioned the usefulness of Schön's conception of reflection-in-action, and proposed that "reflection-on-action" is the more useful construct on the grounds that it takes into consideration the time required for a careful examination of practice. In the "heat of action," Court argued, there is seldom time to "remove oneself from the situation" in order to reflect. Further, Court found Schön's definition of the "action-present" to be unclear and inadequate:

Imagining Schön's example of a teacher working over a period of time (a whole school year would not be unreasonable) with a difficult student, there would be incidents or days on which the teacher would reflect after the fact, when she could no longer make a difference in that the incident or the day is over. Her relationship with the student is on-going however, so she can still make a difference in terms of the larger picture. In Schön's sense this is the "action-present." But reflecting at home on a Saturday night over a cup of tea, or even in conversation with a fellow teacher on the same day as a troubling incident has occurred does not seem like reflecting-in-action, because the action in which the teacher interacted with the student is over. Reflecting-on-action seems a more appropriate term. (Court, 1988, p. 145)

Beyond finding Schön's use of the term "action-present" wanting, Court suggested that it may be more useful to introduce into the discussion of reflection-in-action the notion of "deliberation."

This is not the term that Schön uses, but deliberation is discussed, in relation to reflection by John Dewey, whose work has influenced Schön. Deliberation and reflection both involve a kind of "thoughtful thinking" and both, I would assert, require at least a momentary "time out" from the action. . . . The difference between deliberation and reflection lies, it seems to me, in deliberation being more focussed on a specific problem, more deliberate, one might say, and less free ranging than reflection can be. (Court, 1988, p. 146)

The important question to which Court alludes, is whether the term "reflection" has a significance that goes beyond the term "deliberation." This investigator agrees with Court when she says that the term "deliberation" seems to be more focussed on a specific problem than "reflection." But this is
precisely the point at which this investigator would argue for the importance of the term "reflection." It is useful to recall Joseph Schwab's (1970, 1971) analysis of deliberation in his classic treatment of the "practical arts of the eclectic." Deliberating on a practical problem, according to Schwab, involves examining the problem from a variety of theoretical "lenses," and comparing and contrasting the consequences of taking action according to various views. The question is whether Schwab's "deliberation" would allow the problem to be reshaped to the extent that Schön is referring to with his notion of "reframing." It seems right to say that a practitioner could deliberate on a problem without necessarily reframing it. It also seems right to say that, once reframed, the problem would open up totally new territory for deliberative inquiry to proceed. In this investigator's judgement, Schön is talking about something that goes far beyond the bounds of deliberation when he speaks about problems of practice, through construction and reconstruction, taking on entirely new meanings for a practitioner.

Educating the Reflective Practitioner

To obtain some insight into the issues of designing appropriate educational experiences for reflective practice in general, Schön (1987) has looked toward what he refers to as the "deviant position" of the arts, and he has drawn upon the architectural design studio and the conservatory of music to develop a model of artistry in professional education. He then asks how we might marry the deviant position of the arts with the legitimate role and function of science derived from universities to assist in rethinking the role of practicum in professional education. To that end, Schön has put forward the notion of a "reflective practicum." Although the model is somewhat sketchy--perhaps necessarily so--Schön's illustrations of professional education for reflective
practice are rich in detail and they make his analysis of professional education compelling. But these ideas have yet to be translated and applied to the context of teacher education for reflective practice, a task which the remainder of this document addresses.

Before moving to Schön's notion of a reflective practicum, it will be well to review the general orientation to professional thinking that has been put forth thus far. First, reflection-in/on-action is an account of professional thinking that focusses on problem setting and problem solving. Problem setting involves framing and reframing practice situations—in short, assigning new significance to particular events or experiences. The main ingredient of what this study aims to set out in observational criteria is already foreshadowed: the central feature of a reflective practicum is reflection itself. It is the act of reconstructing experience and it is accomplished when a practitioner can see a situation in a new light. Thus, for Schön, much of the matter of learning a profession has to do with learning the competence of framing and reframing problems of practice. Of central importance is what might be thought of as the "reconciliation" of reflection-on-action, when the practitioner might overcome the paralysis that may accompany becoming aware of a particular representation of his or her current understandings of practice, and achieve a greater level of performance.

The Reflective Practicum

One important feature of Schön's conception of a practicum setting is that it provides a "virtual world," that is, a world that represents the practice world, but which allows the student to experiment at lower cost. In the context of teacher education, this notion needs to be unpacked. The student teacher's reality in a practicum is becoming part of a school, albeit in a special role.
And, the cost of student teaching can be very dear. Supervisory dialogue and the student teacher's own internal dialogue may provide a virtual world, depending on how we choose to use the term, but, in the end, the student teacher is actually immersed in the practice setting. However, experimenting in this situation may indeed be costly as students' self-esteem, their ability to continue with the practicum, or even their future job prospects may be "on the line."

A second feature of a reflective practicum has to do with the supervisor, or "coach," to use Schön's term. The practicum situation of learning by doing in the context of science teaching should involve the supervisor as a helper—someone who is sensitive to issues and concerns of becoming a science teacher. Third, the competence to be learned in practicum is a design-like competence; it is holistic, it involves reflection-in-action and reflection-on-action, characterized by the framing and reframing of indeterminate situations.

Professional competence, according to Schön, is the sort of thing about which one could say either you get it as a whole, or you don't get it at all. The beginning of practicum is likely to be confusing and mysterious since the competence to be learned cannot simply be told to the student in a way that he or she could at that point understand. Even when the coach is very good at describing what he or she does, the likelihood of the student grasping the meaning that the coach has in mind is very small. Under these circumstances some students discover that they must learn the required competence for themselves; they cannot be taught it. Yet, as time passes by, some students and coaches begin to communicate effectively. They begin to finish each other's sentences, or leave sentences unfinished, confident that their essential meanings have been grasped. Of course, some students never do understand what the coach is talking about, and some coaches never get through to their
students. Nevertheless, many succeed in crossing an apparently impassable communications gap to achieve some degree of convergence of meaning.

Schön (1987) has proposed three "coaching models" to characterize a reflective practicum: follow me, joint experimentation, and hall of mirrors. These are not mutually exclusive models; rather they point out three analytically distinct features of a reflective practicum that may, in the end, blend together in practice.

In the dialogue of coach and student, each of these approaches calls for a different sort of improvisation, presents different orders of difficulty, and lends itself to different contextual conditions. (Schön, 1987, p. 295)

It is important to remember that the three approaches to coaching are idealized types. In practice, a coach may shift from one coaching model to another, or the several approaches may be combined.

The "follow me" model is foundational to a reflective practicum, suggesting that the supervisor/student relationship involves two component processes: telling and listening, and demonstrating and imitating. The supervisor must at first try to discern what the student understands, what he or she already knows how to do, and where the difficulties are. These things must be discovered in the student's initial performances. In response, the supervisor can show or tell, that is, demonstrate a particular technique that he or she thinks the student needs to learn, or, with questions, advice, criticism and instructions, describe some feature of practice. The supervisor models actions to be imitated and experiments with communication, testing with each intervention both the diagnosis of the student's understandings and problems, and the effectiveness of his or her own strategies of communication. The student tries to make sense of the supervisor's demonstrations and descriptions, testing the meanings that have been constructed by applying them to further attempts to display skilfull practice. In this way, students reveal the sense they have made
of what has been seen and heard.

The model of "joint experimentation" takes an exploratory, analytic stance: the coach joins the student in experiment in practice, testing and assessing the student's ways of framing problems and acting in uncertain situations.

In joint experimentation, the coach's skill comes first to bear on the task of helping the student formulate the qualities she wants to achieve and then, by demonstration or description, explore different ways of producing them. Leading the student into a search for suitable means of achieving a desired objective, the coach can show her what is necessary according to the laws of the phenomena with which she is dealing. . . . From her side, the student's artistry consists in her ability and willingness to step into a situation. She risks declaring what effects she wants to produce and risks experimenting with an unfamiliar kind of experimentation. . . . The coach works at creating and sustaining a process of collaborative inquiry. . . . [he] puts his superior knowledge to work by generating a variety of solutions to the problem, leaving the student free to choose and produce new possibilities for action. (Emphasis added, Schön, 1987, p. 296)

The "hall of mirrors" model points to how the coach's performance, in the very process of supervising the student, is exemplary of the craft that the student is attempting to acquire. Under such circumstances the coach's behaviour mirrors that which he is attempting to encourage in the student.

In the hall of mirrors, student and coach continually shift perspective. They see their interaction at one moment as a reenactment of some aspect of the student's practice; at another, as a dialogue about it; and at still another, as a modeling of its redesign. In this process they must continually take a two-tiered view of their interaction, seeing it in its own terms and as a possible mirror of the interaction the student has brought to the practicum for study. In this process there is a premium on the coach's ability to surface his own confusions. To the extent that he can do so authentically, he models for his student a new way of seeing error and 'failure' as opportunities for learning. . . . But a hall of mirrors can be created only on the basis of parallelisms between practice and practicum--when coaching resembles the interpersonal practice to be learned, when students recreate in interaction with coach or peers the patterns of their practice world, or when . . . the kind of inquiry established in the practicum resembles the inquiry that students seek to exemplify in their practice. (Emphasis added, Schön, 1987, p. 297)

Some students are more successful than others in joining the supervisor in reflective experimentation. These students seem to be distinguished by three qualities (Schön, 1987, pp. 294-5): they are highly rational in their ability to
recognize logical inconsistencies when these are pointed out; they abhor inconsistency and incongruity; and they are ready to test their assumptions by appeal to directly observable data. Further, they are

inclined toward cognitive risk taking: more challenged than dismayed by the prospect of learning something radically new, more ready to see their errors as puzzles to be solved than as sources of discouragement. (Schön, 1987, p. 294)

Schön's conception of reflection-on-action is particularly useful when considering the nature of the dialogue that might occur between a student teacher and a supervisory teacher in a so-called "reflective practicum." Further, the three coaching models seem to be promising starting points for conceptualizing the character and dynamics of a reflective practicum in general terms. The following section develops an analytic scheme for examining the supervisory dialogue collected from such a practicum in the context of constructivist science teaching.

The Analytic Scheme

The analytic scheme that has been developed for the study consists of two parts. The first part is a diagrammatic representation of the interaction of among the student teacher, the supervising teacher, and the domain of "practicum phenomena." The second part of the analytic scheme is a set of statements that characterize the sorts of "agendas," that is, inquiries and dialogue, in which the student teacher and supervisor engage in the context of constructivist science teaching.

It is proposed that the dynamics of practicum can be represented in a similar, though not identical, fashion to the view of constructivist science teaching presented in the preceding chapter. To begin, there is a similar triangular arrangement among the supervising teacher \( (S,T) \), the student teacher
(SₜT), and, in this case, the realm of practicum phenomena (PP) under consideration, as represented in Figure 4.

Figure 4. The Reflective Practicum

Practicum phenomena consist of classroom teaching events—both of the supervisor and the student teacher—and, to a lesser extent, the general interactions among the student teacher, school staff members, and students outside of the classroom context. These phenomena are subject to examination by both the supervisor and the student teacher, and serve as the focus of their discussions. Further, it is assumed that the supervisor and the student teacher experience these phenomena in rather different ways, at least initially, by virtue of the fact that the student teacher is in the position of learning the practice
of the supervisor; in part, he or she is learning to perceive teaching events as the supervisor perceives them.

The supervising teacher has a rather extensive repertoire of ways to apprehend and represent the phenomena under consideration. This repertoire is comprised of a variety of "frames" and "appreciative systems" that allow the supervisor to attend to certain features of practice situations, and not others. Some of these frames, at least those that he or she is able to articulate, are derived from pedagogical discourse, and give rise to "thematic experience" (Brauner, 1987), which, like scientific experience, consists in specialized ways of perceiving events.

By virtue of his or her position, the student teacher does not initially have command over the supervisor's ways of representing the phenomena under consideration; these things must be learned. In the beginning stages of practicum, therefore, and perhaps throughout the practicum in some cases, the student teacher experiences the phenomena under consideration in an "ordinary" manner, relying on ordinary perception, derived through his or her use of ordinary language based upon extensive prior experience in school settings (primarily as a student). As the practicum proceeds, it is hoped that he or she will gradually learn to "see" teaching in the way the supervisor does, thus becoming more familiar with the frames and appreciative systems the supervisor uses to represent and interpret practicum phenomena.

The lower half of the model represented in Figure 4 depicts the different ways in which the supervising teacher and the student teacher experience the domain of practicum phenomena to which they both have access. The upper half of the model, depicted by the two-way arrow between the supervising teacher and the student teacher, represents their communication about the events they have experienced. This communication is of a very special
character, the conceptualization of which is aided by Schön's analysis of education for reflective practice. Two points are emphasized by the diagram. First, pedagogical knowledge must be modelled by the supervisor through the processes of demonstration and description. This is because description alone is insufficient for portraying the meaning of the supervisor's practice. Or, in Ryle's terms, know-how is not reducible to knowing that. The second point that is emphasized by the two-way arrow between the supervising teacher and student teacher is the idea that the student must construct the meanings of the supervisor's model of practice, and then apply those meanings to his or her own practice through imitation. The notion of imitation is explored further in the next chapter. For now it is sufficient to say that Figure 4 emphasizes the idea that pedagogical knowledge, though amenable in part to description, is taught and learned in the context of "doing."

Schön regards instructional supervision as including "any activity that supports, guides, or encourages teachers in their reflective teaching" (Schön, 1988, p. 19). By reflective teaching, he means "giving kids reason":

listening to kids and responding to them, inventing and testing responses likely to help them get over their particular difficulties in understanding something, helping them build on what they already know, helping them discover what they already know but cannot say, helping them coordinate their own spontaneous knowing-in-action with the privileged knowledge of the school. (Schön, 1988, p. 19)

Schön goes on to describe in general terms the sort of reflection on phenomena that takes place in reflective teaching:

- A teacher attends to an odd, surprising thing a kid says or does: she allows herself to be surprised.

- She frames her interpretation of the kids utterance as a puzzle to be solved. She assumes that the kid is making sense and her problem is to discover that sense.

- She gets curious about it and inquires into the puzzle. She invents on-the-spot experiments through which to explore it.
- As a consequence of these explorations, or in their very conduct, she helps the kid connect his spontaneous understandings or know-how to the privileged knowledge of the school. (Schön, 1988, pp. 21-22)

Schön asks how one might help a teacher build her capability for and inclination toward reflective teaching. He notes that there are three levels of attention in the "coach-teacher-phenomenon" triad that are required in order for this to occur:

1. The kid's interaction with some phenomenon.
2. The teacher's interaction with the kid's interaction with the phenomenon: how does she interpret what the kid says and does? How does she think about it, explore it, test her understandings, draw lessons for what she will say and do next?
3. The coach's interaction with the teacher: how the coach understands and responds to the teacher's understandings, feelings, ways of inquiring. (Schön, 1988, p. 22)

Schön represents these three levels of interaction as follows:

\[ \text{COACH (TEACHER (KID'S PHENOMENA))} \]

According to Schön, "coaching" reflective teaching always involves a three-fold task of (1) making sense of and responding to the substantive issues of learning/teaching in the situation at hand; (2) entering into the teacher's ways of thinking about it—particularizing one's description or demonstration to one's sense of the teacher's understanding; and (3) doing these things in such a way as to make defensiveness less likely.

In the context of "constructivist" science teaching approaches, as these were presented in Chapter Four, the agendas for a reflective practicum would include the following general areas of the supervisor and student teacher's inquiries:
1. Exploring the ways in which pupils might make sense of natural phenomena and classroom events. Looking first for apparent incongruities and "surprises" in what pupils say, and then asking one's self how a sensible person could have said that.

2. Investigating the use of language in the discipline of science, in teaching, and in learning science. Attention is focussed on the variety of "ordinary language meanings" that a pupil might bring to the teacher's "scientific" language.

3. Investigating "alternative frameworks," or "alternative conceptions," possibly derived from ordinary language usage, that pupils might hold about the phenomenon under consideration.

4. Searching for evidence that pupils constructed different meanings of classroom events: discussing what pupils might have "seen" in the demonstration, experiment, illustration, etc.

5. Inquiring into the context in which pupils function--their social and family background, individual characteristics and interests, etc. that may come to bear on their interpretations of the phenomenon, or of classroom life generally.

6. Inquiring into the sorts of meanings that pupils might construct from the behaviour of the student teacher or supervisor.

These six "agendas" of a reflective practicum in constructivist science teaching comprise the analytic scheme for the study. Each of the six items has been derived theoretically from a critical analysis of pertinent literature on constructivism and reflection.

Summary

This chapter began with a critical analysis of Schön's formulation of reflective practice. Although several caveats were identified in the course of the analysis, certain ideas of Schön's were found to be particularly fruitful. Among these are ideas about the nature of professional knowledge and how it is learned. First, much of professional knowledge is displayed in action, and is not reducible to propositions. Second, students of the professions learn in the context of doing. Even when a supervisor's description of a practice seems to be particularly good, the meaning that a student ascribes to it is constructed in
the context of action through observing the supervisor's demonstration and then imitating the particular feature of practice in question.

Schön's notions about problem setting, framing and reframing were also seen to be potentially useful for making sense of practicum phenomena. The fundamental idea here is that problems do not present themselves to practitioners as givens, but must be constructed from the "materials of the situation." Efficacy in professional work is seen by Schön to reside in the practitioner's ability to frame and reframe problems--searching, as it were, for better understandings of the situation. Reflection, according to this line of reasoning, is accomplished when a practitioner reconstructs a situation by assigning new significance to features of the situation, or by attending to certain features that were previously ignored. When reflection is accomplished, the practice situation takes on an entirely different meaning for the practitioner, which leads to new possibilities for further inquiry and action.

Finally, those of Schön's ideas that were found to be potentially useful were fashioned together with a constructivist view of science teaching in an analytic scheme for observing and analysing characteristics of a "reflective practicum" in constructivist science teaching. This scheme consists of two parts: a diagrammatic representation (Figure 4) of the interaction among the supervising teacher, student teacher, and practicum phenomena, and a set of six agendas for a reflective practicum in constructivist science teaching. This analytic scheme is used in the following chapter to derive a "clue structure," or set of criteria for identifying patterns or characteristics of a reflective practicum, specifically in terms that address the identification and illustration of Schön's three "coaching models."
Chapter 6

THREE "COACHING" MODELS

As noted in the preceding chapter, Schön sees much of the matter of learning a profession in terms of learning the competence of framing and reframing problems of practice. The role of a frame in setting a practical problem is much like that of a concept in directing perception: it tells us what to look for, and what significance to ascribe to it. Further, Schön suggests that competence in framing problems is the sort of thing you either get as a whole or you don't get at all. The early stages of practicum are bound to be mysterious for students, he says, since this competence cannot be communicated in a form that they would at that point understand. In the context of architectural education, where the focus is on learning to design, Schön describes the failure of effective communication between student and studio master thus:

In the early phases of architectural education, many students who have taken the plunge begin to try to design even though they do not yet know what designing means and cannot recognize it when they see it. At first, their coaches cannot make things easier for them. They cannot tell them what designing is, because they have a limited ability to say what they know, because some essential features of design escape clearly statable rules, and because much of what they can say is graspable by a student only as he begins to design. Even if coaches produce good, clear, and compelling descriptions of designing, students, with their very different systems of understanding, would be likely to find them confusing and mysterious. . . . At this stage, communication between student and coach seems very nearly impossible. (Schön, 1987, p. 100)

Schön has derived from his analysis of practicum experiences in the design studio and other settings three models of "coaching"—follow me, joint experimentation, and hall of mirrors—which he claims should assist participants to move beyond the bind of communication failure in the early stages of practicum. Each represents a possibility for conceptualizing a so-called
"reflective practicum," that is, a practicum in which a student learns how to "see" practice situations as a competent practitioner does. Each of Schön's three "coaching models" is discussed and illustrated in turn in this chapter with excerpts of supervisory dialogue taken from the case studies of Rosie and Kevin's practica. Since these models are investigated with the use of the analytic scheme developed in Chapter Five, this scheme is presented here again for the convenience of the reader. The first part of the scheme consists of the diagrammatic representation of the "reflective practicum" in Figure 4.

![Diagram of the Reflective Practicum](image)

**Figure 4. The Reflective Practicum**

- **$S_T$** - Supervising Teacher
- **$S_T$** - Student Teacher
- **PP** - Practicum Phenomena
In the context of a constructivist view of science teaching, the following set of "agendas" for a reflective practicum were derived theoretically by synthesizing the fruitful ideas from a literature pertaining to constructivism with those emanating from Schön's analyses of reflective practice and "coaching" for reflective practice. These six agendas comprise the second part of the analytic scheme for the study, and are utilized in this chapter to identify the determining characteristics of Schön's three coaching models for reflective practice.

1. Exploring the ways in which pupils might make sense of natural phenomena and classroom events. Looking first for apparent incongruities and "surprises" in what pupils say, and then asking one's self how a sensible person could have said that.

2. Investigating the use of language in the discipline of science, in teaching, and in learning science. Attention is focussed on the variety of "ordinary language meanings" that a pupil might bring to the teacher's "scientific" language.

3. Investigating "alternative frameworks," or "alternative conceptions," possibly derived from ordinary language usage, that pupils might hold about the phenomenon under consideration.

4. Searching for evidence that pupils constructed different meanings of classroom events: discussing what pupils might have "seen" in the demonstration, experiment, illustration, etc.

5. Inquiring into the context in which pupils function--their social and family background, individual characteristics and interests, etc. that may come to bear on their interpretations of the phenomenon, or of classroom life generally.

6. Inquiring into the sorts of meanings that pupils might construct from the behaviour of the student teacher or supervisor.

The task pursued in this chapter involves the application of this analytic scheme to actual practicum events by examining transcriptions of lessons and supervisory dialogue taken from the case studies of Rosie and Kevin in a practicum setting. The analysis below begins with the "follow me" model of coaching, since it is regarded as being foundational to a reflective practicum.
"Follow Me"

Returning to the conceptualization of practicum represented by Figure 4, the two-way arrow between supervising teacher and student teacher is conceived in terms of the follow me model. The supervisor's communication to the student teacher consists in demonstration and description of teaching, both of which constitute the modelling of pedagogical knowledge. Since the student is learning about teaching in the context of "doing," his or her communication to the supervisor is principally conceived in terms of imitation, though not excluding the student teacher's discourse about teaching. The idea is that the student constructs the meaning of the supervisor's model through imitation.

A couple of points should be made at the outset of this analysis. First, the supervising teacher took seriously the notion of "modelling" as it is discussed by Schön (1987). The focus of analysis in the early stages of practicum was on the supervisor's teaching, as he endeavoured to demonstrate and describe features of his own practice. In this respect, the case provides a good example of Schön's "follow me" model of coaching. Second, this supervisor was particularly keen to explore students' intuitive conceptions of natural phenomena, as he emphasized the investigation of their ideas and interpretations of classroom activities throughout the practicum. Accordingly, there were times when the database for supervisory discussion was a video taped record of student group work.

The Context

The following analysis is set in the context of a Grade 10 group of twenty-seven students studying a unit about electricity--their first unit in Science 10, which has just begun following the school semester break. At this time, Rosie was beginning her fourth week in a period of student teaching.
spanning thirteen weeks. At twenty-six years of age, she has completed a Bachelor degree in Engineering Science, and has worked as a metallurgical and packaging engineer for two years prior to entering a Science Education program at U.B.C.

As mentioned in the introductory chapter of this document, at the time of this study Colin was an eighteen-year veteran of physics teaching. He is well known and respected among his colleagues for producing top students in the province—gold medal, scholarship, and "physics olympics" winners, some of whom have become outstanding physics students in Canadian universities. Colin holds a Master of Arts degree in Science Education from U.B.C., and, at the time of this study, was in his third year of participation in a research project at U.B.C. focussing on constructivist teaching approaches.

The database for this portion of the study consists of audio and video tapes and verbatim transcriptions of eight lessons taught over a three-week period in the second month of practicum, interspersed with six supervision conferences (also transcribed verbatim). Especially informative excerpts from these data have been selected for detailed analysis and presentation here, while entire lessons/discussions appear with analytical comments in the appendices.

The classroom teaching centred around a sequence of lessons that Colin had designed for the unit on electricity. The first half of the unit dealt with static electricity, including activities relating to (1) various historical models of the atom and how they explain static charge, (2) charge by conduction, (3) the electrostatic series, (4) factors determining the size and direction of forces between charged objects, and (5) charge by induction. The latter half of the unit dealt with electric current and included an exploration of various ways of producing electric current, problems relating to series and parallel circuits, and the concept of potential difference. The teaching occurred in five periods of
sixty minutes' duration, two of which were devoted entirely to laboratory station work concerning ways of producing electric current and problems relating to series and parallel circuits.

The "electric banana": Introducing Rosie

The first lesson for this study was taken from the latter part of the section on static electricity. In this lesson Rosie was attempting to teach the class about charge by induction, demonstrating the effect by bringing charged strips near a banana that was suspended from the ceiling. The following rather lengthy excerpt from the lesson will serve to orient the reader to Rosie's teaching and the analysis that follows. ("S" refers to an unidentified student, and an ellipsis indicates a slight pause, rather than omitted material.)

Up to the point of the lesson where we enter, Rosie has rubbed a vinyl strip with fur to create a negative charge, brought the strip up to the banana demonstrating that the two are attracted, and asked the students to indicate by "voting" whether they thought the banana was neutral, positive, or negative. The majority of students thought that the banana was positive. She then rubbed a plastic strip with cotton to create a positive charge, and the following discussion occurred:

Rosie: Okay, so let's have a vote again . . . if I charge this strip and make it positive . . . and we said that the banana's positive, then how many people think that nothing will happen this time when I bring the charged strip to the banana? (no hands) Okay, how many people think they will attract? (no hands) . . . the positive strip to the positive banana? Okay, how many people think they will be repelled? (majority of hands)

Sara: They'll be repelled.

Rosie: (demonstrates)

Glen: I don't think the banana likes you.

(the banana is attracted to the strip once again)
Paul: I think that the banana has poles.

Mary: I think the banana is neutral.

Rosie: You think it's neutral, and can move anyways?

Beth: Yeah, that it can be positive or negative.

Rosie: Okay, Paul is saying that he thinks one end's positive and one end's negative. So how would I test that?

Steve: Check them both.

Rosie: Okay, so I'll do this side and see what happens, and then I'll do this side and see what happens. Okay we'll do the side with the stem first. (demonstrates that the stem side is attracted to the positively charged plastic strip) I'll do it on the other side this time. (demonstrates that the other side is also attracted to the plastic strip)

Steve: No, it's pushing.

Rosie: Yeah, it was spinning the one way ... Paul, do you think it has poles? (still demonstrating)

Paul: I don't know.

Rosie: Okay, let's stop it ... it will be easier to see what happens. We all agree that the banana's positive, except for Mary and Steve think it's neutral. Is that right? (both ends of the banana are clearly attracted to the plastic strip) Okay, so what do you think about that? Do you think it has poles?

Glen: That's [the one end] positive and that's [the other end] positive too. So that's ... something (perplexed) ... it's not positive if it's attracting ... if they attract.

Rosie: Does anyone ... okay, so with Paul's idea, we saw that there aren't poles to it ... we saw that when we had a positive strip, it attracted on either end. Then we tried with the negative strip ... with the vinyl strip on one end and it repelled, and we saw yesterday that ... uhm, opposite charges attract. So do you have any ideas on what could be happening? Mary, you said something about the banana being neutral.

Mary: It's neutral, so it's got positive charge and negative charge. So, they attract I guess ... I don't really know.

S's: (laughter)

Rosie: Okay, one sec ... Beth?

Beth: If the banana's neutral and you've got a positive strip,
then it has more protons than the banana. So it would attract it. Wouldn't it?

Rosie: Okay, but when we used the negative strip, it also attracted.

Beth: Yeah, well it's got . . . when you have uh, . . . it has more negative than the banana does.

Rosie: Right.

Beth: So that attracts too.

Rosie: So that attracts. But then the positive strip has more positive . . .

Beth: . . .. than the banana so it attracts as well.

Rosie: But you said that the banana has more positive.

Mary: It's got the same amount of positive as negative.

Rosie: Okay, I'd just like to grab on to Mary's idea about there being positive and negative charges. Now, what if the charges inside that banana . . . the electrons . . . can move around freely. Can you think of a way that . . .. if this banana's neutral and I charge this strip . . . the negative strip . . . now, if the charges are free to move around . . . inside . . . how that would explain that repulsion . . . or attraction rather? (demonstrates again)

Glen: That's vinyl now?

Rosie: Yeah, this is negative . . . it's vinyl.

Glen: So that must be positive.

S's: (silence)

Rosie: What if I told you that the banana could act positive or negative? Then it's neutral. What if I brought the electroscope up here and tested the banana?

S: There wouldn't be enough . . .

Rosie: There wouldn't be enough what?

S: . . . enough charge.

(several students discussing the demonstration)

Rosie: (demonstrates again) So there we go again. So this end of the banana is negative . . . and this end of the banana could be acting like it's positive . . . (tests with the electroscope) I don't think we're going to get anything off the banana 'cause it
doesn't conduct electricity. Okay, well Mary's idea about there being positive and negative charges is is close to what we're talking about. The last time yesterday we were talking about inducing, having charges by conduction by contacting things together. Now, am I contacting the banana when I'm inducing this charge? No. It seems that we can make the banana act like it has a charge without even touching it. Okay, we said that we... this banana is acting like it's positive... because it's being attracted to this negative strip. So what we call this kind of charging is called by induction. So it's making a charge without actually touching it. Now, Mary, your idea about having free charges what actually happens is the charges are free to move around in the banana. And what you can think of as happening is when I bring this charged strip up to the banana, then it pushes all the negative charges away because the negative charges are repelling. So the negative charges go down to the other end of the banana. So you're left with more positive charges... then if you have more positive, they're attracted to the negative. Carl, does that...

Carl: Uhm. (reluctant)

Rosie: Okay, so... so... what was that Carl? Okay, I'm going to go back. Where did I lose you? When I started talking about inducing charges? Is that... okay. Let's not use the vinyl strip. Let's start fresh... and we'll talk about what happens with this positive strip. Now, if the charges are free to move inside the banana, and I make this strip positive... what happens to this end of the banana when I bring a positive strip up to it? Diane?

Diane: Then that becomes positive because...

S: It would have to be negative.

Diane: Oh yeah, it would have to be negative, right.

Lesson 1 continued in this vein for approximately five more minutes, after which Rosie introduced a laboratory activity showing how a thin stream of water flowing from a tap can be attracted to a charged object, thus demonstrating another context in which the principles of charge by induction can be invoked. Students wrote notes on the "electric banana," and worked on the lab for the remainder of the period.

The above excerpt illustrates at least three features that were characteristic of Rosie's teaching up to this point in the practicum. First, her ability
to respond to students' ideas while proceeding with her demonstration is commendable. Though she is the person who actually charges the strips and holds them up to the banana, it is the students who are directing her trials. So, for example, when Beth and Steve have the idea to test both ends of the banana, she does so for them. Colin described this characteristic of Rosie's teaching in terms of "thinking on your feet," and he made a point of drawing it out and complimenting her on it. But we can also see in the excerpt that, though Rosie responds to students' ideas concerning trials for the demonstration, she misses some of the significance of what students say in the way of explaining the behaviour of the charged banana. Paul's idea about the banana having poles is very insightful. If one imagines that the electrons inside the banana can move freely, and that they are attracted to a positively charged strip, repelled from a negative strip, then one can readily imagine that the banana has poles when it is charged. When the negatively charged strip is brought up to one end, that end will become positive, the negative electrons being repelled to the other end of the banana. If the positive strip is brought up to the same end of the banana it will become negatively charged, the electrons being attracted to that end. In either case the banana will have poles, thus it is attracted to a negative strip at one time, and a positive strip at another. But, in reference to Paul's idea, Rosie announced to the class that they "saw that there aren't poles to it."

A third characteristic of Rosie's teaching, illustrated in her rather lengthy monologue explaining charge by induction toward the end of the excerpt, may be familiar to those readers who have practised clinical supervision with student teachers. This is a pattern that might be called a "teacher elaboration" pattern (Kilbourn, 1982), whereby the teacher often elaborates a student's idea, contributing much of the reasoning or explaining herself. The responsibility for
solving puzzles and making connections among ideas is seen to be the teacher's, and the pattern of elaborating students' responses gives them the implicit message that she will do the conceptual work for them. Colin recognized the elaboration pattern in Rosie's teaching, and this became one of the principal foci on which the practicum would proceed. In the language of traditional clinical supervision, Rosie's tendency to elaborate students' responses was the "salient pattern" with which the Colin planned to intervene.

The Supervision Setting: Introducing Colin

On the day following Lesson 1, after Rosie and Colin were given a transcription of the "electric banana" demonstration, and they had watched the lesson on video tape, a supervision conference was held during which the technique of pattern analysis was introduced. The following excerpt of that conference is pertinent to the "teacher elaboration" pattern. ("C" identifies the speaker as Colin.)

Colin: One of the . . . uh . . . things that I've noticed is that you take on a lot of the responsibility for what is happening in the class. And by that I mean . . . you see it as your role to always explain things. Now what I mean by that is . . . in this transcript . . .

Rosie: 'To make sure they have their thoughts straight.

Colin: Like, if you go through this transcript here . . . like there's these numbers of words that you use [points to Rosie's rather long utterances], and the student responses are quite short. And then there's a longer explanation . . . and a short response . . .

Rosie: Pontificating.

Colin: No, you're not pontificating. But it seems as if . . .

Rosie: I'm just trying to clarify it.

Colin: You're doing a lot of the explaining. Do you see what I mean?

Rosie: Well, isn't that what teachers do? Like, that's a part of it, isn't it?
Colin: Well, can you think of maybe . . . well, of course it is. But can you think of sometimes another way of doing that? For example, uhm, here's an example. Uh, I wrote this down . . . it's a sequence. Somebody . . . you asked a question . . . uh, "What did Mary say?" And she didn't know. And you said, "Mary said you need a good foundation." Now, that's just a small thing. And that was true . . . that was fine. But you could have done the same thing by asking Mary, "Mary, what did you say?"

Rosie: Yeah, ". . . say it a little bit louder."

Colin: Or, "Beth, what did Mary say?" So what I'm saying is maybe a little cross-reference in the class would accomplish many of the same ends that you achieve by . . . being referenced to you.

Rosie: Yeah, 'cause I guess quite often the kids, when they answer, I can hear them 'cause I'm really conscious . . . of trying to hear them. But most of the kids don't hear what they're saying. And so if I just get them in the habit of saying, "Okay, can you repeat that," or whatever, instead of . . . 'cause I know . . . I guess that's what I was doing today. I was basically repeating it for all the people that didn't hear.

Colin: Well, I think that your explanations are good. But the way I see the objective here is to gradually, as much as possible, give over the responsibility for learning to the kids. And they will . . . I think they're quite willing to take that on, but they have to learn what you mean by that. But if you're always seen in the explaining role, well that's the role that you will be cast in.

Rosie: Is that what most teachers are like?

Colin: I don't watch many teachers, actually. But I think that, as teachers, we tend to talk too much. (5 second pause) Oh yes, we talked about tomorrow . . . what do you think about planning it in that way that we discussed? Bring a couple of examples of things that you think are triggers of change.

Rosie's response to the issue that Colin raised about her doing much of the explaining in class is important for at least two reasons. First, it is not clear that she understands what he has in mind when he speaks about "giving over the responsibility for learning to the kids." She construes Colin's concern in terms of repeating student responses for the benefit of those who couldn't hear them. This may be a result of the particular example that Colin chose to illustrate his point about the teacher elaboration pattern. Another interpretation is that in the process of defending her teaching Rosie has failed to see the
effect of the elaboration pattern on pupils in the way that Colin does. Such speculation must be taken as circumstantial, given a rather limited database. However, Colin's apparent failure to communicate effectively is interesting in its own right, telling of the difficulty inherent in the expression of ideas about something as complex as teaching. It may be the case that Rosie is unable to grasp his meaning because she has not seen a demonstration of "giving over the responsibility for learning to the kids."

The second important aspect of the dialogue lies in the hint we get of Rosie's conception of what it means to teach. For her, it is common place for a teacher to "make sure students have their thoughts straight"--to assume the role of "the explainer." For Colin, the role of the teacher is to make the provision for students to do their own explaining--to provoke them to work things through for themselves. Again, the issue at hand is complex and it warrants careful examination beyond the bounds of the database available here. Nevertheless, there is sufficient evidence in the above dialogue to suggest that Rosie and Colin are at an impasse with regard to a fundamental premise about what constitutes teaching. The question arises: How might Colin proceed with the practicum, given that Rosie may not be in a position to appreciate what he means in his critique of her teaching? This question lies at the heart of the analysis that follows, and points to the importance of modelling in teacher education.

The predicament that Colin and Rosie face is not unlike the general description Schön (1987) has provided of a "communication gap" that sometimes exists between student and supervisor in the early stages of practicum. Returning to the case of Rosie's student teaching, and the question of how Colin might proceed in portraying what he means by "giving over the responsibility for learning to the students," we go now to the next lesson and
its accompanying supervision conference. There, we see Colin doing the teaching in a concerted attempt to demonstrate, or model, for Rosie some of the teaching patterns that fall under the general rubric of giving students the responsibility for learning. The focus of analysis shifts from Rosie's teaching to Colin's, thus representing a move away from traditional clinical supervision. What follows are excerpts of the lesson, together with portions of the supervision conference in which Colin supports his demonstration by describing four features of his teaching.

**Giving Reason to Students' Ideas**

As the finale to the series of lessons on static electricity, Lesson 2 continued with charge by induction, and concluded with a "debriefing," or review of the section on static charge. Colin began the lesson with a review of the two ways of giving an object charge:

Colin: You've dealt now with two ways to give an object charge. What were they? (3 second pause) What was one way?

Glen: Rubbing? Like you're rubbing something to create a charge?

Colin: Okay, when you rub two things together . . . there's a word to describe that. Yes?

Linda: Positive and negative.

Colin: There are two types of charges. There are two in that. And there are two ways to get those charges. One way was one mentioned by Glen . . . rubbing two things together. What word did described [sic] that case . . . in which we give something a charge by contact? Yes, Mark?

Mark: Conduction.

At this point it is appropriate to leave the lesson for a moment and go directly to Colin's supervision dialogue with Rosie, in which he describes a feature of his practice illustrated in the lesson thus far. Again, the supervision
conference is based on a verbatim transcription of the lesson, and takes place after Colin and Rosie had a chance to view a video tape of the lesson:

Colin: Now, can I tell you what was going through my mind here now? I thought that this first part here ... uh, this was quite deliberate, but on the tape it's quite soft. Uh, there are ... in my view, there are two ways to looking ... looking at a student response. One is to say, "Well, what's wrong with it?" The other is to say, "What's right about it?" Now, here is a question: "You've dealt with two ways to give electrical charge. What were they? What was one?" Okay, so I didn't get an answer to both of them so I said, "What was one?" Ah, the kid said, "Rubbing." Uh, "Like you're rubbing something to create a charge." "Okay, good." And now I've expanded that ... "You rub two things together ..." I didn't use the same words. Uh, it's a bit leading, of course. Sometimes it's wrong to ask a leading question. In my view you shouldn't ask leading questions too much before an activity. But when you're reviewing it ... and make sense of it, it's more appropriate to ask leading questions. But this is the part that I remember. "Okay, you rub two things together. There's a word to describe that." So he said, "Yes, positive and negative." Now, that was not the correct response in my mind ... at least what I meant by the question.

Rosie: Yeah, you wanted conduction and induction.

Colin: Right, I wanted conduction and induction. But what I ... here, this illustrates what I mean. Now, I could say, "No, that's not what I'm looking for. You're wrong." Now, what I did was realize that conduction and induction were two different things ... there were two different charges ... so I tried to validate his response by saying, "There are two types of charge." In other words, I was trying to explain why that person said that.

Rosie: And then still bring it back around to get conduction.

Colin: Right, I didn't stay there. "One way was mentioned." Okay, "Rubbing two things together," and bring it back. Now, that's a pattern that I do quite deliberately. And that's what I mean by validating the students' ideas. That is, try to give some sense to the students' responses. Because, well, one of the things, if you don't do that ...

Rosie: They'll stop responding.

Colin: Yeah.

Rosie: 'Cause they think that, "Well, if I don't have the right answer, then I'll shut up because I'll just get put down, or whatever."

Colin: And instead of saying, "Is that the right answer?" in my mind, I just kind of think consciously, or almost unconsciously now, "What is right about that answer?" Or, "What can I make of that answer?"
Rosie: Uhm hmm.

Colin: But that zipped by really fast on the tape, but I remembered it quite clearly. So, going through my mind as I was doing that . . . I was doing that quite deliberately.

Rosie: Uhm hmm.

The pattern of teaching that is illustrated in the lesson excerpt above and described by Colin in conference with Rosie, is referred to here as "giving reason to students' ideas." As Colin notes in his discussion with Rosie, his intent is to sort out what is right about a student's response, rather than what is wrong with it. The pattern falls into a general constructivist orientation that Colin brings to his teaching. However, what is of more concern to us here is his approach to supervision; a couple of things are worthy of comment at this time.

First, Colin sets the stage for the exercise by providing Rosie with the opportunity to experience his teaching. Only then does he proceed to make sense of it with her. His dialogue concerning what was "going through his mind" during the lesson, and his deliberate attempt to model the pattern, is indicative of the care with which he set about his demonstration. Further, he makes the provision for Rosie to collaborate to some extent in making sense of his teaching. Yet, there is an interesting irony to the situation. In attempting to intervene with Rosie's salient pattern of "teacher elaboration" by demonstrating and describing what "giving reason to students' ideas" means, Colin falls into the dilemma of elaborating on what he does when giving reason to students, etc., rather than demonstrating this process in the conference by giving reason to Rosie's ideas and interpretations of what happened when he taught the class. This is the sort of dilemma that is addressed by the discussion of the "Hall of Mirrors" model below.
Another comment that is worth making here has to do with Colin's recognition that, though he has made explicit a feature of his teaching for the sake of demonstration and description, it is the sort of thing that he normally does almost automatically now. For example, he says, "I just kind of think consciously, or almost unconsciously now, what is right about that answer?" This point underlines the importance of modelling in teacher education. The idea that will be put forth in more detail later is that, while the description of the features of a model are useful and necessary, the demonstration itself may be "absorbed" in a holistic fashion, with only some of its features being statable, or amenable to description. Indeed, as will be shown below, Rosie "picked up" certain features of Colin's demonstration that were never articulated. For the time being, however, let us return to the explicit description of Colin's demonstration.

Caring for Students

With these foreshadowing issues in mind, let us return to Lesson 2, continuing with Colin's review of two ways of charging an object, and moving on to another feature of his teaching: the implicit message that he cares for students.

Colin: Okay. Do you remember that from yesterday? Conduction . . . contact . . . rubbing two things together. Now you had another effect. The other effect was kind of strange. It produced all kinds of results that none of us expected. What was the name for that? And what was different about it from conduction?

S: Induction.

Colin: Okay, the word was induction. What does it mean? How is it different from the idea of conduction? (pause) How is it different from contact. Linda?

Linda: Uhm, it's different because . . . uhm, there's . . . the electrons aren't . . . or the uh, . . . aren't really . . . well, okay . . . like they're moving from one place to another.
Like they're not going away from it? Like you're not losing electrons from the atom. It's just moving ... they're transferring over ... (sigh) ...

Colin: Well, I like your idea a lot. I think this is ... Paul, you remember you were talking about poles on the banana?

Paul: Yeah.

Colin: Well, is this pretty close to what you mean?

Linda: Yeah, that kind of idea, yeah.

In the supervision discussion that occurred about this portion of the lesson, Rosie begins by noting how Colin rewards the students for their responses:

Rosie: Yeah, "Well, I like your idea a lot." That ... yeah, that sort of stuck out in my mind when you said that. I think that was ... it could have been Paul or someone. "I think this is ... well, you remember you were talking about poles on the banana?"

Colin: In that case, what I had in mind was that, actually, not just ... it's nice to reward a good response if you can see the depth of the response even beyond the student immediately. But in that case, that was referring to something the previous day. And what I'm trying to give Paul ... I was thinking, "Yeah, that was such an interesting response, I've thought about it ... and I'm going to tell you that I've thought about it." And Paul will say, "He's thinking about what I'm saying." (3 second pause) But I think that it ... it does a lot of things. One of the things it does is to show that you care about what the kids are saying. And I actually believe that that helps your discipline problems. If you show that you're really interested in their thoughts and ideas, well you're interested in them.

Rosie: Yeah. Well, just something that happened in Evelyn's class today 'cause ... she did the first class and then I did the second class ... and there wasn't much talking. Uh, they're grade eights so they're kind of rambunctious and I was trying to get their attention. And a couple of kids ... I think about five of them said, "Shhh ... she's trying to talk." And I'm going, "Oh, this is great. They're helping me out." And so I don't know ... that was kind of a good feeling. But I think it comes out of that because I try to talk to them individually. And I think that has come out of that in that class as well.

Colin: Well, you can't pretend to care about them, but if you really do and can find a strong way ... you see, caring isn't weakness. And if you can show a kind of strong way to do that ...

Rosie: Uhm hmm.
In this exchange, Colin has pointed out a three-fold implicit message for students that may have accompanied his remembering, from the previous lesson, Paul's idea that the banana behaved as though it had poles: (1) Colin thought about what Paul said, (2) he cares about Paul's ideas, and (3) he therefore cares about Paul. Rosie applied this notion to her own experience teaching another teacher's Grade 8 class: since she talks to some of these students individually, she interprets this as showing them that she cares about them; therefore some of them helped her solve a discipline problem.

Looking Beyond the Words

We continue now with the lesson, and the next feature that Colin describes in his teaching. This has to do with a distinction Colin draws between "words" and "ideas," designed to look beyond the words that students use in an attempt to appreciate their ideas themselves. First, another excerpt of Lesson 2:

Colin: Paul, you remember you were talking about poles on the banana?

Paul: Yeah.

Colin: Well, is this pretty close to what you mean?

Linda: Yeah, that kind of idea, yeah.

Colin: That when you bring an object near, without touching, it separates the charge. So the total thing is zero, but the charge is separated into two parts. [to Paul] Is that what you meant by poles?

Paul: I used different words.

Colin: Well, that's all right. The words don't really matter. Describe it in your own words. So there's a separation of charge involved. That's one feature. The other feature is they don't actually touch. Now, when you have charges without touching, what is the word that describes that again? Sheila?

Sheila: Uhm, (5 second pause)
Colin: Beth, can you help her out?

Beth: Induction.

Colin's questions to Paul and Linda about what was meant by saying the banana had poles falls into the general pattern of giving reason to students' ideas. His discussion in the dialogue with Rosie below illustrates his concern for letting students formulate their ideas, at least initially, using their own words.

Colin: Now, there's an interesting thing here about words. I have quite strong feelings about that ... sometimes the ideas are right but the words are wrong. And sometimes the words are right, but their ideas are wrong. And there's kind of an interesting little piece here. Uh, "So the total is zero, but the charge is separated in two parts. Is that what you meant by poles?" Now, I'm not trying to put words into Paul's ... uh. And his response is interesting. He said, "I used different words." I said, "Well the words don't matter." I guess what I'm saying there is ... I'm trying to give the message to the kids that even if they don't know the words ... I find myself saying that quite often. Uh, now this is quite interesting. "When you have charges without touching, what is the word that describes that?" Now what I'm looking for there is that the idea is one thing ... the word is another. It's, uh, it has some value to know both. But you don't necessarily have a sense of the idea just because you know the word induction. But you should know the word as well at some point. Now, interestingly there's a note on the transcript here of a five-second pause. I remember that, uhm, I think it was Sheila who I asked that question if I remember correctly. And I remember she felt a little uncomfortable. I said, "Okay, just relax."

Rosie: Yeah, 'cause she was sort of formulating it. You could sort of see the crank going ...

Colin: Yeah.

Rosie: Like, you knew she had it there and she just needed to spit it out.

Colin: Actually that's an excellent way of putting it. I had a sense ...

Rosie: 'Cause I remember that too. 'Cause I was sitting here and just looking over and she was kind of ... you know.

Colin: Yeah, it's coming but it's not quite out yet.

Rosie: (laughs)
Colin: I didn't have the sense that... you know, I could sit here until hell freezes over but nothing will happen... which you can sometimes. And you can prompt or whatever. But I feel you can... it's not exactly getting kids off the hook. I mean, you're describing... developing a trust situation and you say, "Okay, I can wait for you." And then you get it out in a half-formed way... and it comes out, and what you're saying is you're prepared to give a person a bit of time... and that you're really interested in what they have to say.

Colin suggests to Rosie that by allowing students to use their own words to formulate their ideas, and by giving them ample time to do so, one establishes a sense of trust in the classroom. The implicit message for students, once again, is that their teacher is genuinely interested in what they have to say. Once students have had a chance to communicate their ideas, it may be appropriate to establish the correct words, that is, the words accepted by the scientific community, as the next excerpt of the lesson illustrates.

Colin: Now when you have charges without touching, what is the word that describes that again? Sheila?

Sheila: Uhm, (5 second pause)

Colin: Beth, can you help her out?

Beth: Induction.

Colin: What is... how do you spell that?

Beth: I-N-D-U-C-T-...

Colin: Okay, so it's spelt with an I... IN... duction... no contact. Looking at each other, gazing across the room.

The excerpt of supervision dialogue that accompanies this episode of the lesson focusses on the memory device Colin developed in the lesson for remembering the difference between induction and conduction.

Colin: At this point I had been working on the concept... and then we were trying to remember just what is the term for that and uh...

Rosie: An acronym, something for them to hold on to in context.
Colin: Yeah, it's a mnemonic device. Sort of a ... bit of a memory thing. I mean that's why you used contact, conduction. Not because they are exactly the same meaning but ... I don't know how other people's minds work, but that's how my mind works and I remember things based upon those things.

Rosie: Yeah, just like on the voltage. On the negative and positive terminal.

Colin: That's exactly what I was going to say. You used it today.

Rosie: Yeah, because that's the only way I can remember things.

Colin: Remember you said that the short line [circuit symbol for the negative terminal of a cell] is like the negative sign. You know, I was just going to use your example. Okay.

A parallel between Colin's handling of Rosie in the conference and the practice of classroom teaching he is demonstrating can be seen in the way he rewards her example of a device she used to help students remember the standardized symbols for the terminals of a cell. The implicit message for Rosie is that her example is a good one; she is on the right track.

Making Lessons Interesting

The final feature of Colin's teaching that he described in the supervision conference dealt with the relationship between student interest and discipline. At this point in the lesson, he moved from his initial review of charge by conduction and induction, to an "electrophorus demonstration" of the four steps required to charge an object by induction. The thing of interest in the following rather lengthy excerpt is how Colin teased the students when they could not get the electrophorus to work. Of course, at that time they did not know the steps that were necessary to charge the electrophorus, which may be one of the reasons why they became so enthusiastic about finding out its secrets.
Colin: Now, uh, I want to look at one example to actually illustrate that... that in kind of a puzzle. This particular experiment doesn't always work extremely well because of the day. We did try it earlier. 'Hope it's not going to embarrass me now.

S: Are you recording it?

S: Every precious word is put down in writing.

Colin: Now, this thing here (holds up an L.P. record) is made of plastic. What kind of plastic do you think it is?

Sheila: Vinyl.

Colin: Because it is vinyl... do we charge it with the fur? So I'm putting a charge on the record. (rubbing in a circular motion)

S: (notices that the record is warped)

Colin: Do you know why that's warped?

S: You left it in the car?

S: From heat.

Colin: Actually I thought I was being really smart and I ended up being really stupid. You see, electrostatic experiments work much better when things are dry. So I put it over there in the fume hood under the heat lamp, and I didn't have it flat. And I heated it a bit too much.

S: What record is it?

S's: (discussing among themselves)

Colin: What record? This is Bach. Now you think it was warped before was the record was melted. (rubbing in a circular fashion) Uh, I'm not trying to listen to the record... vinyl... I notice I'm getting a charge. If this is vinyl what kind of charge will it be... positive or negative?

S's: Negative.

Colin: And you know by... because of the electostatic series. Now, where's my charge transfer? Have you seen this before? (holds up a metal disk with a glass handle in the middle) It's a plate that has two different kinds of materials on it. How is this part different from this, Harry?

Harry: Well, it isn't metal... like one part conducts and the other part doesn't.

Colin: Which one?
Harry: The metal will conduct.

Colin: Okay, so this is a good electrical conductor. There are different types of conductors . . . you can conduct heat, for example. So this is a good electrical conductor. And what you can do (demonstrates) here . . . (puts metal disk on the charged record, then holds it up to an electroscope; the needle doesn't move) Well imagine that. I think that we could try the other plate. Uh, Jennifer could you get that?

Bill: (inaudible)

Colin: I'm not sure what you mean by that Bill . . .

Bill: Okay, uhm . . . you said that somebody thought the metal conducts . . .

Colin: Yes, this metal conducts . . . and this [the glass handle] is an insulator. So I can hold it by this (demonstrates) and I can carry it around. Steve, would you turn it [the record] around to the other side please?

S: Side two.

Colin: You see what I've done . . . is I've transferred charge from there . . . uh, what am I doing now? (ouches the electroscope) Jim?

Jim: Grounding.

Colin: What does that mean?

Jim: You're getting the extra electrons off. The electric charge.

Colin: Okay, good . . . so I'm neutralizing it.

Jim: Yeah.

Colin: (demonstrates that the metal plate will move the needle of the electroscope: the plate has been charged, apparently by being touched to the charged record) Now did you watch that closely? Uhm, Glen? Earl, Can you do that?

Earl: I'll try. (attempts the demo, other students giving instructions. The electroscope needle doesn't move)

Bill: Okay, so you have to rub it.

Colin: Okay . . . rub it then. Take it off . . . okay . . .

Earl: (tries again, and the needle barely moves)

S: It's wearing down.
Colin: Is it wearing down?
S's: Yeah.
S: It's wearing up.
Colin: It's still working.
S: But it doesn't go around as far.
Earl: (tries again . . . the needle still doesn't move)
Colin: You disappoint me . . . you think I've been tricking you.
S's: (laughter)
S: Real good Earl.
Colin: Well, I don't know what's wrong. Are you concentrating?
S's: (laughter)
Colin: Are you letting your mind wander all over the place?
S: He's probably holding a charged magnet.

As the above portion of Lesson 2 illustrates, Colin's students were captivated by how he could make the needle of the electroscope move with the electrophorus. However, Rosie took Colin's behaviour as "playing dumb," or "joking around," seemingly unaware of its effect on the students' enthusiasm.

Rosie: Oh, here . . . just about you playing dumb.
Colin: Oh yeah.
Rosie: Uh, Colin: "You disappoint me . . . you think I've been tricking you." And the kids laugh. "Well I don't know what's wrong."
Colin: (laughs)
Rosie: (mimics) "Well I don't know what's wrong. Are you concentrating? Are you letting your mind wander all over the place?" "He's probably holding a charged magnet." That was good.
Colin: Actually, they thought I had something up my sleeve.
Rosie: Well that's what I did too.
Colin: (laughs)

Rosie: When I was watching it.

Colin: Actually, that part of it ... I was enjoying myself so much I didn't really have any deliberate ... I was just . . .

Rosie: . . . joking around.

Colin: Well I . . . in a way, but what I was . . . if I was trying to illustrate anything it was that you can have fun at what you're doing. I was just having fun . . . playing dumb and doing these sorts of things and I think it has . . . it adds something to the lesson in fact, I think, you could probably say why you do that. I mean I was enjoying . . . you can lose yourself in a situation at times. (3 second pause) One of the interesting things I've noticed is that . . . uh, if you look at concentration span, there have been times when you have had quite long lessons. But the kids have really been interested. (5 second pause) Isn't that true?

Rosie: Yeah.

Colin: Why do you think that is?

Rosie: Well, there was stuff for them to do. They were . . . I think I have a pretty good attitude towards the kids. And that's coming . . . what I was hoping when I went into teaching, 'cause I'm not one of these over-bearing . . . I was bit worried about discipline, but I figure, well if I treat them as people then hopefully . . . I think most people if you treat them well, they'll treat you well back, sort of. And so that's sort of my philosophy I guess. I mean discipline . . . except I know I have to come down harder and they'll be a little bit . . . I mean I find myself a bit wishy washy. Uhm, now I don't know what my point was.

Colin: Well, what we were talking about was how you can have long lessons and the kids stay interested.

Rosie: Yeah, and so I think because of that the kids know I pay close attention to them, they will pay closer attention to me. You know what I mean? Like if somebody has a question . . . I mean I try always to get back to them, even . . . I see them raising their hand and then they put it down. And if I notice that I'll still say, "Well, did you have a question?" And so I think that because I'm interested that that comes back . . . that's part of it.

Colin: I think you've put together several things there. One is that discipline comes from that kind of atmosphere. And I think the other thing is that discipline is not an end in itself. You know sometimes a discipline problem can come out of the fact not just because they don't respect you . . . that's one reason. If they like you or respect you they'll behave themselves. But there's another. They might like you and respect you and still be a discipline problem because you're too dull. It's uninteresting. You don't really care about what they think. And I think one of the things that's happening is that some of your
longer lessons . . . it's just remarkable how the kids have been quite intrigued. It's because you're making it interesting. Now, they do like you. But it's also because they're interested in what they're doing.

After making the point that one can enjoy one's self in the classroom and, at the same time, bring about a sense of wonderment with a discrepant event and a little teasing or humour, Colin invited Rosie to reflect on why students found some of her lessons interesting, despite their length. It is interesting that Rosie interprets students' attention in terms of their discipline, rather than their interest, as Colin does. For her, student attentiveness is associated with good deportment, which is a result of mutual respect. For Colin, student attentiveness is associated with an interesting lesson, good deportment being a by-product. Again, we see some evidence of a rather fundamental difference in the way Colin, an experienced teacher, and Rosie, a novice teacher, construe an aspect of teaching.

The fact of the matter is that while Rosie had taught a few interesting lessons, she lacked enthusiasm in much of what she did in the classroom. It was Colin's opinion that she required more cadence in her voice, and generally more "pizzazz," to use his term, in her teaching. Indeed, making Rosie's lessons more interesting was a concern. What is seen in this dialogue is Colin's attempt to have Rosie think about her teaching more in terms of whether it is interesting for students. In effect, through demonstration and description, he is attempting to provide Rosie with a new "frame" for judging her teaching.

Imitation

Having taken a look at Colin's demonstration and description of four features of his teaching—giving reason to students' ideas, caring for students, looking beyond the words, and making lessons interesting, it will be well to return to Rosie's teaching to see whether some of the other features of the
model can be identified. As noted in the introduction to this chapter, the analytic scheme for observing and analysing a reflective practicum in constructivist science teaching features the role of "imitation." Unlike its use in ordinary language to mean something like "mimicry," the sense of imitation developed here means a highly creative and constructive process, much like Aristotle wrote about with his concept of "mimesis" (Edel, 1982, pp. 349-352). According to Aristotle, all learning in the practical and productive arts is based on this special form of imitation.

In search of the elements of Colin's model of teaching, we go to a brief excerpt from the final minutes of Lesson 2 where Rosie has taken over the "debriefing" of static charge, and is attempting to review the steps required to charge an object by induction. (The four steps of charging the electrophorus by induction, which Colin taught in the middle portion of the lesson, are not essential for the reader to know at this time.) It is important to point out, though, that this teaching episode occurred before Supervision Conference 2, that is, before Colin described the features of his model. Of interest to us is the supervision dialogue concerning this episode that occurred in the last portion of Conference 2, after the model had been described.

Rosie: Okay, the last thing we're going to cover in debriefing is induction, which we saw yesterday and today. Number six . . . (pause) Induction (writes). Okay, first of all I'll give you a little definition and then we'll talk about the conditions that are required. (writes) A charged object is brought close to a neutral object . . . and the neutral object . . . becomes charged . . . then we say that the neutral object has been charged by induction. (pause) Now you saw today there were four conditions necessary for charging an object by induction. Can anyone remember what the first condition was? Ruth? Oh, I'll let you finish copying this down.

Glen: What does that mean . . . condition?

Rosie: Oh, there's four conditions. Sandy, can you think of a condition?
Sandy: (silence)

Given the nature of Colin's model, the reader might be able to predict Rosie's response to this episode when, during the supervision conference, she came across it again in the transcript. To be sure, there was a problem with language:

Colin: The first kid you asked didn't know them. Isn't that right?

Rosie: Yeah, but I think it was . . . that's what I was wondering . . . if it was the way I had worded it or something.

Colin: Yeah, let's look at that. I remember that.

Rosie: I called them conditions.

Colin: Yeah, you see it was a different word.

Rosie: Okay, "You saw today there were four conditions necessary for charging an object by induction. Can anyone remember what the first condition was? I'll let you finish copying it down." "What does that mean, condition?" "Oh, there's four conditions. Can you think of a condition?"

Colin: Yeah, do you see what's happening there?

Rosie: Yeah. So they just . . . 'cause I used a different word.

Colin: Yeah, it was a different word suggesting a different idea.

Rosie: Uhm hmm. Well you just called them four steps. To me . . . I guess that's the thing. To me it seems like the same word. But I know what I'm talking about. It's not the same word.

Colin: Well, to my mind, what the difference between step and condition is that "condition" describes four things that exist at the same time, whereas "step" suggests a sequence. Condition does not.

Rosie: Yeah.

Colin: So when you used that word, I thought to myself, "That suggests in my mind something slightly different than the word step." But in your mind condition might have meant that.

Rosie: Yeah, I guess that was the first word that kind of fit. I didn't have it clear or something . . . how to present it, so . . .

Colin: Well, I guess what it illustrates, though, is that condition is certainly
a more complex word than step, so there are more complex words like induction and conduction that you want them to know. But, other than that, it is probably wise to use as short and simple words as possible. But the problem I think in that case was not that they didn't know the four steps, but that they weren't sure about what you meant by condition.

Rosie: Oh yeah. Because I sort of led them back to what they were doing. And I sort of had to . . . long windedly . . . and then they came out with it.

Whether or not Colin was aware of it, there is a very interesting move on his part at the opening of this excerpt. His making as if the first student didn't know the steps of charging an object by induction (the initial framing of the problem) is analogous to the sort of interpretation that a naive teacher might make. By putting it forth, he fashions an environment within which Rosie can "reframe" (Schön, 1983), or reconstruct, the problem from an alternative point of view, namely, that which is concerned with the distinction between words and ideas (as discussed by Colin earlier in Conference 2). For Rosie, "condition" meant the same thing as "step" at the time of teaching. However, after reading the transcript, she realized that students cannot be assumed to take the two words as being equivalent, and, in so doing, reframed the problem in terms of the meaning students might attach to the word condition. Here, then, is a case in which Rosie looks on her teaching using a frame that Colin has provided in his model, the description of which came earlier in the same conference.

Another issue that arises is the extent to which Rosie internalizes and actually tries to use some of the previous ideas and frames that have been layed out in earlier supervisory conferences. We would expect to see evidence that these ideas and frames are being put to use by Rosie—both in her teaching itself and in the way she observes and understands her teaching in subsequent supervisory conferences.
With this in mind, we move now to a point in the practicum 11 days later, to Lesson 5, which dealt with the debriefing of electric current. Rosie had assigned a set of problems dealing with various units used in measuring charge, current, resistance, potential difference, and so on. We enter the lesson at the beginning, just after she has handed back the assignments, and is about to take up the questions:

Rosie: Okay . . . the first few questions most people didn't have any problem with. (students talking) Can I have your attention? (3 second pause) Okay, the first few questions most people got right, so I'll just go through them orally. If you know the answer, raise your hand and we'll go through them. And the word problems I'll work through on the overhead. Okay, the first one. Number one . . . what is meant by the term circuit? Sheila?

Sheila: Uhm, the complete path of electric current.

Rosie: Okay, so it's a complete path. Uh, number two . . . how many electrons are there in one Coulomb of charge? Fred?

Fred: I don't know, I didn't do that one. I haven't done it.

Rosie: Okay, yeah, that's right. You weren't here. Jim?

Jim: Uhm . . .

Rosie: Number two . . . how many electrons are there in one Coulomb of charge?

Jim: In one Coulomb of charge there are $6.24 \times 10^{18}$ electrons.

Rosie: Right. Okay now, the third one . . . a few people had a bit of problem with the math. Number three . . . how many electrons are there in three Coulombs of charge?

S: Are you left-handed?

Rosie: Yeah, I'm left-handed. I've been left-handed for three weeks, at least.

S: More than that.

Rosie: It's a left-handed way of making check marks. Okay, how many electrons . . . (writes) . . . in three Coulombs? Sandy, did you get that one? Okay, what did you have as your answer?

Sandy: (inaudible) . . . times . . . (inaudible)
Rosie: ... times ten to the ... okay, that's right. I just gave you half 'cause you didn't multiply it out. Harry, what would be the answer on that?

Harry: Uh, $1.7 \times 10^{19}$ electrons.

Rosie: Now, Glen, there were a few people ...

Glen: That means three point ... no, it doesn't ... it means $Q$.

Rosie: No, okay ... some people had that equals $6.24 \times 10^{18}$

Glen: Look at it ... it says, what is ... how many electrons ... or what is the question?

Rosie: Number three.

Mary: It's multiplication.

Rosie: Yeah, Mary can you explain why this answer isn't correct ... to multiply it this way?

Mary: It's not multip ... uh, because it's ... there's three of them there ... not to the third power.

Rosie: (pause)

Earl: I got it right.

Rosie: Glen, can you explain why you ...

Glen: What is the question?

Rosie: It's number three. Okay, they're asking, "How many electrons are there in three Coulombs of charge?"

Glen: And a Coulomb equals $6.24 \times 10^{18}$

Rosie: Right.

Glen: So if you just times it, you won't get ... you won't get a Coulomb of charge ...

Cindi: Eighteen.

Glen: I don't know, but you have to cube it.

Rosie: Cube it? Earl? Okay, let's say ... okay, let's look at a smaller number Glen. Okay, 'cause there are a few people that did this and I want to make sure people understand why this isn't the correct way. Okay, Glen, let's say that we had ... let's say I was multiplying this number ... three times ... five times ten.
Glen: One hundred and fifty.

Rosie: Why wouldn't you go (writes 50 x 50 x 50) ... what would that be?

Glen: That would be . . .

Rosie: It would be fifty cubed . . .

S: One hundred and twenty-five thousand.

Rosie: Yeah, one twenty-five thousand. Now do you see the similarity?

Glen: I know the similarity . . . it's just the question. No, I know how to do that.

Rosie: You know how to do . . . okay. Number two asked, "How many electrons are there in one Coulomb?" Glen, maybe you can see me after class and I'll explain that.

Glen: Okay.

It is difficult to say what Glen may have been thinking during this exchange. As it turned out, he didn't stay after class to sort out question three with Rosie. But one thing that seems fairly certain in hindsight is that by asking, "What is the question?" he meant, "What does this question mean?" or, "What is this question asking?" Of course, Rosie took him to mean, "Which question is this?" The following is the pertinent discussion between Colin and Rosie.

Colin: Uh, there was a point here on the second page . . . uh, "Some people had that equal to six point two four times ten to the eighteenth." Glen: "Look at it . . . it says what is . . . how many electrons . . . or what is the question?" Now, what do you think that student meant? (8 second pause) How did you respond to that? (20 seconds, as Rosie reads over the transcript)

Rosie: Yeah, this is Glen: "That means three point . . . no," . . . oh, here, you mean.

Colin: What was the question . . . and what was your response?

Rosie: Number three.

Colin: Well, did they mean, "What question number are we working on?" Is
that what the question meant?

Rosie: Oh . . . oh, I see. He's saying, "What's the question asking?" And I'm saying, "Well, the question number is number three." And then . . . (13 second pause) . . . and then he asked again, "What is the question?"

Colin: And this time you pick it up.

Rosie: "Okay, they're asking how many electrons are there in three Coulombs of charge?"

Colin: That's right. You see here . . . it's an interesting pattern because he's saying, "What does the question mean?" And you're saying, "It's number three."

Rosie: (laughs)

Colin: (laughs) And then he comes back and says, "What's the question?" And you say, "It's number three," and what it means, which is what he wanted in the first place. It's uh . . . those sort of things happen all the time. It's very hard to understand what a kid means all the time. One of the things . . . I think it's a really good . . . you've created a nice atmosphere in that. Glen knows you didn't understand what he meant. And he's not afraid to come back.

Rosie: I was surprised, actually, that he was having problems with that. Anyways . . .

Colin: The thing is that communication is a two way street. Sometimes they don't understand what you mean, and sometimes you don't understand what they mean. You've got to sort that out. Uh, I like this where you said . . . you dealt with the powers of three. You recognized that that was the problem.

At this point in the practicum, Rosie is more familiar with Colin's ways of making sense of teaching. As illustrated in the above excerpt of supervision dialogue, she makes sense of the lesson excerpt appropriately, once he reframes it for her. In other words, one can begin to see in Rosie's analysis of her teaching the sort of thinking that we would expect, given Colin's explication of the features of the demonstration he has provided. As Lesson 5 continues, there is further evidence that Rosie is beginning to develop some of the patterns of teaching that Colin has modelled. Specifically, there are two areas in the following excerpt where Rosie attempts to imitate Colin's "giving reason to students' ideas":


Rosie: Okay, number four . . . what is an Ampere of current? Jennifer?

Jennifer: Uhm, (reads from notebook) an Ampere of current is one Coulomb per second.

Rosie: Right, and what does an Ampere measure?

Mary: Current.

Jennifer: Yeah.

Rosie: Right, current. That's good. Okay, number seven . . .

S: Five.

Rosie: Oh sorry, number five . . . what is meant by the term potential difference? Merv?

Merv: Is this number seven?

S: Five.

Rosie: Or . . . sorry, number five. What is meant by the term potential difference?

Merv: Uh, I tried that, but I had difficulty with it.

Rosie: Were you here on Thursday? Do you remember . . . we were discussing potential difference. Don, maybe you can help him out.

Don: Joules divided by Coulombs?

Rosie: Right, that's the units we used. So what would potential difference be a measure of?

Don: Volts.

Rosie: Okay, yeah . . . it's measured in volts, and you said that potential difference is measured in Joules per Coulomb. Now, okay . . . well, what I'm looking for is that potential difference is a measure of energy. It's a measure of energy per charge . . . per unit charge . . . that's why it's Joules per Coulomb. Okay, number six . . . what does it mean to say that a battery has a potential difference of ten Volts? Bill?

Bill: (15 second pause) Uhm, capable of delivering a certain amount of energy?

Rosie: Uh . . . (gestures for Bill to repeat response)
Bill: Capable of delivering a certain amount of energy?

Rosie: Beth, can you say . . . I can't hear what Bill's saying.

Beth: Do you want me to move? (laughter)

Rosie: No (laughs) I mean can you repeat it a little bit louder?

Beth: Capable of delivering a certain amount of energy.

Rosie: Okay, and how much energy would that be? If we're saying that the potential difference is 10 Volts?

Beth: (to Bill) Okay, tell me your answer.

Rosie: Well, or, Bill, just speak louder.

Bill: How much energy?

Rosie: Okay . . .

Bill: I thought you said, "What does it mean." Okay . . .

Rosie: . . . if the potential difference is 10 Volts.

Bill: (11 second pause) Uh, 10 Volts.

Rosie: Okay, or 10 Joules per Coulomb. Okay, number seven . . . what is the function of a battery in a closed electrical circuit? Cindi?

When Rosie asked Don what was meant by the term "potential difference," she was expecting the answer, "a measure of energy." When he answered, "Joules divided by Coulombs," and then, "Volts," she gave reason to his responses, much like the way Colin demonstrated.

Further, a significant change can be seen in Rosie's teaching insofar as the "teacher elaboration" pattern is concerned. The long utterances in which Rosie provided so much of the conceptual work of the class have disappeared, replaced by a rather consistent demand that the students work things out for themselves. Even when she exhausts Don of ideas of what potential difference means and she has to suggest that it is a measure of energy, she does so parsimoniously.
Finally, we see the "cross-referencing" of students' ideas that Colin spoke about in Conference 1, when Rosie sets the stage for Bill and Beth to collaborate on their answers to question six. Thus, there is some evidence that Rosie is beginning to acquire some of the features of the model that have been quite systematically demonstrated by Colin. She is certainly placing more of a conceptual demand on her students, quite hesitant now to do much of the explaining for them.

Clues for Identifying "Follow Me" Coaching

One of the issues of the analysis up to this point has been that effective communication about the practice of teaching is difficult, if not impossible, in the early stages of practicum. Student teachers may come to the practicum setting with very different systems of understanding teaching and comprehending the critique received from their supervising teachers. Indeed, there was reason to suspect that, at the outset of the practicum, Rosie held a very different conception of what it means to teach from that of Colin. The case of Rosie and Colin illuminates at least three additional reasons why communication may break down in practicum, all of which underline the importance of modelling in teacher education: (1) supervising teachers may need to "rediscover" what it is that they know, as it has become rather commonplace, perhaps "automatic," in their practice, as we saw with Colin's "giving reason to students' ideas"; (2) there may be facets of what supervisors know how to do that are not reducible to propositional, or articulable form and therefore these would require demonstration; (3) knowledge about teaching that is propositional may have meaning that only unfolds gradually for students, with much time and practice in the classroom and in the context of imitation.
While the demonstration and articulation of the features of the model take a prominent role in supervision, these are seen to be necessary, though not sufficient, conditions around which a student teacher might learn. There was a holistic character to the way in which Rosie took to Colin's model. For example, there was a particular manner to the way she asked questions toward the end of her practicum. She would often "build up" to a question with three short statements: the first would remind students of an experience they had in the classroom, the second focussed their attention on an aspect of that experience, and the third would ask what it meant. This pattern pervaded Colin's teaching, though he never articulated it in his work with Rosie; it was something she "picked up." In fact, when the pattern was pointed out to Colin, he agreed that it characterized his teaching, but said it was something of which he was not conscious, or about which he had never thought in that way.

Thus far in the analysis, four clues can be formulated for the identification of the "follow me" model of a reflective practicum in constructivist science teaching. These clues are stated as follows:

A. The supervising teacher takes the lead in exploring the meanings that pupils construct from classroom events. In the context of this exploration of pupils' ideas, the supervising teacher investigates the sense that the student teacher makes of what pupils say and do, as well as the way in which the student teacher conceptualizes "teaching."

B. The supervisor determines what the student teacher needs to learn on the basis of performance. This begins by exploring the sense that the student teacher makes of the aspect of performance in question.

C. The modelling of pedagogical knowledge includes the demonstration and description of various features of practice that the supervisor thinks the student teacher needs to learn. There is an explicit attempt made to demonstrate these features of practice so that their importance can be discussed later in the privacy of the supervision conference.

D. The critique of teaching begins with the student teacher's performance, then shifts to the practice of the supervisor, then back to the student teacher's practice. In this way, the supervisor assesses the student's progress in the contexts of practice and criticism.
A complete transcription of Lesson 2 and Supervisory Conference 2, together with analytical comments, appears in Appendix A for the reader who is interested in seeing how Colin and Rosie's discussion about his demonstration went from beginning to end. The complete transcript of Lesson 2 also enables the reader to obtain a greater understanding of the "flow" of Colin's lesson on "charge by induction." What follows is further analysis of Colin's supervisory practice.

Investigating Students' Conceptions of Electricity

Another feature of Colin's supervisory practice was related to his curiosity about students' conceptions of science subject matter. As mentioned in the introduction to this section, there were times when the database for supervision discussion consisted of video tapes of student group work. The analysis that follows centres on Colin and Rosie's discussion of a video tape that was made of three students working on problems related to series and parallel circuits. In Lesson 4, students were assigned to work on three problems related to series and parallel circuits for the duration of the period. They were given a small light bulb in a bulb holder, two batteries, and a supply of wire. Rosie wrote the following problems on the board:

1. Use one battery to light the bulb.
2. Use two batteries to light the bulb.
3. Use two batteries to light the bulb so it shines as brightly as it did in #1.

During the lesson, Colin and Rosie circulated among the students observing their progress on the three problems. The investigator video taped several groups as they constructed various circuits and discussed their ideas about the
solutions to the problems. One particularly informative portion of the video tape was selected by Colin to view and discuss with Rosie after school.

A complete transcription of the video tape discussed by Colin and Rosie is presented in Appendix B. The transcription includes the students' dialogue as well as diagrams of the circuits they constructed in attempting to solve the third problem. Further, this transcription of the video tape is interspersed with supervision dialogue, that is, the discussion between Colin and Rosie about the students' strategies in solving the problem as well as their conceptions of electricity that were manifest in these strategies. Appendix B also includes the investigator's analytical comments regarding Colin and Rosie's discussion of the video tape. Thus, Appendix B includes the students' dialogue, their various attempts at assembling the circuit that would solve problem #3, Colin and Rosie's analysis of the students' strategies and conceptions about electricity, as well as the investigator's analytical comments regarding the supervision dialogue. Three remaining "clues" for identifying the "Follow Me" model of coaching reflective practice emerged from Colin and Rosie's conference about this lesson episode.

Three More Clues

As demonstrated in the material presented in Appendix B, Colin and Rosie were able to identify certain conceptions of electricity that were manifest in the strategies used by the students in solving the third problem dealing with circuits. Moreover, Colin was able to show Rosie how he thought the student's conceptions of circuit changed as they were able to solve the problem. To begin, the students seemed to conceive of electricity as being comprised of two kinds of current: positive and negative. Thus, they attempted to light the bulb by connecting it to the negative terminal of one battery and the positive
terminal of another. When the light bulb did not light, the students seemed to move on to another theory about "positive and negative electricity": the "negatives and positives cancel each other." Using this theory, they tried to connect the bulb to the positive terminals of different batteries.

Eventually, the students realized that what they needed was a "complete pathway" for electricity to travel from one terminal, through the bulb, and back to the other terminal of the same battery (the conventional direction of current flow was not dealt with in the unit). Thus, they developed their initial conception of "circuit." When this happened, they also realized that the circuit they thought was using two batteries was really only using one; the other battery was being by-passed. Finally, the students realized that the battery itself was part of the circuit, as Student 1 signified by placing her hand across the terminals of the battery to show that the current was passing through the battery as well.

The analysis of Colin's supervision style in the context of leading Rosie through the video tape of the circuit problems has given rise to three additional "clues" for identifying the "follow me" model of coaching reflective practice. These are stated as follows:

E. The supervisor and student teacher observe classroom phenomena together, and then discuss the significance of a particular event. The student teacher is invited to comment first, after which the supervisor goes on to explain the significance he or she "saw" in the event.

F. The supervising teacher surfaces his or her own confusions about making sense of what science students say and do. This is done to assist the student teacher in setting realistic goals for the practicum, as well as to indicate that the professional life of a teacher is one of continual growth.

G. The supervising teacher displays genuine interest in exploring the ways in which students make sense of phenomena and classroom events. The supervisor makes a concerted effort to show the value in expanding one's repertoire for understanding students' thinking and dealing with problems they have with the subject matter of science.
It is worth mentioning that Rosie made very good use of the analysis of the video tape of students working on the circuit problems. In the following lesson she gave the class a short questionnaire designed to identify their conceptions of electric current—whether it consists of two kinds of electricity (positive and negative), the nature of the "pathway" made for electricity to travel, and whether this pathway included the battery or not. She found that approximately one-fifth of the class conceived of electric current as "positive and negative" electricity. Further, the questionnaire revealed that about one-third of the students thought that the current was used up by the bulb, such that the wire returning to the battery contained less electricity than the wire going to the bulb. These conceptions were incorporated into subsequent teaching strategies, as Rosie attempted to explain the differences between the "alternative conceptions" of electric current and the scientific concept of electric current, as well as show the students why and how the concept of "potential difference" was used.

In summary, the "Follow Me" model of coaching reflective practice has been analysed and presented here in the context of Colin's supervisory practice. A set of seven "clues" has been derived from this analysis for the identification of particular characteristics of the model.

It has been suggested that the "Follow Me" model is foundational to a reflective practicum. Once it is in place, it is argued, the other two models of "coaching" may grow out of it. An idea that will be extended in the concluding chapter of this document, but which is timely to mention here, is that the "follow me" model is appropriate for most practicum situations because most student teachers appear to need professional direction. This assertion is not intended to mean that Rosie was inadequate, or incompetent in any sense.
Rather, it foreshadows the stage of development at which she appears to function as a student teacher and suggests that there are additional demands placed on both supervisor and student teacher in the "Joint Experimentation" and "Hall of Mirrors" models, which are explored in turn in the remainder of this chapter. Next, we move to Kevin's practicum with Gary, and the "Joint Experimentation" model of coaching.

"Joint Experimentation"

One of the additional demands placed on the student teacher in the "Joint Experimentation" model of coaching reflective practice is that the student must be able to say what he or she wants to produce in practice. As Schon says, "[Joint Experimentation] is bound to be inappropriate when [the student] is unable to do so or when the coach wants her to grasp a new way of seeing and doing things that transcends the boundaries of a particular local effect" (Schön, 1987, p. 296).

The main element of Joint Experimentation is the collaborative inquiry of the supervisor and student teacher. About the supervisor in such collaboration, Schön writes the following:

The coach works at creating and sustaining a process of collaborative inquiry. Paradoxically, the more he knows about the problem, the harder it is for him to do this. He must resist the temptation to tell a student how to solve the problem or solve it for her, but he must not pretend to know less than he does, for by deceiving her, he risks undermining her commitment to their collaborative venture. One way of resolving this dilemma is for the coach to put his superior knowledge to work by generating a variety of solutions to the problem, leaving the student free to choose and produce new possibilities for action. (Schön, 1987, p. 296)

The sort of collaborative inquiry that characterizes the Joint Experimentation model of coaching reflective practice was prevalent in much of Gary's work with Kevin.
The Context

A couple of general points should be made before illustrating the Joint Experimentation model with excerpts from Gary and Kevin's supervision dialogue. First, Kevin was particularly keen on a "constructivist" perspective from the very early stages of his methods course in the fall. Very enthusiastic about teaching, Kevin is a likeable twenty-four-year-old who claims that he always wanted to be a teacher in spite of the fact that his first degree is in engineering. One day in November when Gary came to the university to talk with Kevin's methods class about his so-called "interpretive discussion" technique for eliciting and negotiating students' ideas about a particular topic, Kevin was most receptive to the ideas. Of course, by that time he knew that Gary was to be his supervising teacher in practicum. Nevertheless, he seemed to appreciate the salient features of Gary's "interpretive discussion," as he pointed out to his peers in the class how the technique would serve to reduce the risk for students engaging in discussion, as well as place the responsibility for assessing the reasonableness of ideas on the students themselves. In short, Kevin seemed to have an affinity for the sort of teaching that Gary demonstrated; he showed that he appreciated its central features.

The second general point has to do with Gary. One of his characterizing attributes is that he genuinely honours the prerogatives of other people. He felt that it was very important not to "impose" his teaching style on Kevin, but rather to let Kevin develop his own style. If Kevin wanted to explore some of Gary's teaching techniques, that was fine. If not, and there were no serious problems in Kevin's classes, then that was fine too. In fact, this attitude was so prevalent that toward the middle of practicum, Kevin would seldom observe Gary teaching. Gary's idea, again, was that he wanted Kevin to develop his own style, and not to feel obliged to emulate Gary.
The "nail and bolt": Introducing Kevin

The analysis below begins with excerpts from a lesson and supervision discussion that occurred in the third week of practicum. The lesson was fifty-five minutes in duration, about the tenth that Kevin taught. The class is a Grade 9 group of twenty-eight students beginning a unit on heat and temperature. These students had studied heat and temperature during the previous year in the Grade 8 science course, so Kevin's idea for the first lesson of the unit was to find out what the students remembered about the concepts "heat" and "temperature." The lesson began with Kevin asking students to write down one or two ideas they had about heat, and these were discussed for about ten minutes. This was followed with the "ball and ring" demonstration of the thermal expansion of metals, which Kevin used to review ideas about the Kinetic Molecular Theory taught in the Grade 8 course.

The main activity for the lesson involved students heating a nail and a considerably larger bolt in a bunsen burner until both were red hot, then placing them in separate beakers containing equal volumes of water, and, finally, measuring the temperature increase of the water in each beaker. The class results were entered in a table on the blackboard. We enter into this lesson with a rather lengthy excerpt taken from the latter half of the lesson at the point where these results are about to be discussed.

Kevin: Okay, you might as well copy down that chart, okay? Is everyone's data up on the board?

S: (hickups)

Kevin: Is that a yes? Has everyone copied down that table?

S: No sir.

Kevin: Then why are you talking?
S: I'm sorry. What lab is this?

Kevin: You finished copying this down Jeni? Okay, can we discuss this? Why did I make you do an exercise like this? Just to occupy time? Mark?

Mark: To prove that bigger objects carry more heat, probably.

Kevin: Okay.

Mark: And have more heat.

Kevin: That could be. Linda?

Linda: To see how heat changes temperature?

Kevin: Okay, now what is our view of heat and temperature? What do you think of heat and temperature now? What was that trying to show? I think a couple of people said already and they had a good idea of what it was trying to show. What is your view of heat now that we've done this exercise? Were both bolts [sic] at the same temperature when you heated them up?

Mark: No.

Karen: Almost.

Kevin: Yeah, probably the same temperature. I mean you heated them up to uhm ... a high temperature. Now did ... pretty well everyone observed a bigger change in the bolt ... and I want to know why that occurred. Glen?

Glen: It's bigger and had more heat.

Kevin: Okay, it had more heat. Why did it have more heat?

Glen: Because it had . . .

Kevin: It was at the same temperature wasn't it? Karen?

Karen: Because it has more molecules and therefore it has more heat to transfer into the water.

Kevin: That killed a couple of answers. Mark?

Mark: Well, I was going to say because it's bigger and there could be more heat stored in it than in a tiny nail. So it would go through the water and make it warmer.

Kevin: Are you laughing?

S: I don't know.

Kevin: Anyone else? Judy, you didn't really understand heat and
temperature at the beginning. What do you think of heat and temperature now? What's the difference between heat and temperature?

Judy: Uhm . . .

Kevin: Which one had more heat . . . the nail or the bolt?

Judy: The bolt.

Kevin: Which one was at a higher temperature . . . the nail or the bolt?

Judy: The bolt.

Kevin: Okay, I think we all kind of felt that the nail and the bolt had the same temperature because they were in the flame and the flame was at a constant temperature. So how can something have more heat, yet the same temperature? Ross?

Ross: Well, the bolt has because it's larger and if it's larger it has the ability to absorb more heat at the same temperature. So then when you put it in the water, that much more heat can come into the water than in the nail.

Kevin: What is thermal energy then? Carmen?

Carmen: I don't know. Uh, maybe it's heat that is produced and then can be kept in . . . stored in . . . because it isn't released as heat.

Kevin: Okay, do you have something Linda?

Linda: I was just going to say it might just store heat.

Kevin: Okay. So from this experiment we kind of concluded that heat has something to do with mass or the size . . . so if it's bigger, it's got more mass, so it's got a larger heat. And temperature . . . you people keep mentioning kinetic . . . kinetic energy, or kinetic . . .

Mark: Kinetic molecular theory.

Kevin: Kinetic molecular theory, or whatever. Temperature . . . how do we measure heat? If we measure temperature with a thermometer, how do we measure heat?

S: (inaudible)

Kevin: Pardon?

S: By placing the same . . . (inaudible)

Kevin: Okay.
S: What do you mean by measuring heat? Like just find the difference?

Kevin: Well, actually you're saying that heat is ... this is a definition that people have been giving and I'm not sure whether everyone understands it ... but heat [sic], you said, (points to the word "TEMPERATURE" on the blackboard) was the average kinetic energy, is that right? And what was heat?

S: Total.

Kevin: Heat was the total kinetic energy? (writes) Okay, I'm not going to really tell you exactly how we're going to measure heat because this whole section ... we're talking about heat and the different concepts involved around here ... so we're going to figure out a way that we can measure heat. Gwen, did you have?

Gwen: Uhm, maybe if you did. the temperature times mass ... would that give you heat?

Kevin: So you're thinking because this heat has something to do with ... I mean everyone seemed to come up with the idea that the bolt caused a larger rise in temperature so it had more heat. So temperature times mass ... I think that's getting along the right track. Because it certainly had the same temperature but it had a higher heat, and the only thing that was different was the mass. That's good. Uhm, that's what I want to leave with you this lesson. I want you to realize that things can have the same temperature, but have a larger amount of heat. And the basic difference is mass. Because the larger bolt ... you're not really sure about that Jeni? Ask me a question, then.

Jeni: I don't understand what you're talking ... what you just said.

Kevin: Susan?

Susan: Wouldn't it be the volume ... times ...

Kevin: What's the difference between volume and mass?

Susan: Oh, nothing. I'm sorry, I was thinking about weight.

Kevin: Yeah. Mass and volume are basically ... I mean mass is density times mass equals volume.

Jeni: But how is it that something can have ... I mean ... uh, the same ...

Kevin: temperature ...

Jeni: Yeah ...

Kevin: ... but different heat.
Jeni: I didn't understand that.

The excerpt above displays a couple of characteristics of Kevin's teaching thus far in his practicum. He shows that he can handle a discussion reasonably well and "get right down to" an important and fundamental distinction in science, namely, the distinction between heat and temperature. In addition, we can see that students respond quite well to Kevin; there seems to be no lack of genuine involvement on their part. But we can also see that Kevin is somewhat awkward in his questioning: there are a few minor slips with words, such as, "Were both bolts [sic] at the same temperature?" Also, he is rather abrupt with Susan when she asked about measuring heat by "volume times . . . (temperature)." To respond to Susan by saying, "What's the difference between volume and mass?" may have closed off a reasonable line of inquiry.

In the final portion of the excerpt Jeni says that she doesn't understand how two objects can have the same temperature but different amounts of heat. This was quite perplexing for Kevin, as the following excerpt from his discussion of the lesson with Gary reveals:

Gary: Kevin, I talked to you just after the lesson, and this was yesterday's lesson . . . you've actually had one since then with this same class . . . or this same topic. You didn't feel very good about it. You were feeling kind of down. Uh, why was that?

Kevin: I guess I have a bit of problems sometimes. I certainly didn't feel totally organized . . . and the discussions, I find, they go well when they're happening, but I'm wondering if we're getting anything accomplished. And there was a bit of reference at the end of the lesson that one of the girls didn't pick up what we'd been talking about. Some of the fundamental basics. That was a bit of a drag for me. A bit of a downer. Uhm . . .

Gary: Because you felt like you were trying to get something across and she wasn't picking it up.

Kevin: Yeah.

Gary: Did that make you feel like there was a . . . that you weren't being
Kevin: Yeah, to a degree ... a bit of a gap ... a communication gap. And I guess, if I sat down and thought about it logically, I could have thought, "Well, her partner was sitting there trying to explain it to her, and so there were," I mean a large number of people did pick it up. So, you know, logically I suppose I would have deduced perhaps that it was an effective lesson. But ... the reason that I sometimes feel down after a lesson is that I'm not sure afterwards whether we have a lot of concrete things to show for it. It's hard to guage exactly what they've learned or whether they've gotten ... whether they've understood the concepts that we've been discussing.

Gary: You feel disappointed sometimes when you get a little bit of feedback that seems to suggest that not everybody got it.

Kevin: Yeah.

Gary: Do you get the feeling that at the end of a good lesson that everybody should understand everything?

Kevin: Yeah, I mean it would be nice.

Gary: Yeah, you set pretty high expectations for yourself.

Kevin: Yeah.

Gary: Can you think of some ways that you ... that you can check the whole class ... and ... instead of picking on one kid and getting some feedback from one kid that seems to suggest that he or she doesn't understand, and therefore you kind of sit back and say, "Well, nobody understands." Is there a way that you could check the whole class and kind of get a consensus of understanding or misunderstanding of what, a concept?

Kevin: To check them objectively, we could probably have them do some sort of exercise ... and then I could check it the next day when they come in.

Gary: How about more informally?

Kevin: Well, with the raising of hands and things like that ... and having seen how much they understood ... how much that's influenced by peer pressure and whether a kid who raises his hand hasn't really understood, I'm not really sure.

Gary: Okay.

Kevin: But certainly that's a way. If I can create an atmosphere where they're not afraid to say, "I don't understand," then that would be a good way of checking.

Gary: Okay. But you're right, I think, that peer pressure sometimes ... very much will influence how honest they're going to be about that.
Uhm, maybe there's a bit of an art in just asking the right question, or asking a question which doesn't condemn them for ignorance in volunteering something. Can you think of a way of . . .

Kevin: . . . a way of putting that?

Gary: . . . checking with a question?

Kevin: You mean specifically like a question related to the topic that we were dealing with . . . heat and temperature?

Gary: Could be.

Kevin: (5 second pause) Something that would . . . I'm having trouble.

Gary: Okay, well how about something like . . . I noticed in the lesson that you gave this afternoon . . . you asked a question such as, "Does anyone not know . . ." or "Do you all understand that?"

Kevin: Uhm hmm.

Gary: Uhm, how about something like . . . "Who would like me to explain that again?"

Kevin: Okay.

Gary: Or, "How many of you would really be offended if I backed up and went over this one more time?" Or, "Hands up if you've got a really clear understanding of what I'm saying right now."

Kevin: And then you can check up on it.

Gary: And then . . . rather than say, "Hands up if you've no idea what I'm saying," . . . "Hands up if you'd like me to . . .

Kevin: . . . move on."

Gary: . . . well, or to try this again, or talk about it in another way," or "Just if you feel kind of hazy about it."

Kevin: Yeah, something that obviously in no way is judgemental and you're really telling them that, "I'm ready to go over this again if you want me to."

Gary: Yeah. Almost assuming . . . like I'm almost assuming that half of you don't understand this right now, so just give me a check of how many of you would like me come back. And if there are only one or two, then at that point, it's probably not necessary to back up and go over it again. But you keep those kids in mind and address them later on in the period as you're walking around checking their work.

Kevin: Yeah, I think I was struggling for that. There was a point . . . well, particularly in today's lesson when I wanted them to do that, and I wasn't able to verbalize that. I definitely remember that point.
It would be deceiving to suggest that there is a limited amount of input from the supervisor in the "joint experimentation" model of coaching. As the above excerpt illustrates, Gary is actually doing quite a bit of teaching, and yet the discussion is guided by Kevin's prerogative to get a sense of accomplishment at the end of his lessons. The thing that makes Gary's supervision different from Colin's is that "the problem" seems to be set more often by the student teacher, rather than by the supervisor. There is a definite sense of collaboration in Gary and Kevin's inquiries, although this is true for Colin and Rosie as well. But the collaborative effort is more pronounced in Kevin's practicum. Consider the following excerpt, taken from the end of the same supervision conference, where Gary and Kevin are planning the upcoming lessons:

Gary: Uh, okay, well where do we go from here? Next lesson . . . let's see.

Kevin: Well, I repeat "A" [with Block D--another class], so I'll try to implement . . . you know, I guess I'm first concerned about changes that we could do to the lesson that I taught today.

Gary: Okay, fair enough.

Kevin: Uhm, I'm not exactly sure what I would do differently, except for perhaps use the blackboard to spell things out in our . . . put down our definitions . . . I don't think we've really touched on thermal energy. I haven't really explained that clearly enough. I'd like to . . . I'm almost not comfortable to write out my own definition . . . I'm really tempted to use the text book, which is something that I don't really want to do, but I'll have to look into that. I'll think about that and put it into my own words. Or get them to.

Gary: Encourage them to as well.

Kevin: Yeah.

Gary: I asked the kids, when I did this lesson, to get them to develop analogies of heat and temperature. Uh, and . . .

Kevin: Actually, Mark gave me an analogy. He said, "Well, I'm just starting to think about it like this . . . ."
Gary: Uhm hmm.

Kevin: And, you know, that's an excellent way.

Gary: One kid said, "Think about two piles of dollar bills. One with only a few bills in it, one with hundreds of bills. The average value of each bill in that pile is the same as that pile. That's equivalent to the average kinetic energy . . . two things of the same temperature being the same."

Kevin: Uhm hmm.

Gary: "But there's more money in that pile than this pile." That's an analogy of more heat in this one.

Kevin: More thermal energy.

Gary: More thermal energy, yeah. And if you're taking a handful of that and putting it somewhere else, then you're transferring heat.

Kevin: Then you're transferring heat, yeah. I mean, is that the way we're going to be thinking about thermal energy? Because we haven't totally clarified that in our minds.

Gary: Yeah. I used it as . . . uh, thermal energy is the total amount of money you've got in your bank account, whereas heat is the amount of money that you spend . . . you know, getting your allowance. The transient amount. I'm not sure how valid that is, but that's the best I could make out of it. Uh, okay, so your next time through, then, for D Block with the same lesson, you're going to try to use the blackboard a little bit more.

Kevin: Right.

Gary: And, uh, maybe make the graphing instructions a little more clear, and, the purpose . . . you know, here again, we got into the lab without saying really what we were trying to do in the lab. Uhm, so what I've got down on the board here is to calculate the relationship between the heat energy transferred to water and the subsequent temperature change. We're trying to find out the relationship between them. You know, when you saw when you plug in the kettle, you give it energy and the temperature goes up. Okay, so let's measure some of these things. Let's measure how much energy, let's measure how much temperature and see how they relate. Uh, and in terms of what you want them to write down by the way of a lab write-up, maybe spend some time going over . . . I'll tell you what I ask them to do typically when they're doing labs.

Kevin: Okay.

Gary: The title and the purpose and that type of thing. I set up a format. I always give them a purpose . . . and then
Kevin: ... and then they have to give a conclusion.

Gary: Yeah, and the graphing. Now the period after that ... okay, so what are they going to come in with?

Kevin: They're going to come in with the lab write-up done.

Gary: Okay, but not all of it. They haven't done the slope yet have they?

Kevin: No, we haven't calculated ... in question number 4, they're basically asked to calculate the slope. So they will have done that. Uhm, we aren't getting into specific heat yet, which is what the slope is referring to. So I think ... the way I see the exercise in the book being ... it's something that they're having them do now ... and it'll become clearer ... I mean, "This is why we did this at this time."

Gary: Okay.

Kevin: So I wasn't exactly sure how much time I was going to spend going into slope, although they don't have the big concept of slope.

Gary: All right. Yeah, I suspect that you're probably going to have to back up and go over that idea again with them on slope. Since that's something that they haven't had any experience with.

Kevin: What are we going to say this means?

Gary: Well, hopefully it should be able to tell us what is the relationship between heat and temperature.

Kevin: Uh, no ... because we're graphing ... oh yeah, okay.

Gary: Okay? Now the lab that's suggested after that ... you change the mass of the water and graph it again ... 

Kevin: We'd felt that we'd almost done that one.

Gary: Okay. That's showing what is the effect of different temperatures on the ... 

Kevin: We could discuss that ... we could say, "Okay now I'm going to take another immersion heater and I'm going to add it to these different masses of water. What is going to happen? Okay, well, obviously it's going to take longer to heat up. What would that do to this graph?"

Gary: Yeah.

Kevin: "It's going to take ... ." Well, let's say I want to find out how long it takes to heat up to 30 degrees. Well, they could go along the graph and see how long ... 

Gary: Uhm.

Kevin: ... that it would take longer. 'Draw an imaginary line of what it
would look like.

Gary: Okay, good.

Kevin: And we could almost do that as an exercise.

Gary: Very predictive . . . okay, I like that. Uhm, so what direction are we going? We're trying to find out the relationship between the . . .

Kevin: . . . the heat and . . .

Gary: The heat and what the temperature of something is heat and . . .

Kevin: Mass.

Gary: What the mass of something is . . . and I think the activity that would come after that is to find out what effect does it make on what sort of material there is. If they're using oil or alcohol, or water . . .

Kevin: Uhm hmm, and then . . .

Gary: From that we develop into that . . .

Kevin: . . . specific heat . . .

Gary: . . . formula. And that's related to specific heat. The kind of material.

Kevin: . . . material.

Gary: Okay.

Again, we can see that Gary manages to do a considerable amount of teaching in the excerpt, yet it is somehow woven into Kevin's interests in understanding and improving his practice. A pattern that can be seen in the dialogue begins with Kevin "setting" the problem, which enables Gary to explore what Kevin sees in the way of appropriate responses to the problem situation, and ends with Gary telling Kevin about the sorts of things he (Gary) does in such situations. So, for example, Gary teaches Kevin about establishing the "purpose" for a lab activity, or ways of structuring the students' lab report.

What is striking about the excerpt is the sense of collaboration that is evident. Gary and Kevin finish each other's sentences while planning their lessons and speak as though they are a team: "let's try this, we thought that,
we could almost do such and such." In short, Kevin is treated as an autonomous teacher; the agenda for the practicum is his agenda. But Kevin is fully competent and, perhaps more important, willing to "enter into a situation," as Schön says, willing to let himself be puzzled by things, willing to put what he does and thinks in the classroom "on the line." Further, Kevin is genuinely concerned about teaching, curious about how students make sense of things, self-starting in his inquiry into their world. In short, it appears that the Joint Experimentation model of coaching reflective practice presupposes a certain level of maturity on the part of the student teacher.

Kevin's disposition and capacity to reflect on his practice is succinctly demonstrated in the following excerpts taken from the last lesson Kevin taught to his Grade 9 class and the discussion with Gary afterwards. This lesson occurred after the unit on heat and temperature was completed; it was a review of a four-lesson unit on the solar system and the universe. During the lesson, one student asked if the moon were a star. The following discussion ensued:

Karen: I think it's a planet that acts like a star.

Kevin: It's a planet that acts like a star? How does it act like a star?

Karen: 'Cause it gives off light?

S: No it doesn't. It only seems to.

S: It's reflecting light from the sun.

Kevin: John, something quick . . . what do you . . .

John: Well, does it have something to do with when you set up that thing?

Kevin: When I set up what thing?

John: The thing right here . . . you know?
Kevin: Oh, the spectroscopes when we were looking at the lights?

John: Yeah. Isn't it like that ... the sun reflects off something?

Jeni: The light from the sun ...

Kevin: Okay, everyone's attention up here. Does the moon ... is the moon like a star? Does it give off light, or does it reflect light? Elise?

Elise: It reflects light.

Kevin: Okay ... everyone feels comfortable with that. It's reflecting light from the sun. You know, like a ...

Carol: Well ... well, if it wasn't reflecting light it probably wouldn't show ... like the faces of the moon.

Kevin: Shadows?

Grace: If it wasn't reflecting, like it would be so bright you'd just see ... all the colour.

Karen: You wouldn't see all the shadows.

Carol: Well, that's because there's [sic] craters.

Karen: Yeah, that's because there's [sic] craters.

Grace: There's [sic] shadows on the craters.

Kevin: If it was generating light you might not see those shadows.

We move immediately to the discussion of this episode in the supervisory conference:

Kevin: Uh, a couple of kids offered up some really good evidence to suggest that the moon isn't a star.

Gary: Uhm hmm.

Kevin: And uh, basically, I didn't carry that at all. They started suggesting things.

Gary: Evidence that it was a star?

Kevin: Evidence that it wasn't.

Gary: Oh, it wasn't, okay.
Kevin: Yeah, so that's what we're working through here now (refers to transcript of the lesson). I think some of the ideas they offer are quite profound and I don't think I totally... uh, really appreciated some of the things they were saying. I did feel a bit uncomfortable about maybe the fact that I was paraphrasing and perhaps I wasn't choosing the proper paraphrase. I felt after looking over this and reading it a bit that maybe I was guiding the conversation a bit too much. Like she said, "Well, if it wasn't reflecting, like, it probably wouldn't show like the faces of the moon." Now, perhaps she was thinking about phases.

Gary: Yes.

Kevin: ... or maybe she was thinking of faces, which would imply shadows. So I... I think here I would have much... I would have felt a lot better had I asked her to elaborate on that.

Gary: Yeah.

Kevin: We seem to be getting a lot of short answers out of people and I think in order to get the gist of what they mean and what they really, uhm, comprehend exactly what their concept is... I would have liked a bit more explanation on some of these things.

Gary: Uhm hmm, how could you get it?

Kevin: By simply saying, "Could you elaborate? Explain further, what do you mean by this?"

Gary: Yeah, your comment here about shadows...

Kevin: I mean, that's out of the blue.

Gary: Okay, embedded in that word... shadows, question mark, is your interpretation of what she meant by "faces of the moon."

Kevin: Uhm hmm. And she would say... my question is, she may say, "Oh, yeah, that's right." I mean she may just be going along with me there.

Gary: Okay, so this is kind of hazy communication between you and the student.

Kevin: Right.

Gary: So you said, "Shadows?" And actually it wasn't even that student who responded to that question.

Kevin: But here she uses it again, "There's [sic] shadows on the crater," so she has adopted...

Gary: I guess the point I'm trying to make is that instead of making it with just a word like that, that you should be... I'm talking about clarification and I can't clarify what I'm trying to say. Uhm, if you're trying to check for the understanding of the kids then you should be as
clear as you possibly can about what you mean . . . about your clarification statement or your clarification question.

Kevin: Right.

Gary: Okay, rather than just a single one-word answer. Maybe there's a little bit of role modelling that comes into play here. If you want them to clarify and elaborate, then you should clarify and elaborate. Although you do that.

Kevin: And also I shouldn't really be interpreting something until I have a fuller clarification because I think that's a big jump there. Just reading . . . actually before hand I thought I was making a couple of jumps.

The above excerpt of supervision discussion includes an excellent example of reflection-on-action by Kevin. He looks back on what a student says in class and reconstructs it: did she say, "faces of the moon," or was it, "phases of the moon"? Which was she proposing as evidence that the moon does not produce its own light, for either the "faces" or "phases" of the moon could count as evidence for the claim. Again, Kevin lets himself be puzzled by what the student said.

Clues for Identifying "Joint Experimentation" Coaching

From the analysis of Gary and Kevin's supervision conferences, two clues are derived for detecting the "Joint Experimentation" model of coaching reflective practice. These are as follows:

A. At times, the student teacher takes the lead in reflective inquiry. This means that much of the problem setting and reframing that takes place in supervisory conferences is done by the student. The supervisor follows the student teacher in the inquiry, offering advice and criticism and suggesting various strategies when these are appropriate.

B. The student teacher is able to say what he or she wants to produce in practice. There is a willingness to become puzzled about what pupils say and do, and a concern about "getting it right" that continually provokes the student teacher to raise questions about his or her practice.
The process in this model of coaching is **joint experimentation** because both the supervisor and the student teacher share in the choice of issues to be discussed and developed, the specific design of the student teacher's experiments in practice, and the assessment of "how things went." The student teacher's perceptions of practice are taken seriously by the supervisor in this process. This means that the student teacher's opinions about the lessons and relationships with pupils are treated with "dignity," as though the student teacher were a fully autonomous professional. Further, the student teacher is given the prerogative to say what he or she would like to produce in practice; it is not the case that the supervisor simply tells the student teacher what is required. In this sense, the Joint Experimentation model of coaching reflective practice is distinct from the "Harvard-Newton" model of clinical supervision (Cogan, 1973) in which the supervisor decides unilaterally about the "salient" feature needing change. In other words, the coach "enters into" and facilitates the inquiries of the student teacher, rather than simply carrying out his or her own inquiries and reporting these to the student teacher. By doing so, the supervisor is able to sustain the student teacher's inquiries, while, at the appropriate times, contributing advice and gentle criticism.

The predominate model evident in Gary's supervisory practice is that of Joint Experimentation. This section has been concerned with identifying the characteristics that enable the classification. It has been argued that there are specifiable demands that are placed on both the supervisor and student teacher in situations where Joint Experimentation is evident: the student teacher must be competent and willing to initiate the questioning of practice. In turn, the supervisor must allow the student teacher to "set the agenda" for their work together. The above two clues focus on these attributes of Joint Experimentation.
"Hall of Mirrors"

The final task for this chapter is to investigate the "Hall of Mirrors" model of coaching reflective practice in the context of constructivist science teaching. As with the Joint Experimentation model, it is argued that the "Hall of Mirrors" model places additional demands on the supervisor and student teacher. The nature of these additional demands is foreshadowed by Schön's discussion of the "parallelisms" that can be created between the practice setting and the supervision setting.

The Hall of Mirrors model points to how the supervisor's practice, in handling the student teacher, provides exemplars of the practice that the student teacher is attempting to acquire. Schön discusses this phenomenon thus:

In the hall of mirrors, student and coach continually shift perspective. They see their interaction at one moment as a reenactment of some aspect of the student's practice; at another as a dialogue about it; and at still another, as a modeling of its redesign. In this process they must continually take a two-tiered view of their interaction, seeing it in its own terms as a possible mirror of the interaction the student has brought to the practicum for study. In this process there is a premium on the coach's ability to surface his own confusions. To the extent that he can do so authentically, he models for his student a new way of seeing error and 'failure' as opportunities for learning. . . . But a hall of mirrors can be created only on the basis of parallelisms between practice and practicum--when coaching resembles the interpersonal practice to be learned, when students recreate in interaction with coach or peers the patterns of their practice world, or when . . . the kind of inquiry established in the practicum resembles the inquiry that students seek to exemplify in their practice. (Schön, 1987, p. 297)

The Hall of Mirrors is created around consistencies between the supervisor's teaching and supervision that make his or her "model of pedagogical knowledge" all the more powerful. First, the student teacher can experience the supervisor's model in action, now at another level of teaching. The student teacher may consider what it is like to be the "recipient" of the model, that is, he or she may be given to think about the effect of the supervisor's teaching approaches from the perspective of a student. If student teachers experience
the effect of the model in this manner they may be in a better position to reflect on children's learning of science. Further, student teachers may contemplate the nature of teaching by reflecting on their own learning in practicum.

In order for a Hall of Mirrors to be created, the similarities between practice and practicum must not only be present, they must also be recognized by the student teacher. The assertion here is that, if the model is to work, a student teacher must be aware that he or she is being handled in such a way as to demonstrate the features of practice that need to be acquired. The additional demand that is placed on the supervisor in order for the Hall of Mirrors to work is that he or she must display for the student teacher a consistent and coherent model of teaching.

A diagramatic representation of the hall of mirrors model as it might be created in a science teaching practicum is shown in Figure 5 below. In order to display better the mirror effect of the practicum on the practice of science teaching, the upper part of the diagram—the conceptualization of practicum—has been inverted. It should be clear that the two parts of the diagram have been conceived in such a way as to enable their superimposition in Figure 5. This has been done quite deliberately in order to conceptualize and represent the parallelisms that are seen by this investigator to exist between the practice setting and the supervision setting. These parallelisms in the relationships between the supervising teacher and student teacher on the one hand, and the student teacher and science pupils on the other hand, are represented by the dotted lines. The upper half of Figure 5 represents a reflective practicum in terms of the Follow Me model of supervision, emphasizing the ways phenomena are perceived, and the demonstration/imitation aspect of communication.
Thematic Experience

Ordinary Experience

Pedagogical Discourse

Ordinary Language

Imitation and Construction of Pedagogical Knowledge

Demonstration and Description of Pedagogical Knowledge

Scientific Knowledge

"Children's Science"

Scientific Language

Ordinary Language

Scientific Experience

Ordinary Experience

T - Teacher
S - Student
NP - Natural Phenomena

S_p - Supervising Teacher
S_t - Student Teacher
PP - Practicum Phenomena

Figure 5. The Hall of Mirrors
The lower half of Figure 5 represents science teaching according to the "constructivist" perspective developed in Chapter Four. In the main, the diagram is intended to show in a general way how practicum may mirror practice in the context of a constructivist approach to science teaching.

The following illustration of the Hall of Mirrors model of coaching reflective practice is taken from the case study of Kevin's practicum. The analysis focusses on their dialogue about a video tape of a lesson that Gary taught during the previous year. (The video tape was made for the purposes of pre- and in-service teacher education, part of the aforementioned research project's activities.) The class is a Grade 9 group of twenty-six students studying a unit on heat and temperature, this particular lesson concerning thermal expansion of solids.

Below, are excerpts of a portion of the lesson dealing with "the ball and ring" demonstration, interspersed with excerpts of Gary and Kevin's discussion as they viewed the video tape. At the time of this particular discussion, Kevin was in his eighth week of the thirteen-week practicum, and he had just finished teaching the same unit on heat and temperature. It should be noted that Gary and Kevin's dialogue about the lesson was recorded for two purposes: (1) as part of the database for the present study of science teaching practicum, and (2) for the production of a "video tape exemplar" to be used in preservice teacher education (the idea being to have a student teacher take part in analysing an episode illustrating various techniques used in a "constructivist approach" to science teaching).

The first excerpt of the lesson is very short, merely serving to orient the reader to the "ball and ring" demonstration. Immediately preceding the ball and ring demonstration, students observed the lengthening of a piece of nichrome wire as it was heated by an electric current. Gary used the nichrome wire
demonstration to elicit students' ideas about the Kinetic Molecular Theory. Then, the following introduction was given for the ball and ring demo:

Gary: I'm going to try something a little bit different here. Some of you probably have seen this before ... I'd be surprised if you hadn't. (holds up the ball and ring) I have two objects which are made of brass. One is a ring ... and this is a little sphere. Now, they're machined in such a way, or constructed in such a way that the inside diameter of the ring is exactly the same as the outside diameter of the ball. So as I put the two of them together, they just barely fit. There's no room in there to rattle around at all. It just is a perfect fit. Okay? Now I'm going to ask you in a moment to sketch this ... and to make some observations as I heat one or the other of them up. I want you, as you're drawing this, again, to make some predictions. Think about some possible tests that we could do with these two objects ... and think of some predictions ... some things that you think might happen.

(students work in their notebooks, while Gary draws a diagram of the ball and ring on the board)

As the following excerpt of supervision dialogue illustrates, Kevin is quite familiar with Gary's general orientation to science teaching at this time in the practicum (it should be evident that Kevin is intentionally "cueing" Gary to make certain points for the intended viewer of the video tape, which, in its final version, will include Kevin and Gary's dialogue.) The discussion is focussed on a technique for eliciting students' ideas about heat and thermal expansion of solids by having them predict what will happen when the various "tests" are performed on the ball and ring. After they have given their predictions, and Gary has conducted the tests they suggest, students will be invited to explain the results. The technique that is illustrated thus utilizes prediction, observation, and explanation (P.O.E.) as means by which students' ideas are explored.

Kevin: So you've just done what you said you were going to do. You've explained what ... perhaps what you're going to do and they're going to make some predictions. Now ... I mean, my question here is why,
uh . . . is that a vital part to your lesson . . . for them to make predictions?

Gary: Uh, yeah. Yeah, it is. Uh, from the point of view of getting them involved . . . but also to pull on their . . . their own notions of how the world works. To use their own theories . . . their little mini-theories . . . their preconceptions of . . . what they bring into a science course with them . . .

Kevin: Uhm hmm.

Gary: . . . and, uh, hopefully, through these kinds of investigations, if they can come face to face with what they . . . with what they believe to begin with . . .

Kevin: Uhm hmm.

Gary: And then if we can give them some experiences . . . with their own guidance . . . and lots of involvement, as you mentioned earlier . . .

Kevin: Right.

Gary: . . . as being an important characteristic . . . then their knowledge can become personalized . . . and, uh . . . sometimes, if they're faced with discrepant events that don't always match what they came in believing. And if they have some kind of crisis, then they are forced to rethink. They are forced to come to a new explanation. They are forced to come up with a new theory, or hypothesis.

Kevin: Right. And you provide them with that . . . and if . . . they weigh the evidence and they feel . . . hopefully they'll feel that this new explanation better . . . uhm, better explains the phenomenon.

Gary: Yeah.

Kevin: Yeah. I was just going to ask a question, but I guess we could continue viewing . . . are they going to have some . . . sort of room to debate amongst themselves . . . their various predictions . . . and . . .

Gary: (nods) Let's look for that.

Kevin: Okay. (turns on video again)

The dialogue to this point portrays a rather typical description of an approach to teaching, albeit more or less consistent with the conceptualization of science teaching presented in Chapter Four. There is little evidence of a Hall of Mirrors in Gary and Kevin's discussion so far. Let us return now to the lesson.
In addition to the P.O.E. technique for eliciting students' ideas about heat, the video tape of this lesson illustrates a discussion style that Gary refers to as "interpretive discussion." Like the P.O.E., the interpretive discussion is designed to elicit students' ideas about the subject matter of the lesson, its main aim being to encourage the **negotiation** of ideas among students.

Gary: Okay, what kind of tests can you think of . . . that we might have? Lorne?

Lorne: You could heat them up . . . and then the ball will expand because of the heat . . . and then you won't be able to pull it out.

Gary: Okay, and so you're saying you'll heat . . . heat them both up?

Lorne: Yeah, one inside the other. Put the ball inside it . . .

Gary: Yes. (puts the ball inside the ring) Like that?

Lorne: . . . and then heat it up.

Gary: Yeah.

Lorne: And then you won't be able to pull the ball out.

Gary: I see . . . okay. Uh, why do you think that might be?

Lorne: Uhm, I think that the metal inside the ball is going to . . . is going to expand.

Gary: Okay, good.

Lorne: (softly) . . . and so will the metal in the ring.

Gary: Okay . . . Cindy, what would you test?

Cindy: But that wouldn't work because . . . uhm, if you did that then the ring would expand too . . . and they probably both would expand at the same rate, so then you'd still be able to move it.

Gary: I see, okay. So you suggest the same test, but you predict a different result.

Cindy: Yeah.

Gary: Interesting. Okay. Tracy?

Tracy: Uhm . . . (inaudible) . . .
Gary: Sorry ... a nice, loud voice so that everyone can hear you.

Tracy: If you heat up the ring ... then the ring will expand ... and then you put the ball inside the ring ... there'll be much more room?

Gary: Okay, so you're suggesting a second test where I heat up the ring, but not the ball?

Tracy: Yeah.

Gary: You think, then, that it'll fit much better? (puts the ball through the ring)

Tracy: Yeah.

Gary: Okay. Greg?

Greg: I think ... uh, if you heated up the ball ... like if you put the ring inside, or around the ball ... then heat it up ... you wouldn't be able to get it off. Or, either way.

Gary: Okay. Harry?

Harry: Uh, to the thing that Lome said ... with the ball inside the ring ... well, I think that would work because the ball has more or ... more or less mass than the ring has. So I think it would heat up differently because one has more mass than the other ... (inaudible) ...

Gary: Okay, do I hear you saying, then, that ... uh, the rate at which they expand or contract depends on how much of the stuff there is?

Harry: Yeah.

Gary: Okay. Ellen?

Ellen: I just think you should heat up the ball ... and then see if it'll fit through the ring or not ... just ...

Gary: Okay. What do you think would happen, Ellen, if I heated up the ball without the ring?

Ellen: Well, the ball would expand and then it wouldn't fit through.

Gary: Okay. Can anybody think of any other tests? Yeah?

Peter: I think both Cindy and Tracy are wrong ... even though ...

S's: (laughter)

Peter: Like, if you put the ball inside the ring ... they both
expand. But the ring doesn't just expand out, it also expands inward.

Gary: Yeah?

Peter: So it would be tight ... you wouldn't be able to get it out.

Gary: Okay, let's try all of these things. Let's try all of these things. I'll just heat the ball up first, but we'll try each one of them. (begins heating the ball) Uh, what I hear a couple of you saying is that the ball will no longer fit. Uh, any other variations on that? Do I hear a no?

Russ: Sure ... no.

Gary: Russ, what do you think? (continues to heat the ball)

Russ: Well, I think that if you heat up either ... both of them will expand anyways.

Tara: The ball's not in [the flame].

Russ: So if you heat up the ring, uhm, the ball won't fit through. If you heat up the ball, it won't fit through. And if you heat up both, it won't fit through either.

Gary: Okay, so whatever I do, I can never get it through there. All right. Yes?

Harry: Well, if you just heat up the ring ... the ring ... well, like ... okay ... yeah, the ring will expand. It'll also expand inward ... and outward.

Gary: I'm keeping this one [the ring] cold.

Harry: Oh.

Gary: I'm just heating up the ball now. Yeah?

Tracy: I was just stretching.

Gary: All right. Well, let's try it then. Okay? Watch carefully.

In the above excerpt there is clear evidence that students are listening closely to one another, as they collaborate (even argue at times) in making their predictions. There are at least four "patterns" in Gary's teaching that may contribute to the negotiation of meaning that is evident among the students. First, it seems right to say that by suspending his own judgement of
their predictions, Gary gives students the responsibility for assessing the reasonableness of each other's ideas. The pattern of accepting a student's suggestion with a neutral, "Okay," or, "I see," would contribute to this effect. Second, Gary often invites students to elaborate on something that was said, encouraging them to explore their reasoning further. Third, he will often moderate the discussion by comparing one student's idea with that of another, encouraging them to compare and contrast their contributions to the discussion. A fourth pattern is Gary's tendency to check his own understanding of students' ideas by paraphrasing what they have said.

In the following excerpt of supervision dialogue, we see Gary and Kevin exploring some of the elements of the interpretive discussion style. The character of this dialogue is markedly different from that of the previous section. Here, we can see that a Hall of Mirrors is created between Gary's style of supervision and the practice that is under discussion. In other words, we can see the same patterns in Gary's supervision that are being pointed out in his teaching:

Gary: Over the last few minutes of . . . uhm, of this lesson, you can see that we're in a discussion mode here. And I'm just curious to know if you have any observations of the kind of strategies that I'm using in the discussion.

Kevin: Well, I've noticed a number of things. First of all, the students are making a variety . . . a number of predictions . . . and there seems to be no lack of involvement. Or, you don't seem to really be prying, uhm, predictions out of these kids. There's a fair amount of openness that you've developed in the classroom.

Gary: That they'll respond . . .

Kevin: Yeah.

Gary: . . . and volunteer without being . . .

Kevin: That's very impressive. I mean, the kids are ready and willing to give, uh, give some predictions. And, I mean, and that takes a certain amount of risk.
Gary: That's right.

Kevin: Because they could be way off base with some of these . . . predictions.

Gary: Actually, that's really important. Can you think of any ways that you could develop that . . . that sense of trust, really?

Kevin: Well, for one . . . with their predictions, all of your answers are very neutral. You don't in any way . . . uhm, give any teacher signs as to they're on the right track, or . . . you seem to accept them all with the same, "I see." And, perhaps, ask for further clarification or . . . or just elaboration. And . . . it would . . . as a student I would find that very easy to respond to . . . maybe wanting a bit more out of you, but you don't seem to be giving it to them right yet.

Gary: Okay.

Kevin: And I noticed as well . . . when you . . . uhm, were responding to one of the students, you related it back to another student's remarks. Therefore, the student . . . the first student feels that his remark had some value. And the second student, you know, you link up their . . . even though she was actually contradicting the initial prediction, it was . . . there was a link made . . . so they felt that both of them had weight. And they would be able to wait and see which one . . . perhaps was right.

Gary: Okay, good. All right. So . . . uhm, a sense of trust . . .

Kevin: Definitely, yeah.

Gary: And . . . uh . . . uh . . .

Kevin: They have . . . well, and that trust allows them to take risks.

Gary: Okay, all right. And what . . . what I'm asking these kids to do . . . is really to . . . to lay their souls bare in the sense of what do they really believe to be true.

Kevin: Exactly.

Gary: Uhm . . . not being tested by any . . . uhm, any observations at this point.

Kevin: Evaluation.

Gary: They're just saying what they think would happen.

Kevin: Exactly.

Gary: And yeah, there's a lot risk in that. And it does take a while. Is there anything else that you notice in the discussion? Is . . . is . . .
Kevin: Well, in their prediction . . . they . . . one student would make a prediction and I notice you would either paraphrase or ask for clarification. And I guess there's a number of reasons for that?

Gary: Can you think of any?

Kevin: Uhm . . . certainly the clarification is for you to . . . to be able to relate to the student if you're not exactly sure what he's saying . . .

Gary: Okay.

Kevin: Also it allows him to really redefine what he's saying . . . he can work it through in his mind as he speaks it out . . . and that's probably a very important part. In terms of paraphrasing, that allows the whole, uh, that would allow the whole class to become part of that answer, because often times, kids throughout the class don't necessarily hear a response.

Gary: Actually I did quite a bit in this particular segment just because . . . probably more than I would ordinarily do in a classroom situation, uh, just for the benefit of the, uh . . . of the microphones that were in the classroom to pick it up.

Kevin: Right.

Gary: And some students have very soft voices . . . and just to ensure that it was actually picked up. But, you're right. And you've picked up a couple of things. One is to check the meaning of . . . of . . . of the student . . . to make sure that what I understand him or her to mean is in fact what they intended to say.

Kevin: Yeah.

Gary: It sometimes gets confused when they are using . . . uhm, when they're using their own language . . . and they're not using . . . kind of scientific language. And they will often use words . . . well, as we learned today, heat and temperature . . . kind of interchangeably.

Kevin: Exactly.

Gary: And they will say heat when they mean temperature. And unless you kind of check for clarification as to what they really did mean, uh . . . we can sometimes be misled.

Kevin: And so paraphrasing would help you do that.

Gary: And paraphrasing would help that. A useful exercise, too, sometimes--I think I might have done it here once or twice . . . is to, uh, get other students to paraphrase what one student has said.

Kevin: Right. That not only says, "Hey, you'd better be awake and listening," but it also says, "Do you understand what they were saying? Can you derive some sort of meaning of your own?"
The parallelisms that are created between practice and practicum can be seen throughout this interchange. To begin, Gary opens up the discussion with Kevin about the discussion in the lesson by inviting him to make some observations about it. Thus, Gary elicits Kevin's ideas about a technique designed to elicit students' ideas. One of the things that Kevin comments about is the open atmosphere that pervades the classroom (a sense of trust, says Gary), this idea being met with encouragement and a further request that Kevin explore the possible reasons for it. Kevin goes on to talk about how students are encouraged to give their ideas because they know their teacher won't judge them unfairly--their ideas "have weight." Gary paraphrases Kevin's ideas about paraphrasing students' ideas. The dialogue is quite intriguing. What is even more striking is that Gary claimed to be totally unaware at the time of the Hall of Mirrors he created.

Clues for Identifying "Hall of Mirrors" Coaching

The analysis of Kevin and Gary's supervisory dialogue has given rise to the following two "clues" for detecting the Hall of Mirrors in science teaching practicum:

A. The quest to understand what science pupils say and do is exemplified by the supervisor's attempt to elicit the student teacher's thoughts about a particular event. The supervisor displays the practice that is under discussion at the very time of discussing it. That is, the model and the articulation of its features are delivered to the student teacher at the same time.

B. The supervisor displays a consistent and coherent model of teaching in the classroom and in the handling of the student teacher. The discussion of "practicum phenomena" resembles the discussion of "natural phenomena" in the classroom. This happens, for example, when the supervisor elicits the student teacher's understanding of pupils' understanding of the subject matter.
It may seem to the reader that the Hall of Mirrors model of coaching reflective practice is more likely to be created when the Joint Experimentation model characterizes the supervisor's handling of the student teacher. The inference is quite acceptable, given that constructivist science teaching makes an explicit attempt to "begin with" students' representations and explanations of events, and proceeds to test these against further evidence collected from the laboratory. The parallel is drawn, in this case, from viewing the practicum setting as a laboratory for testing the student teacher's ideas about practice, just as science pupils use the classroom laboratory for testing their ideas about natural phenomena. And, the supervisor's role in sustaining the student teacher's inquiries appears to be much like the teacher's role in facilitating pupils' classroom inquiries, as can be clearly seen in Gary's style of supervision.

However, these are not sufficient grounds to conclude that the Hall of Mirrors created in coaching reflective practice is inconsistent with the Follow Me style of supervision. In the context of constructivist science teaching it may seem that the Hall of Mirrors is more amenable to Joint Experimentation than it is to Follow Me, but this should not exclude the possibility of a mirror effect between a supervisor's "leading" the student teacher in inquiry, and a teacher's "leading" pupils' investigations of scientific phenomena. Clearly, to have any effect at all the Hall of Mirrors must be recognized by the student teacher to illustrate the dynamics of teaching practice. That is, the student teacher must see his or her relationship with the supervisor as emulating the relationship between a teacher and pupils, and this is no more likely to hold in Joint Experimentation than it is in the Follow Me version of supervision. Indeed, if teaching is to occur at all, there must be some element of Follow Me present, whether it is in the practice setting or the practicum setting. The point is that the three "coaching" models of a reflective practicum focus on
different aspects of supervisory interactions, and though they are treated here as if they were analytically distinct, they may blend together in practice in numerous ways that depend upon the unique styles of individual practicum supervisors. As it turned out, Colin's work with Rosie offered few illustrations of the Hall of Mirrors according to the interpretations of this investigator. But this should not limit the empirical blend of Hall of Mirrors with the Follow Me model of coaching reflective practice.

Summary

This chapter has presented material from lessons and supervision conferences to illustrate Schön's three models of "coaching reflective practice." This has been set in the context of Colin and Gary's practice as supervising teachers. The models have been treated separately, even though some of the transcripts suggest that the various models may blend together in practice.

The Follow Me model focusses on the supervisor's demonstration and description, as well as the student teacher's construction and imitation of pedagogical knowledge. The clues that were derived from the analysis of Colin's dialogue with Rosie include the following:

A. The supervising teacher takes the lead in exploring the meanings that pupils construct from classroom events. In the context of this exploration, the supervising teacher investigates the sense that the student teacher makes of what pupils say and do, as well as the way in which the student teacher conceptualizes "teaching."

B. The supervisor determines what the student teacher needs to learn on the basis of performance. This begins by exploring the sense that the student teacher makes of the aspect of practice under consideration.

C. The modelling of pedagogical knowledge includes the demonstration and description of various features of practice that the supervisor thinks the student teacher needs to learn. There is an explicit attempt made to demonstrate these features of practice so that their importance can be discussed later in the privacy of the supervision conference.
D. The critique of teaching begins with the practice of the student teacher, then shifts to the practice of the supervisor, then back to the student teacher's practice. In this way, the supervisor assesses the student's progress in the contexts of practice and criticism.

E. The supervisor and student teacher observe classroom phenomena together, and then discuss the significance of a particular event. The student teacher is invited to comment first, after which the supervisor goes on to explain what he or she "saw" in the event.

F. The supervising teacher surfaces his own confusions about making sense of what science pupils say and do. This is done to assist the student teacher in setting realistic goals for the practicum, as well as to indicate that the professional life of a teacher is one of continual growth.

G. The supervising teacher displays genuine interest in exploring the ways in which students make sense of phenomena and classroom events. The supervisor makes a concerted effort to show the value in expanding one's repertoire for understanding students' thinking and dealing with the problems they have in dealing with the subject matter of science.

The Joint Experimentation models of coaching reflective practice was seen to characterize Kevin's practicum with Gary. The analysis gave rise to two clues for detecting the Joint Experimentation model, as follows:

A. At times, the student teacher takes the lead in reflective inquiry. This means that much of the problem setting and reframing that takes place in supervisory conferences is done by the student. The supervisor follows the student teacher in the inquiry, offering advice and criticism and suggesting various strategies when these are appropriate.

B. The student teacher is able to say what he or she wants to produce in practice. There is a willingness to become puzzled by what pupils say and do, and a concern about "getting it right" that continually provokes the student teacher to raise questions about his or her practice.

Particular aspects of Kevin's practicum with Gary were also seen to exemplify a Hall of Mirrors in coaching reflective practice. The remaining two clues have been derived from their supervisory conferences for the purposes of identifying the Hall of Mirrors in the context of constructivist science teaching. These clues are:
A. The quest to understand what science pupils say and do is exemplified by the supervisor's attempt to elicit the student teacher's thoughts about a particular event. The supervisor displays the practice that is under discussion at the very time of discussing it. That is, the model and the articulation of its features are delivered to the student teacher at the same time.

B. The supervisor displays a consistent and coherent model of teaching in the classroom and in the handling of the student teacher. The discussion of "practicum phenomena" resembles the discussion of "natural phenomena" in the classroom. This happens, for example, when the supervisor elicits the student teacher's understanding of pupils' understanding of the subject matter.

The clues that have been presented above in the analysis of practicum events and supervision dialogue constitute the "clue structure" for detecting the patterns around which a reflective practicum in constructivistic science teaching proceeds. These "patterns" have been conceptualized around Schön's notions about "coaching for reflective practice," specifically in terms of his three coaching models. The clue structure has emerged as a result of the "application" of the analytic scheme developed in Chapter Five to the transcriptions of lessons and supervision dialogue. Finally, a discussion of the conclusions, limitations, and implication emanating from the study are discussed in the concluding chapter.
Chapter 7

CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

The challenge for this study has been to conceptualize and investigate empirically the characteristics of a "reflective practicum." The conceptualization that has resulted consists of an "analytic scheme" and a "clue structure" for identifying instances of "coaching" reflective practice. The analytic scheme has been derived from a critical examination of a literature pertaining to "constructivism," as a view of knowledge acquisition that has relevant implications for science teaching. Further, the analytic scheme incorporates ideas emanating from theoretical and philosophical literature related to Schön's analysis of reflective practice.

This study has been concerned with the character of practicum. It has focussed on the experiences of two student teachers of secondary school science—the lessons that they teach, their dialogue with supervisory teachers, their interaction with pupils, and so on—in search of patterns and understandings outlined by Donald Schön's (1987) analysis of a "reflective practicum." The purpose of this study has been to identify the elements of a "reflective practicum" in the handling of student teachers by two experienced science teachers who subscribe to a constructivist approach in their teaching practice.

Schön's (1983, 1987) analyses of the nature of professional knowledge, how it is learned, and the qualities of a "reflective practicum" have enabled an interpretive account of the cases of Rosie and Kevin's practica. The outcome of the study is a set of "agendas" and competencies that were displayed by practicum supervisors in encouraging their student teachers to become more "reflective" about their practice.
The following are the specific research questions that guided the study. The first set of questions is critical and analytic in character, requiring that the fruitful characteristics be determined for a view of "reflective science teaching." Since the study entailed the clarification and elaboration of the theoretical assumptions underlying the study, these are included in the first research question:

1. What are the supportable characteristics of a reflective practicum in constructivist science teaching?
   1.1 What is the constructivist's position?
      1.1.1 What about the constructivist's position is supportable?
   1.2 What is Schöns position?
      1.2.1 What about Schöns position is supportable?
   1.3 What is the combined position about reflective teaching?
      1.3.1 What about the "reflective teaching" position is supportable with regard to science teaching?
      1.3.2 What about the "reflective teaching" position is supportable with regard to a teaching practicum?

The second research question was empirical in character; it entailed the observation, documentation, and analysis of events in two case studies of science teaching practicum, as these were seen from a Schönean-constructivist perspective.

2. What are the patterns of reflective behaviour that can be seen in the participants' discussions, using the general framework Schöns has provided?

In the following section the study is reviewed and the conclusions are formulated in terms of the research questions presented above.
Conclusions

The task required by the first set of questions occupied Chapters Four and Five. Chapter Four included a critical analysis of "constructivism," identifying its strengths in terms of the following over-arching premises: (1) knowledge is not passively transmitted and received, but actively built up by the cognizing subject; and (2) the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. A diagrammatic representation of a "constructivist view of science teaching" was developed in Figure 3 (cf. p. 68). It was argued that science pupils initially organize their perceptions of classroom phenomena according to "alternative" frameworks and conceptions that may be derived from their use of concepts emanating from "ordinary language." Therefore the science teacher must be prepared to notice when students are perceiving events in ways contrary to those regulated by concepts inherent in "scientific language." The importance of reflection was discussed as a means by which the teacher reconstructs action situations and classroom events from pupils' points of view.

In response to research question "1.1" (What about the Constructivist's position is supportable?), the conclusion is that a constructivist perspective on the acquisition of knowledge illuminates the practicum situation by enabling a coherent portrayal of "reflective practice" in science teaching. Empirical research literature conducted by other investigators and interview data with science students in this study supported the tenets of constructivism by showing that students' perceptions of classroom events are often contrary to those perceptions enabled by the use of "scientific language" (i.e., scientific concepts, models, laws, and theories). For example, Grade Nine students spoke about ice cubes of different sizes requiring the same amount of heat to melt, apparently
because they were using the "ordinary" concept of heat, as opposed to the "scientific" concept of heat. The ordinary use of the word "heat" is much the same as the word "temperature," but in science the concepts of heat and temperature are quite different. The "correct" scientific interpretation of the problem is that the two ice cubes require different amounts of heat to melt since there would be a difference in the thermal energy "taken" for their phase change (given that the two ice cubes are of different masses). Thus, heat, according to the language of science, is conceived as the amount of thermal energy transferred from one object to another (from water to ice), rather than a measure of the temperature required to melt the ice. Once the Grade Nine students were able to see how this concept was used, they were able to understand how it could be said that the two ice cubes required different amounts of heat to melt.

Similarly, Grade Ten students who were studying a unit on electricity had difficulty constructing a parallel circuit because they initially conceived of electric current as having two kinds of electricity--positive and negative. Nor did they understand the concept of circuit as being a complete pathway for electricity to travel, in this case including a light bulb and the battery. In short, a constructivist perspective on the acquisition of knowledge was seen as a useful framework for making sense of the sorts of problems students experience in science classes, as many of these problems are associated with different ways of "perceiving" classroom events.

Much of the analysis has centred around three "pedagogical principles" that have been derived from constructivist literature. These pedagogical principles are:

1. Teachers must first develop strategies that will permit them to become aware of their students' ideas about natural phenomena and scientific concepts.
2. These ideas must then be taken into account in the instructional program in order to provide a foundation for extending concepts, or constructing new concepts and the meanings derived from them.

3. As learning is seen to be a purposive activity, students should be actively engaged in the learning situation and should become aware of the purposes that lie behind instruction.

Chapter Five examined Schön's ideas of "reflective practice," and the education of "reflective practitioners." While some of the constructs and images used by Schön were found to be in need of further clarification and refinement (e.g., technical rationality, the varied topography of practice), his primary focus upon the importance of problem framing as the means by which a practitioner perceives practice situations was found to be a fruitful way to address the issues of concern in this study. Schön's notions of reflection-in-action and reflection-on-action were found to be particularly useful as these represent a crucial aspect of problem setting and reframing in the action setting. When practitioners reflect on their practice, they begin to see situations in a new light, ascribing new meanings and new significances to events, or recognizing features of situations that were previously ignored.

Another conclusion, which addresses research question "1.2" (What about Schön's position is supportable?), is that Schön's position about reflective practice is particularly supportable in thinking about the problems associated with learning a profession. To begin, Schön focusses on the importance of demonstration and description as component processes about which a practice is "modelled" for students of the professions. His main idea is that some of the features of a practice are not amenable to description of technical means alone, and, indeed, may not be understood by a student without the opportunity to observe these features in practice as their description is developed over time. Further, it seems to make sense that a supervisor's knowledge of his or her
practice is sometimes "implicit in actions," leaving the supervisor unable to say what it is that characterizes competent practice. In such situations there is a need for demonstration and the associated "imitation" of the student, in which the practice is transferred, as it were, in a more "holistic" way than by articulating its technical antecedents.

In response to research question "1.3" (What about the combined perspective on reflective teaching is supportable?), the combined "Schöenean-constructivist" perspective on reflective practice in science teaching was seen to be theoretically supportable. There is a need for science teachers to develop a disposition for "seeing" the sense that students make of classroom phenomena in order that appropriate ways can be devised for teaching about the ways that "science" makes sense of these phenomena. Thus, a teacher must have a capacity for reflecting on students' understandings of classroom phenomena and science concepts. Yet, this capacity for empathizing intellectually with science students forms an appreciative system that is much like a "way of life" for the teacher. A diagramatic representation in Figure 4 of a reflective practicum was developed as a heuristic device to show some of the processes involved in the demonstration and description of this way of life for the student teacher. Further, the diagram is useful for thinking about the student teacher's imitation and construction of pedagogical knowledge in the practice setting. In addition to the diagramatic representation of a reflective practicum, a set of six agendas for a reflective practicum in constructivist science teaching approaches was developed. The diagram and set of agendas formed the analytic scheme for interpreting case studies of reflective practica in science teaching. The conclusion is that this analytic scheme, which represents the combined Schöenean-constructivist framework is a supportable way of thinking about science teaching practicum.
Figure 4 is repeated above for the reader's convenience. It focusses attention on the different ways practicum phenomena are perceived by supervisor and student teacher. It suggests that the supervisor has familiar ways of "apprehending" phenomena that derive from "thematic experience." In part, this process is enabled by the supervisor's use of pedagogical discourse. The student teacher, on the other hand, initially experiences practicum phenomena in "ordinary ways" according to concepts derived from ordinary language. The two different ways of experiencing phenomena can be reconciled, it is argued, by communication about pedagogical knowledge in the form of

$$S_p T$$ - Supervising Teacher

$$S_t T$$ - Student Teacher

PP - Practicum Phenomena

**Figure 4. The Reflective Practicum**
"demonstration" and "description" by the supervisor, and "construction" and "imitation" by the student teacher. The following is the set of six "agendas" for a reflective practicum in constructivist science teaching. Each of the six items has been derived theoretically from a critical analysis of pertinent literature on constructivism and reflection.

1. Exploring the ways in which pupils might make sense of natural phenomena and classroom events. Looking first for apparent incongruities and "surprises" in what pupils say, and then asking one's self how a sensible person could have said that.

2. Investigating the use of language in the discipline of science, in teaching, and in learning science. Attention is focussed on the variety of "ordinary language meanings" that a pupil might bring to the teacher's "scientific" language.

3. Investigating "alternative frameworks," or "alternative conceptions," possibly derived from ordinary language usage, that pupils might hold about the phenomenon under consideration.

4. Searching for evidence that pupils constructed different meanings of classroom events: discussing what pupils might have "seen" in the demonstration, experiment, illustration, etc.

5. Inquiring into the context in which pupils function—their social and family background, individual characteristics and interests, etc. that may come to bear on their interpretations of the phenomenon, or of classroom life generally.

6. Inquiring into the sorts of meanings that pupils might construct from the behaviour of the student teacher or supervisor.

With the analytic scheme in mind, verbatim transcriptions from two cases of science teaching practicum have been analysed in terms of research question 2. For this task, a set of "clues" for detecting Schön's three coaching models has been derived from the analyses of especially informative excerpts from lessons and supervisory dialogue between the supervising teachers and the student teachers. It is argued here that the models for "coaching reflective practice" take form in terms of the attributes outlined in the "clue structure" for identifying the various models.
Research question 2 asked, "What are the patterns of reflective behaviour that can be seen in the participants' discussions, using the general framework Schoen has provided?" The analytic scheme and "clue structure" for detecting the attributes of Schon's three "coaching models" in the context of a science teaching practicum are practically relevant in answering this question. That is, this clue structure is informative of the actual practice of supervising student teachers of science. The particularization of the coaching models in Colin and Gary's practice has been especially illuminating.

The "Follow Me" model was seen in Colin's practice in terms of his demonstration and description of at least four patterns that contributed to his "giving the responsibility for learning to the kids." Rosie learned to produce the same patterns, it is argued, through her "construction" and "imitation" of the features of Colin's model in her own teaching. In addition, the Follow Me model of coaching reflective practice was helpful in interpreting the discussion between Colin and Rosie of a video tape showing a group of three students trying to solve a problem dealing with parallel and series circuits.

The seven clues for identifying the Follow Me model that was prevalent in Colin's work with Rosie are presented below.

A. The supervising teacher takes the lead in exploring the meanings that pupils construct from classroom events. In the context of this exploration, the supervising teacher investigates the sense that the student teacher makes of what pupils say and do, as well as the way in which the student teacher conceptualizes "teaching."

B. The supervisor determines what the student teacher needs to learn on the basis of performance. This begins by exploring the sense that the student teacher makes of the aspect of practice under consideration.

C. The modelling of pedagogical knowledge includes the demonstration and description of various features of practice that the supervisor thinks the student teacher needs to learn. There is an explicit attempt made to demonstrate these features of practice so that their importance can be discussed later in the privacy of the supervision conference.
D. The critique of teaching begins with the practice of the student teacher, then shifts to the practice of the supervisor, then back to the student teacher's practice. In this way, the supervisor assesses the student's progress in the contexts of practice and criticism.

E. The supervisor and student teacher observe classroom phenomena together, and then discuss the significance of a particular event. The student teacher is invited to comment first, after which the supervisor goes on to explain what he or she "saw" in the event.

F. The supervising teacher surfaces his own confusions about making sense of what science pupils say and do. This is done to assist the student teacher in setting realistic goals for the practicum, as well as to indicate that the professional life of a teacher is one of continual growth.

G. The supervising teacher displays genuine interest in exploring the ways in which students make sense of phenomena and classroom events. The supervisor makes a concerted effort to show the value in expanding one's repertoire for understanding students' thinking and dealing with the problems they have in dealing with the subject matter of science.

Gary's supervision of Kevin was seen in terms of the "Joint Experimentation" model of coaching. It was argued that one of the reasons why this form of collaborative inquiry worked as well as it did was that Kevin was capable of saying what he wanted to produce in his teaching. Not only was he competent in the classroom, but he was capable and willing to become puzzled about what science students say and do. These attributes were discussed in terms of being "additional demands" that are placed on the student teacher in Joint Experimentation. Kevin's capacity to reflect on his teaching made him an excellent candidate for this style of supervision, however, not all student teachers exhibit the maturity necessary to work well in a Joint Experimentation situation. The implications for practicum may include the idea that the Joint Experimentation model of coaching reflective practice is likely more advanced developmentally than is Follow Me. This situation is ironic, however, since much of good teaching depends on the teacher's positive attitude toward experiment in practice. Joint Experimentation is therefore the sort of model we would encourage in all practicum situations, with the expectation that student teachers
would "grow into" it as their practicum proceeded.

The clues for detecting Joint Experimentation are the following:

A. At times, the student teacher takes the lead in reflective inquiry. This means that much of the problem setting and reframing that takes place in supervisory conferences is done by the student. The supervisor follows the student teacher in the inquiry, offering advice and criticism and suggesting various strategies when these are appropriate.

B. The student teacher is able to say what he or she wants to produce in practice. There is a willingness to become puzzled by what pupils say and do, and a concern about "getting it right" that continually provokes the student teacher to raise questions about his or her practice.

Gary's approach to supervision was also examined in terms of the "Hall of Mirrors" model of coaching. Parallelisms were pointed out between Gary's "interpretive discussion" strategy with his science classes and his handling of Kevin in the supervision conferences. The remaining two "clues" have been derived from Kevin and Gary's discussions for the purposes of identifying the Hall of Mirrors model of coaching reflective practice. These clues are:

A. The quest to understand what science pupils say and do is exemplified by the supervisor's attempt to elicit the student teacher's thoughts about a particular event. The supervisor displays the practice that is under discussion at the very time of discussing it. That is, the model and the articulation of its features are delivered to the student teacher at the same time.

B. The supervisor displays a consistent and coherent model of teaching in the classroom and in the handling of the student teacher. The discussion of "practicum phenomena" resembles the discussion of "natural phenomena" in the classroom. This happens, for example, when the supervisor elicits the student teacher's understanding of pupils' understanding of the subject matter.

In addition to the clues for identifying a Hall of Mirrors, a diagrammatic representation of the "parallelisms" that can be created between practice and practicum was formulated in Figure 5 (cf. p. 180).

Thus the features of the three models for coaching reflective practice were formalized in the "clue structure" which illustrated the nature of these
features in the practicum setting. The intention was not to isolate the models in practice, however, since there certainly could be elements of two, or even all three coaching models evident at any one time in a given practice. Rather, the intention is to use the coaching models to describe a particular form of supervisory practice in terms of a general "emphasis" on Follow Me, Joint Experimentation, or Hall of Mirrors, each making a different contribution to the overall effect of a reflective practicum. Therefore, the three models were treated in the analysis as being analytically distinct.

Related to the fourth general conclusion of the study is the claim that a reflective practicum in constructivist science teaching approaches is possible. It was argued that both Rosie and Kevin reflected on their practice by reconstructing classroom events from plausible pupil perspectives. Moreover, it could be argued that Rosie and Kevin developed a disposition for trying to see things from pupils' points of view. It is felt that this is due, at least in part, to the systematic approach taken by the supervisors in investigating pupils' understandings of phenomena and subject matter.

In Chapter Three, the research methodology utilized for this study was discussed in terms of a "tension" that exists between the theoretical perspective (analytic scheme, as it is referred to here) and the data of observations in the practice setting. It was argued that the "match" between the theoretical perspective and empirical events evolved over the course of the study, such that the practicum setting allowed for the derivation of "clues" which enabled observations to be made in terms of the refined theoretical perspective. A short example of how this "refinement" occurred during this study is in order.

In Colin's supervision of Rosie, it became very clear in the early phases of her practicum that she tended to elaborate on students' comments during her lessons. In her dialogue with Colin, Rosie spoke of "explaining science to
students to help them get their thinking straight." The hypothetical construct that Rosie held a "transmission" view of teaching was enabled by the interpretation of these data, both by Colin and by the investigator. This hypothetical construct allowed Colin to modify his handling of Rosie, such that he proceeded to demonstrate and describe an alternative approach that she might try. This he called "giving over responsibility for learning to the kids," and his demonstration took form in terms of four patterns that were displayed and articulated for Rosie. The fact of the matter was that Colin determined what Rosie needed to learn about teaching by observing her lessons. On the basis of his observations and interpretations of Rosie in action, Colin was able to plan his intervention--his "showing" and "telling" moves. However, Rosie's understanding of "giving responsibility for learning to the kids" clearly unfolded gradually in her practicum, and she was eventually able to display in her own practice the elements or patterns of Colin's demonstration. This set of occurrences illuminated the investigator's understanding and ability to articulate the attributes of Colin's "coaching model" as resembling, or corresponding to Schön's "Follow Me" style of supervision. Thus the "clues" for identifying the Follow Me model of coaching reflective practice in the context of constructivist science teaching came about.

Limitations of the Study

Like all conceptualizations, especially those that attempt to characterize a large and complex set of phenomena as this one does, there is a necessary but dangerous tendency to over-simplify things. The analytic scheme and its associated clue structure that have been produced for this study are no exception. Each of the two-way arrows depicted in Figures 3, 4 and 5, for example, have occupied all sorts of scholars for years. The diagrams
themselves raise more questions than they can answer. For example, the figures say little about the concept of teaching, other than the idea that it is predicated on knowledge of the way students currently make sense of things. Similarly, the diagrams say very little about the concept of learning, beyond the idea that it is based on experience and prior understandings of things.

There is a further problem with the Figures alluding to the idea that experience consists in our use of the language. Certainly, we struggle at times to put thoughts into words, and there are times when it seems appropriate to say that a concept may be present without a word. Phenomenologists speak about "lived experience," which, if the investigator understands it properly, can never completely be captured by language. The representations of practice and practicum developed here may overemphasize the idea that one's perception of practice is determined, in large measure, by particular uses of concepts.

Another limitation is in the rather narrow scope of supervision practice addressed by the study. Supervising teachers must be able to communicate many other facets of teaching practice in addition to a type of general, substantive framework about science teaching. Basic techniques of lesson organization, presentation modes, and management techniques, to name a few, must be in place before a novice teacher is even in a position to begin framing and reframing classroom events from pupil's perspectives. The very expectation that student teachers will develop a disposition to reflect on their practice may be quite unrealistic for some students at this stage of their professional lives.

Implications for Practice and Further Research

The sort of practicum experiences that this study has documented and analysed derive from a view that recognizes that pupils ought to be listened to
very attentively in the course of teaching science. The study has demonstrated that student teachers can and do reflect about classroom events from pupils' points of view when the appropriate models of "coaching reflective practice" are in place, and when the conditions that seem to support reflection have been created in the relationship between the supervisor and student teacher. One area for further research is to investigate the use of the analytic scheme and clue structure, together with case material such as the accounts of Colin and Gary's practice in "guiding" the practice of other supervisors. Collaborative work with several practicum supervisors working from a variety of perspectives and with a larger number of student teachers would be an avenue worth investigating. A collaborative venture could be mounted around the idea of gathering information about the various problems encountered by student teachers, for example.

The use of video tape in practicum has worked out particularly well in terms of providing a record on which to base the supervision discussions. The video tape of lessons and student interviews stores a set of phenomena which, upon reviewing, can be reconstructed by the student teacher, especially under the guidance of a careful supervisor. As demonstrated in the work of Colin and Gary, video taped lessons and group-work discussions can be very informative for the supervisor as well. Further research could be carried out on a larger scale investigating the use of video tape for analysing and systematically improving student teaching experiences. There may be other possibilities for using video tape in practicum in addition to those techniques that have been reported in this study. For example, Kevin video taped the "concept maps" of the solar system made by one of his classes so he could keep a record of their ideas for future teaching.
There are implications for methods course experiences that derive from this study as well. The examination of video tapes and transcripts of lessons and pupil interviews has proved to be a powerful technique for investigation pupils' ideas about classroom events and concepts used in science. There could be assignments included in methods courses whereby methods students are asked to record lessons or pupils interviews at their practicum placement sites. These lessons or interviews could focus on specific content areas, such that a methods class could collect an inventory of alternative frameworks and conceptions that pupils bring to science lessons in a variety of domains. In general, the idea would be that methods students would discuss each other's views of the documented lessons or interviews, and collaborate in exploring a variety of ways that pupils might think about phenomena. The beauty of using video tape records of lessons and interviews is that pupil strategies can be observed, much like the strategies of pupils working on circuit problems were by Colin and Rosie when they viewed the video tape. Further, video tapes of lessons, student group work, and methods students making sense of these record collected from previous years would be valuable assets to a methods course resource library. Indeed, some video tapes have been made from the database of this study for use in methods courses and in "additional qualifications" courses for inservice teachers learning about techniques of supervision.

Though this study has given rise to further directions and questions for practice and research, its main contribution is the analytic scheme characterizing a reflective practicum in constructivist science teaching, altogether with the clue structure for particularizing Schön's three models of coaching reflective practice in the cases of Rosie and Kevin's practica. These are put forth so as to provide further clarification, extension, and research into the idea of a reflective practicum in science teaching.
BIBLIOGRAPHY
BIBLIOGRAPHY


APPENDIX A
As the finale to a series of lessons on static electricity, Lesson 2 dealt with "charge by induction," as well as "debriefing," or reviewing the section on static charge (Rosie taught the last half of the debriefing section). The lesson opens below with Colin reviewing two ways of giving an object charge—conduction and induction. During the bulk of this lesson—an "electrophorus demonstration" of the steps required to charge a neutral object by induction—Colin made a deliberate effort to model for Rosie several features of his own practice. About a week later, after a verbatim transcription of Lesson 2 had been prepared and both Colin and Rosie had a chance to view a video-tape of the lesson, a supervision conference was held to discuss the features of Colin's model of teaching. The supervision dialogue that transpired appears in the left column below, interspersed among excerpts of the lesson. Analytical comments accompanying the supervision dialogue are presented in the column on the right-hand side of the page.

LESSON

C: You've dealt now with two ways to give an object charge. What were they? (3 second pause) What was one way?

S6: Rubbing? Like you're rubbing something to create a charge?

C: Okay, when you rub two things together . . . there's a word to describe that. Yes?

S9: Positive and negative.

C: There are two types of charges. There are two in that. And there are two ways to get those charges. One way was one mentioned by (S6) . . . rubbing two things together. What word did described that case . . . in which we give something a charge by contact? Yes, (S18)?

S18: Conduction.

SUPERVISION DIALOGUE

C: Now, can I tell you what was going through my mind here now? I thought that this first part here . . . uh, this was quite deliberate, but on the tape it's quite soft. Uh, there are . . . in my view, there are two ways to looking . . . looking at a student response. One is to say, "Well, what's wrong with it?" The other is to say, "What's right about it?" Now, here is a question: "You've dealt with two ways to give electrical charge. What were they? What was one?" Okay, so I didn't

ANALYTICAL COMMENTS

Colin sets the stage for the exercise by noting that he was deliberately modelling something in the opening episode of the lesson, though on the tape it sounds quite soft.

The episode illustrates Colin's principle of attempting to see what is right about a student's response to a question, rather than what is wrong with it.
get an answer to both of them so I said, "What was one?" Ah, the kid said, "Rubbing." Uh, "Like you're rubbing something to create a charge." "Okay, good." And now I've expanded that . . . "You rub two things together . . ." I didn't use the same words. Uh, it's a bit leading, of course. Sometimes it's wrong to ask a leading question. In my view you shouldn't ask leading questions too much before an activity. But when you're reviewing it . . . and make sense of it, it's more appropriate to ask leading questions. But this is the part that I remember. "Okay, you rub two things together. There's a word to describe that." So he said, "Yes, positive and negative." Now, that was not the correct response in my mind . . . at least what I meant by the question.

R: Yeah, you wanted conduction and induction.

C: Right, I wanted conduction and induction. But what I . . . here, this illustrates what I mean. Now, I could say, "No, that's not what I'm looking for. You're wrong." Now, what I did was realize that conduction and induction were two different things . . . there were two different charges . . . so I tried to validate his response by saying, "There are two types of charge." In other words, I was trying to explain why that person said that.

R: And then still bring it back around to get conduction.

C: Right, I didn't stay there. "One way was mentioned." Okay, "Rubbing two things together," and bring it back. Now, that's a pattern that I do quite deliberately. And that's what I mean by validating the students' ideas. That is, try to give some sense to the students' responses. Because, well, one of the things . . . if you don't do that . . .

R: They'll stop responding.

To begin, Colin reads the question and the student's response, noting that the response was not what he expected.

This initial view may have led Colin to say, "No, that's not what I'm looking for. You're wrong." But he goes on to describe for Rosie how he "thought again" about the student's response in order to "validate" it, that is, provide reason for why the student said what he did.

The "pattern" Colin illustrates with the episode is that of reframing student responses in an attempt to see the sense, or the reasoning, in what they say.
C: Yeah.

R: 'Cause they think that, "Well, if I don't have the right answer, then I'll shut up because I'll just get put down, or whatever."

C: And instead of saying, "Is that the right answer?" in my mind, I just kind of think consciously, or almost unconsciously now, "What is right about that answer?" Or, "What can I make of that answer?"

R: Uhm hmm.

C: But that zipped by really fast on the tape, but I remembered it quite clearly. So I... going through my mind as I was doing that... I was doing that quite deliberately.

R: Uhm hmm.

LESSON

C: Okay. Do you remember that from yesterday? Conduction... contact... rubbing two things together. Now you had another effect. The other effect was kind of strange. It produced all kinds of results that none of us expected. What was the name for that? And what was different about it from conduction?

S: Induction.

C: Okay, the word was induction. What does it mean? How is it different from the idea of conduction? (pause) How is it different from contact? (S12)?

S12: Uhm, it's different because... uhm, there's... the electrons aren't... or the uh... aren't really... well, okay... like they're moving from one place to another. Like they're not going away from it? Like you're not losing electrons from the atom. It's just moving... they're transferring over... (sigh)...

C: Well, I like your idea a lot. I think this is... (S7), you remember you were talking about poles on the banana?

S7: Yeah.

C: Well, is this pretty close to what you mean?

S12: Yeah, that kind of idea, yeah.
SUPERVISION DIALOGUE

R: Yeah, "Well, I like your idea a lot." That . . . yeah, that sort of stuck out in my mind when you said that. I think that was . . . it could have been (S7) or someone. "I think this is . . . well, you remember you were talking about poles on the banana?"

C: In that case, what I had in mind was that . . . actually, not just . . . it's nice to reward a good response if you can see the depth of the response even beyond the student immediately. But in that case, that was referring to something the previous day. And what I'm trying to give (S7) . . . I was thinking, "Yeah, that was such an interesting response . . . I've thought about it . . . and I'm going to tell you that I've thought about it." And (S7) will say, "He's thinking about what I'm saying." (3 second pause) But I think that it . . . it does a lot of things. One of the things it does is to show that you care about what the kids are saying. And I actually believe, that that helps your discipline problems. If you show that you're really interested in their thoughts and ideas, well you're interested in them.

R: Yeah. Well, just something that happened in Evelyn's class today 'cause . . . she did the first class and then I did the second class . . . and there wasn't much talking. Uh, they're grade eights so they're kind of rambunctious and I was trying to get their attention. And a couple of kids . . . I think about five of them said, "Shhh . . . she's trying to talk." And I'm going, "Oh, this is great. They're helping me out." And so I don't know . . . that was kind of a good feeling. But I think it comes out of that because I try to talk to them individually. And I think that has come out of that in that class as well.

ANALYTICAL COMMENTS

Rosie notices Colin's approval of a student's idea that, during charge by induction, electrons move from one place to another within the object being charged.

Colin goes on to discuss the implicit message that may have accompanied his remembering, from the previous lesson, S7's idea that a banana charged by induction behaved as though it had poles.

The implicit message is three-fold: (1) that Colin thought about what S7 said, (2) he cares about S7's ideas, and (3) therefore Colin cares about S7.

Rosie applies this notion to a Grade Eight class of another teacher's in which she had been working: she interprets the fact that she talks to these students individually as showing that she cares about them; therefore some of them helped her solve a discipline problem.
C: Well, you can't pretend to care about them, but if you really do and can find a strong way . . . you see, caring isn't weakness. And if you can show a kind of strong way to do that . . .

R: Uhm hmm.

LESSON

C: (S7), you remember you were talking about poles on the banana?

S7: Yeah.

C: Well, is this pretty close to what you mean?

S12: Yeah, that kind of idea, yeah.

C: That when you bring an object near, without touching, it separates the charge. So the total thing is zero, but the charge is separated into two parts. [to S7] Is that what you meant by poles?

S7: I used different words.

C: Well, that's all right. The words don't really matter. Describe it in your own words. So there's a separation of charge involved. That's one feature. The other feature is they don't actually touch.

C: Now, when you have charges without touching, what is the word that describes that again? (S17)?

S17: Uhm, (5 second pause)

C: (S15), can you help him out?

S15: Induction.

SUPERVISION DIALOGUE

C: Now, there's an interesting thing here about words. I have quite strong feelings about that . . . sometimes the ideas are right but the words are wrong. And sometimes the words are right, but their ideas are wrong. And there's kind of an interesting little piece here. Uh, "So the total is zero, but the charge is separated in two parts. Is that what you meant by poles?" Now, I'm not

ANALYTICAL COMMENTS

Colin suggests that caring for students must be seen to be genuine, and that it should be regarded as a strength, not a weakness.

Colin begins this next dialogue with Rosie by making a distinction between words and ideas.

He reviews the discussion from the lesson.
trying to put words into (S7)'s . . . uh. And his response is interesting. He said, "I used different words." I said, "Well the words don't matter." I guess what I'm saying there is . . . I'm trying to give the message to the kids that even if they don't know the words . . . I find myself saying that quite often. Uh, now this is quite interesting. "When you have charges without touching, what is the word that describes that?" Now what I'm looking for there is that the idea is one thing . . . the word is another. It's . . . uh, it has some value to know both. But you don't necessarily have a sense of the idea just because you know the word induction. But you should know the word as well at some point. Now, interestingly there's a note on the transcript here of a five-second pause. I remember that . . . uhm, I think it was (S17) who I asked that question if I remember correctly. Student 17, whoever that is. And I remember she felt a little uncomfortable. I said, "Okay, just relax."

Colin's question to S7 about what was meant by saying the banana had poles falls into the general pattern of trying to give reason to what students say. Further, the example illustrates how Colin looks beyond the "correct words" to the ideas that students express: it is important for students to formulate their ideas, at least initially, using their own words.

If a student does not have the correct word at hand, as in the case of S17 in this episode, Colin reduces the risk for the student by calling on another student for assistance.
feel you can . . . it's not exactly getting kids off the hook. I mean, you're describing . . . developing a trust situation and you say, "Okay, I can wait for you." And then you get it out in a half-formed way . . . and it comes out, and what you're saying is you're prepared to give a person a bit of time . . . and that you're really interested in what they have to say.

Colin suggests that allowing time for students to formulate their ideas and use their own language contributes to a sense of trust with the teacher. The implicit message, once again, is that the teacher is really interested in what they have to say.

LESSON

C: Now when you have charges without touching, what is the word that describes that again? (S17)?

S17: Uhm, (5 second pause)

C: (S15), can you help him out?

S15: Induction.

C: What is . . . how do you spell that?

S15: I-N-D-U-C-T- . . .

C: Okay, so it's spelt with an I . . . IN . . . duction . . . no contact. Looking at each other, gazing across the room. No contact.

SUPERVISION DIALOGUE

C: At this point I had been working on the concept . . . and then we were trying to remember just what is the term for that and uh . . .

R: An acronym . . . something for them to to hold on to in . . . in context.

C: Yeah, it's a mnemonic device. Sort of a . . . bit of a memory thing. I mean that's why you used contact, conduction. Not because they are exactly the same meaning but . . . I don't know how other people's minds work, but that's how my mind works and I remember things based upon those things.

R: Yeah, just like on the voltage. On the negative and positive terminal.

ANALYTICAL COMMENTS

This dialogue centres on the memory device Colin developed in the lesson for remembering the difference between induction and conduction. His handling of Rosie in regard to the correct term for this device is reminiscent of their dialogue in the previous section: it is her idea that is important; he introduces the term "mnemonic" in a very non-threatening manner. Thus, Colin's treatment of language with Rosie mirrors the practice he is modelling in his own teaching.
C: That's exactly what I was going to say. You used it today.

R: Yeah, because that's the only way my mind works.

C: Remember you said that the short line [circuit symbol for the negative terminal of a cell] is like the negative sign. You know, I was just going to use your example. Okay. The implicit message for Rosie is that her example is a good one; she is on the right track.

LESSON

C: Now, uh, I want to look at one example to actually illustrate that . . . that in kind of a puzzle. This particular experiment doesn't always work extremely well because of the day. We did try it earlier. Hope it's not going to embarrass me now.

S: Are you recording it?

S: Every precious word is put down in writing.

C: Now, this thing here (holds up an L.P. record) is made of plastic. What kind of plastic do you think it is?

S17: Vinyl.

C: Because it is vinyl . . . do we charge it with the fur? So I'm putting a charge on the record (rubbing in a circular motion).

S: (notices that the record is warped)

C: Do you know why that's warped?

S: You left it in the car?

S: From heat.

C: Actually I thought I was being really smart and I ended up being really stupid. You see, electrostatic experiments work much better when things are dry. So I put it over there in the fume hood under the heat lamp, and I didn't have it flat. And I heated it a bit too much.

S: What record is it?

S's: (discussing among themselves)

C: What record? This is Bach. Now you think it was warped before was the record was melted. (rubbing in a circular fashion) Uh, I'm not trying to listen to the record . . . vinyl
... I notice I'm getting a charge. If this is vinyl what kind of charge will it be ... positive or negative?

S's: Negative.

C: And you know by ... because of the electrostatic series. Now, where's my charge transfer? Have you seen this before (holds up a metal disk with a glass handle in the middle)? It's a plate that has two different kinds of materials on it. How is this part different from this, (S19)?

S19: Well, it isn't metal ... like one part conducts and the other part doesn't.

C: Which one?

S19: The metal will conduct.

C: Okay, so this is a good electrical conductor. There are different types of conductors ... you can conduct heat, for example. So this is a good electrical conductor. And what you can do (demonstrates) here ... (puts metal disk on the charged record, then holds it up to a electroscope; the needle doesn't move) Well imagine that. I think that we could try the other plate. Uh, (S20) could you get that?

S21: (inaudible)

C: I'm not sure what you mean by that (S21) ...

S21: Okay, uhm ... you said that somebody thought the metal conducts ...

C: Yes, this metal conducts ... and this [the glass handle] is an insulator. So I can hold it by this (demonstrates) and I can carry it around. (S17), would you turn it [the record] around to the other side please?

S: Side two.

C: You see what I've done ... is I've transferred charge from there ... uh, what am I doing now [touches the electroscope]? (S16)?

S16: Grounding.

C: What does that mean?

S16: You're getting the extra electrons off. The electric charge.

C: Okay, good ... so I'm neutralizing it.

S16: Yeah.

C: (demonstrates that the metal plate will move the needle of the electroscope: the plate has been charged, apparently by being
touched to the charged record) Now did you watch that closely? Uhm, (S6)? (S22), Can you do that?

S22: I'll try (attempts the demo, other students giving instructions. The electroscope needle doesn't move)

S21: Okay, so you have to rub it.

C: Okay ... rub it then. Take it off ... okay ...

S22: (tries again, and the needle barely moves)

S: It's wearing down.

C: Is it wearing down?

S's: Yeah.

S: It's wearing up.

C: It's still working.

S: But it doesn't go around as far.

S22: (tries again ... the needle still doesn't move)

C: You disappoint me ... you think I've been tricking you.

S's: (laughter)

S: Real good (S22).

C: Well, I don't know what's wrong. Are you concentrating?

S's: (laughter)

C: Are you letting your mind wander all over the place?

S: He's probably holding a charged magnet.

**SUPERVISION DIALOGUE**

R: Oh, here ... just about you playing dumb.

C: Oh yeah.

R: Uh, Colin: "You disappoint me ... you think I've been tricking you." And the kids laugh. "Well I don't know what's wrong."

C: (laughs)

R: (mimics) "Well I don't know what's
wrong. Are you concentrating? Are you letting your mind wander all over the place?" "He's probably holding a charged magnet." That was good.

C: Actually, they thought I had something up my sleeve.

R: Well that's what I did too.

C: (laughs)

R: When I was watching it.

C: Actually, that part of it ... I was enjoying myself so much I didn't really have any deliberate ... I was just . . .

R: . . . joking around.

C: Well I . . . in a way, but what I was . . . if I was trying to illustrate anything it was that you can have fun at what you're doing. I was just having fun . . . playing dumb and doing these sorts of things and I think it has . . . it adds something to the lesson in fact, I think, you could probably say why you do that. I mean I was enjoying . . . you can lose yourself in a situation at times. (3 second pause) One of the interesting things I've noticed is that . . . uh, if you look at concentration span, there have been times when you have had quite long lessons. But the kids have really been interested. (5 second pause) Isn't that true?

R: Yeah.

C: Why do you think that is?

R: Well, there was stuff for them to do. They were . . . I think I have a pretty good attitude towards the kids. And that's coming . . . what I was hoping when I went into teaching, 'cause I'm not one of these over-bearing . . . I was bit worried about discipline, but I figure, well if I treat them as people then hopefully . . . I think most people if you treat them well, they'll treat you well

As the excerpt of the lesson shows above, the students were quite puzzled by how Colin was able to make the needle of the electroscope move with the electrophorus. Colin seemed to be tricking them because they didn't know what to look for in the way he was handling the electrophorus; they did not know the sequence of steps required to charge an object by induction. The fact that they were unable to account for how he made the needle move, together with his teasing and humour, was captivating for them.

Rosie takes Colin's behaviour simply as "joking around."

Colin goes on to make the point that one can enjoy one's self in the classroom—in fact, a sense of wonderment brought about by a discrepant event, together with a little teasing or humour, can make a lesson very interesting.

He begins by inviting Rosie to reflect on why students have found her lessons interesting, inspite of their length.

Rosie explains that because she has treated her students with respect, they respect her in turn.
back, sort of. And so that's sort of my philosophy I guess. I mean discipline . . . except I know I have to come down harder and they'll be a little bit . . . I mean I find myself a bit wishy washy. Uhm, now I don't know what my point was.

C: Well, what we were talking about was how you can have long lessons and the kids stay interested.

R: Yeah, and so I think because of that the kids know I pay close attention to them, they will pay closer attention to me. You know what I mean? Like if somebody has a question . . . I mean I try always to get back to them, even . . . I see them raising their hand and then they put it down. And if I notice that I'll still say, "Well, did you have a question?" And so I think that because I'm interested that that comes back . . . that's part of it.

C: I think you've put together several things there. One is that discipline comes from that kind of atmosphere. And I think the other thing is that discipline is not an end in itself. You know sometimes a discipline problem can come out of the fact not just because they don't respect you . . . that's one reason. If they like you or respect you they'll behave themselves. But there's another. They might like you and respect you and still be a discipline problem because you're too dull. It's uninteresting. You don't really care about what they think. And I think one of the things that's happening is that some of your longer lessons . . . it's just remarkable how the kids have been quite intrigued . . . it's because you're making it interesting. Now, they do like you. But it's also because they're interested in what they're doing.

Rosie interprets students' attention in terms of their discipline, rather than their interest, as Colin does. For her, student attentiveness is associated with good deportment, which is a result of mutual respect. For Colin, student attentiveness is associated with an interesting lesson, good deportment being a by-product.

The fact of the matter is that while Rosie had taught a few interesting lessons, she lacked enthusiasm in much of what she did in the classroom. It was Colin's opinion that she required more cadence in her voice, and generally more "pizzazz," to use his term, in her teaching. Indeed, making Rosie's lessons more interesting was a concern. What is seen in this dialogue is his attempt to have Rosie think about her teaching more in terms of whether it is interesting for students. In effect, he is attempting to provide Rosie with a "frame" for judging her teaching.
LESSON

S: He's probably holding a charged magnet.

S22: (tries the demo again, the needle moves a little bit)

C: Take the fur out of the way for him.

S22: (demonstrates again, the needle doesn't move)

S10: He puts it on top of the round thing, not the flat thing.

S6: (S22), put it all on ... all on ... you've got to put the whole think on like that ... (illustrates) ... and then put it on the circle [at the top of the electroscope]. (again, S22 is unable to cause the needle to move very far)

S10: The ledge ... the ledge.

S's: (more discussion about the ledge at the top of the electroscope)

C: Well, I think that ... uh, (S10) ... she seems to have a pretty good idea of how it works.

S's: Yeah, (S10) you do it.

C: Go show (S22) how this operates.

S: You're going to wear out the record. (laughs)

C: Uh, it takes a feminine touch here I think.

S: That's how you made it ... (laughs)

S's: (much laughter)

S12: You have to leave it on long so it'll get strong.

S10: (demonstrates, and the needle moves a little bit)

C: There it is. Try it again. You have to be able to repeat this experiment.

S10: (demonstrates again, and the needle moves a little bit again--about 15 degrees)

C: Three times.

S10: (demonstrates, the needle doesn't move)

S12: Touch it.

S10: Uhm?
S22: (touches the plate to the electroscope and the needle still does not move)

C: Okay, do you think the charge is all gone? Well, let's see.
(demonstrates and the needle moves 90 degrees) There's lots left.

S's: (very excited) Do it once more . . . you have a little thing there in your hand . . .

C: . . . up my sleeve.

S: Yeah.

C: No, nothing up my sleeve. I'll take off my jacket.

S: Do it once more.

S: Your watch.

S: Just do it quickly . . . put it down.

C: My watch?

S: Yeah.

C: Okay . . . take off my watch.

S: Take it all off.

S's (laughter)

S: I wonder why it doesn't work.

S's (several students discussing the demonstration)

C: (demonstrates again, trying both plates again. After a few moments . . .) Well, what I'd like to do is try to figure out what's happening there. To give you . . . the truth is . . . I hardly ever do this, but there's a little bit of a trick.

S: There's a magnet in it.

C: Uh, it's not a magnet.

SUPERVISION DIALOGUE

C: Uh, there are times when this kind of thing can happen. Uh, "The truth is I hardly ever do it . . . but there's . . ." uhm, "Let's try to figure out what's happening." Somebody said, "There's a magnet in it." Now that is the place where there's an inaccurate line of reasoning. And I don't think that

ANALYTICAL COMMENTS

Colin's reply to the unidentified student, "It's not a magnet," is the focus of this dialogue. This is a situation in which Colin could not think of a way to "validate," or provide reason for, the student's response.
very much can develop from that. I might have said, "Uh, there's attraction and repulsion of the magnet," but knowing about magnetism, I know that I'm not going to be able to get static charge out of that. At least I don't think ... I couldn't think of a simple way. So I just said, "No, it's not a magnet." But when you say no in that kind of way ... uh, presented in a fairly neutral tone. That is, uh, instead of saying (abruptly), "No, it's not a magnet." You say (calmly), "No, it's not a magnet." And then ... in other words, "That's all right for your first guess." In other words, the tone of voice that you use ... uh ... indicates whether you're ...
S: Rubbing the flat of the record . . . like, not the warped part?

C: I don't think that would make any difference.

S23: You touched your finger to the . . . what's it called . . . the circle part.

C: (S23), let's see if you can do it.

S23: (demonstrates)

S: She's smart.

S: Yeah, well she's sitting there [close to the demonstration].

S23: Do it again?

C: Yeah, discharge it again. (S23 demonstrates again) Very good (S23), you've got a good eye. Actually, that's about the quickest I've ever had anybody find it too. You're too smart . . . too close to it too. Now what I did actually . . . I tried to touch it quite carefully and I touched it behind you. But sharp-eyes-(S23) picked that up.

S17: How come that worked for (S22) when he didn't touch it?

C: Okay, that's a very good point. What I am doing when I'm touching it is grounding it. Now, I have an idea that when he's touching it like this, he's grounding it through the centre, or what he did . . . is he sort of touched it there and grounded it on the outside [the edge of the plate]. Did you see that?

S22: Yeah.

C: So touching it with my finger or touching it on the outside is basically the same thing.

S22: Okay.

SUPERVISION DIALOGUE

C: Oh, one of the things that happened I thought in the . . . the record . . . It didn't quite work as well as I thought it would . . . as I hoped. But the whole event was quite successful. As a matter of fact there was . . . sometimes . . . it was (S22) . . . was able to transfer his charge although he wasn't able to do it quite correctly. I think he was grounding it, but I didn't see that as a big problem. The results don't always have to always be . . . I

ANALYTICAL COMMENTS

This dialogue concerns the fact that science demonstrations don't always work the way one expects, or hopes. Such was the case with Colin's demonstration of charging the electrophorus by induction.
mean we live in an imperfect world.
Things don't have to always work out
exactly right. And uh, if you
remember when I first started it
didn't work at all. The first time I
did it.

R: I don't remember.

C: Yeah. And if you find yourself in
that situation, just relax . . . say,
"Well, can we do something," and if
you're patient and breathe deeply you
can usually work your way through
those things. So what I'm saying is
that you . . . there were a couple of
times, for example, when you ran
into . . . there was once I remember
a few lessons ago where . . . about
a week ago already, when you ran
into a bit of difficulty and you said,
"Would you like to take over?" And
I said, "No."

R: (laughs)

C: Because I knew that you were per­
fectly competent at working through
that. So when you run into a bit of
difficulty, just take a deep breath
and say, "Well . . ." And if it doesn't
work at all, you just say, "It doesn't
work." But usually you can make
something of it and this is what
happened here. It didn't work the
way I expected, but the overall thing
. . .

R: Yeah.

C: I was able to make it work and I
was able to make some of the
counter examples that in fact . . .
it's almost . . . what happens if that
works well, it's almost as if you
planned it.

Colin's advice in such situations
is to relax, be patient, and
breathe deeply.

He reminds Rosie of a time
during one of her lessons in the
previous week when her
demonstration didn't work, and
gives his judgement that she is
perfectly competent at working
through such difficulties on her
own.

Colin's point has to do with
"improvisation," that is, making
something out of an unexpected
event in the lesson. Further,
improvisation can be seen in
terms of how a particular event
may contribute to the "whole"
lesson, despite the fact that it
was unexpected.

Successful improvisation creates
the illusion that it was planned.

LESSON

C: But the thing about that . . . that was kind of accidental,
but it doesn't happen all the time. Now, I want to get through
this a bit faster, so let's just go over what is happening,
(holds up the record) This is charged. Put this on (puts the
record down on the table) . . . It's negative on the bottom.
When this [the metal plate] is sitting on here [the record], what does it do to the electrons on the bottom of this conductor?

S's: (silence)

C: It's negative on the record . . . what does it do the negatives on the bottom here [of the plate]?

S: It repels them.

C: Where do they go?

S: To the top of it.

C: So they go to the top of the plate. So they . . . the electrons go to the top . . . what does it leave on the bottom?

S's: (several comments) The plus ones. The protons.

C: Okay, the positives lose their partners . . . the negatives go to the top, so the bottom part is positive and the top part is negative. How is that like induction? What were the features of induction, (S21)?

S21: Induction?

C: IN-duction.

S21: Uhm, the uh, you don't have to touch. The objects don't have to touch.

C: Okay, that's one.

S21: They don't come in contact.

C: They don't come in contact. What is the other?

S21: (silence)

C: I think it was the one that (S12) described to us. Do you remember what you said (S12)?

S12: Uh, that the electrons transferred to the . . . uh, it depends . . . like if it's negative, then they'll go away from them so that they'll become more positive on the one side. Like they don't go away . . . the electrons don't go away, but they transfer to one end.

C: Okay, so this was like that in that the number of positives and negative on the plate . . . it still stays the same, but they divide.

S21: Uhm hmm.

C: (to the class) Is that clear? It's the negatives on the top and the positives on the bottom. Now, when I touch this and
ground it, what happens? (S16)?

S16: The . . . you're taking all the . . . the (inaudible)

C: Good . . . the negative electrons . . . they're being repelled. They want to get as far away as possible. So when I touch it, they get away through my hand. Now, I have to remove my finger before I do anything else. For example, if I lifted it like this and I kept my finger on there, it wouldn't become charged . . . or remain charged. Why not?

S: You grounded it.

C: It goes back to what it was before. The electrons go all the way back. So there are four steps involved . . . One, take this and put it near the record. Now it looks like they're touching, but the little grooves . . . they keep the two apart. So I bring a neutral object near a charged one. Then what do I do? What was the second step? (S7)?

S7: You touch it.

C: You ground it. And then what do I do? (S24)?

S24: You have to take your finger off.

C: And then?

S24: Lift it up.

C: All right. Now, this [the record] was negative to start with. What charge ends up being . . . the net charge here [plate]?

S's: Positive.

C: So they're not the same. So one of the features of charge by induction is that this ends up being the opposite charge of . . . the thing that I started with. Now this [the plate] used to be in science classrooms in the nineteenth century. It's called an "electrophorus." And if the days are dry, you can keep charge on there for a long time. You see, one of the things is that I'm not actually taking any charge away. By induction, I'm taking the charge just to ground. I'm not removing any from the record at all. So let's go over those again. Charge by induction: no contact, but you get the charge. Four steps, again: number one, (S17) . . .

S17: Bring it near.

C: Bring it near. Number two . . . (questioning very quickly)

S12: Put your finger on the . . .

C: Ground it. Number three . . .

S12: Take your finger off.
C: And...

S21: Pull the object away.

C: ... the object away. Any questions about that? All right. Now, uh, what I'd like you to do is just take about two or three minutes to write that up and then I'd like to deal with the debriefing. I'm going to do half of that.

(students work for a few minutes on their notes, while (C) and (R) circulate answering questions)

C: All right, would you stop please? Leave a space if you need to and finish it off tonight.

S: Do you have to say why it works?

C: Uh, you can make it as complete as you want. All right. That's a good question. Uh, if you think that you understand why, good. But, on the other hand, I don't want a page on each feature. But, uh, be succinct, which means be as short and to the point as you can, and yet include as many details as you want ... as you can. But don't feel that you have to write a book. Is that all right?

S: Yeah.

S: So, you put your finger on the plate ... and then...

C: Well, we're going to review this. Now what I want you to do in this debriefing part ... is put this in the section where it belongs. Now, remember in the debriefing ... the emphasis is going to be on brief. So what I'm trying to do here is summarize the main ideas that you've covered in the last few days. Does anyone know where the term comes from ... debriefing?

S: (silence)

C: Well, it comes from the military. If you've been on a spy mission ... (S25) ... you've been on a spy mission, and you go and find out things. You come back and we debrief you to find out what you've learned. You've been on a spy mission investigating static electricity, and I want you to come back and summarize what you should have learned. Uh, when you study for a test, this is the part you should concentrate on. As a matter of fact, you're going to getting a quiz on this tomorrow.

S: Tomorrow?

C: On static charges. Not a test ... a quiz. Now what did you learn about the atom? You know that it has a...

S's: Nucleus.

C: ... structure. What does the word structure mean (S21)?
S21: Form.

C: Form ... okay. No, the idea of the structure ... you started out with ... knowing probably something about an atom. Some of you I saw ... (S5), you had a little dot. That was a fairly primitive model. Remember when you were asked to sketch an atom? And I remember you saying, "Oh, gee ... I'm not sure how to do this." Some people had more primitive models, some people had more sophisticated ones. Well, you used ... in the end you ended up relating this to a model that is in the book. This (draws on overhead) is called the ... planetary model. Why would it be called that? (S13)?

S13: Because it shows the electrons orbiting or something, I don't know.

C: Sure, it's like the planets around the sun. But realize that this is a model. That is not really what an atom looks like. I'm not so sure we even know what an atom looks like. We have various models. So your model ... might be a little bit less sophisticated that this one, but this is pretty primitive compared to other models. So a planetary model had a ... what was at the centre?

S: Nucleus.

S: Kernel.

C: Okay, in particular, what was the Latin name for kernel? (S6)?

S6: Nucleus.

C: Nucleus ... the centre ... or kernel. What charge is on it? (S1)?

S1: Uhm, there's no charge on it? Oh ... positive.

C: Are you positive?

S1: (laughs) No.

C: Do you think she's right, (S20)?

S20: Uh yeah, I do.

S: Positive.

C: These are positive. And that's rather important because these don't move. That's in the centre, it's in the nucleus of an atom. Very dense ... very small ... positive. And what is on the outside? (S10)?

S10: Electrons.
C: And what charge is on the electrons... (S3)?

S3: Negative.

C: Okay. And the whole idea was that these [electrons] move easily... and in the nucleus there's a positive charge... there's a particle that has a positive charge. What was its name?

S: Proton.

C: (S15)?

S15: Uh...

C: Positive charge in the nucleus?

S15: Oh, uhm, proton.

C: Okay. Protons are the positive ones... neutrons are neutral... and the whole thing about these is they don't move. (writes) How many types of charge are there... (S9)?

S9: (silence)

C: How many types?

S9: Three.

C: What are the three?

S9: Positive, negative and neutral.

C: All right, that third one... we don't usually classify as a kind of charge. That's when we have equal number of positive and negative. So, I agree that neutral is different from positive and negative, but let's emphasize that there are two different kinds. There are two types of charge... and we call them... negative... and... positive (writes). And when we have equal number of positive and negative, what do we have (S9)?

S9: Uh... I wasn't...

C: If the number of positives and the number of negatives are equal... so everyone has a partner, what is the charge?

S9: Neutral.

C: Okay, good. So I'll put your third one in there. This is neutral when the positives and negatives are the same. Now you see how I'm doing my notes... keeping them very brief? This is a summary. If I need more detail, go back to the main part of the lab. All right, the other thing is... we looked at the way in which things become charged. There was the first method of charging. (S2), what was that called?
S2: (silence)

C: All right, it was by contact... the word started with a "C" as well. Do you remember what the word was?

S2: (silence)

C: (S25), can you help her?

S25: (silence)

C: (S24)?

S24: Conduction.

C: Okay... CON... duction. And that was by contact. Now, uh, one of the things that you did... was you took a vinyl piece of strip... how did you recognize it as being vinyl?

S: Notch.

C: The vinyl strip of plastic? How did you recognize it as being vinyl? What was the identifying... mark? (S12)? (S22 talking) (S22), be quite. Okay, (S12)?

S12: Sorry... what was the...

C: How did you recognize that it was vinyl?

S12: Well, because...

C: It was shaped a little bit differently. Do you remember?

S12: The notch.

C: Good. It had a little nick on the corner like that. I think that someone pulled a bit of a trick on (R) here, and cut a little notch out of one that was acetate. [to (R)] Do you remember that?

R: Yeah, (smiling) that's a dirty trick for them to do.

C: Okay, this has a little notch... and this was vinyl. And when you rubbed it with... what? What did you use for this? (S23)?


C: Uh, okay... and this became negative. Where did those negatives come from? (S13)?

S13: Uh, they came from the fur.

C: So the electrons moved the electrons from there to there (diagrams on overhead)... I'll say the electrons... and what does that leave back here (S1) on the fur?
S1: Uhm, protons.

C: Okay, so that leaves positives. So, we have uh, the vinyl which builds up an excess of . . . electrons. Do you understand what the word excess means (S6)? What does excess mean?

S6: Uhm, more than.

C: Okay, good. More electrons than protons. Now what was the other kind of strip that was involved? (S20)?

S20: Acetate?

C: Good. And in this case . . . this was (draws) squared off right? What did you rub that one with, (SI5)?

S15: Uh, with uh, cotton?

C: Okay, so this was cotton. And what kind of charge was left on it?

S15: Uhm, you're asking me?

C: Yeah.

S15: Uh, positive.

C: And how did that happen?

S15: The, uhm, there was a shortage of electrons.

C: Yes, okay let's say . . . (writes) deficit, or deficiency of electrons. Now, where do the electrons go?

S15: On to the cotton.

C: Okay. So the electrons transfer this way (draws arrow) and therefore this becomes negative. Charged by conduction. (pause) Any problems with that? It's clear? Now, the next thing that you did . . . you developed something that we might call the law of . . .

S's: . . . forces.

C: . . . forces. What could that refer to (SI7), do you think?

S17: Uhm, why the charges change?

C: Well, I wasn't really thinking that . . . I was thinking of describing the two types of charges that you can get.

S17: Conduction and induction?

C: That's how you charge two objects . . . but, what do we mean by a force?
S17: Uhm, the pulling and pushing.

C: Okay, and what was the fancy name for pulling?

S17: Oh, for pulling is attraction.

C: And for pushing?

S17: Uhm, repelling.

C: Okay. And do you remember how that was related to charges?

S17: Uhm, no ... I don't know.

C: Which two things repelled?

S17: The fur and the ... (5 second pause)

C: (S8), which two things repelled?

S8: The same.

C: All right when the charges are the same ... that is, when they're both positive, they repel (S17) ... when they're both negative ...

S17: They repel.

C: They repel. And how do you get attraction? (S19)?

S19: Opposite charges.

C: Okay, so one way that you can summarize that is to say, "Like charges repel ... (writes) and ... unlike charges attract."

Now, when you did this as an experiment ... remember you charged it ... put it on a watch glass and you tested ... which factors (writes) ... determine the size of the force? What were some of them? Can you think of one, (S12)?

S12: Uhm, well I guess how well it's been charged?

C: Okay, when you say how well it's been charged ... do you mean how much charge is on there?

S12: Yeah, well ...

C: Okay, if you rub it more charge on it ... if you rub it less, you don't put as much on. Is that what you mean?

S12: Yeah.

C: Okay, in that case we'll say the force ... (writes) depends on the amount of charge involved. And the idea was that if you have more charge it pushes more; if you have less charge it doesn't push as much. Uh, what else was involved?
S: The amount of negative charges and positive charges?

C: I think that's what I wanted to say in this one. Okay, what else... (S7), I haven't even asked you a question today, have I? Maybe once or twice.

S7: Uhm...

C: What is another factor?

S7: I'm not sure.

C: How does... how did distance change the result? Was that you (S13)?

S13: Yeah.

C: What relationship is there to the distance?

S13: The farther away, the weaker the force is.

C: Okay, the closer... (writes) the two objects... are, the greater... the force. Actually, there's even... I wonder if you've heard of this in Math. When the distance gets small, the force gets big. They're changing in the opposite way. Has any body heard the word that describes that? Well, it's kind of... it's called an "up-side-down" relationship, or it's an inverse relationship. That is, the smaller the distance, the greater the force. Now, uh, we have less than fifteen minutes left [to (R)]... sorry...

R: That's all right.

C: (R)'s going to take over now. (offers felt pen for the overhead)

R: I've got my own.

C: She has her own equipment. (smiles)

R: Okay, the last thing we're going to cover in debriefing is induction, which we saw yesterday and today. Number six... maybe I will use yours (C's felt pen). I wrote on paper. (pause) Induction (writes). Okay, first of all I'll give you a little definition and then we'll talk about the conditions that are required. (writes) A charged object is brought close to a neutral object... and the neutral object... becomes charged... then we say that the neutral object has been charged by induction. (pause) Now you saw today there were four conditions necessary for charging an object by induction. Can anyone remember what the first condition was? (S1)? Oh, I'll let you finish copying this down.

S6: What does that mean... condition?

R: Oh, there's four conditions. (S2), can you think of a
condition?

S2: (silence)

SUPERVISION DIALOGUE

C: The first kid you asked didn't know them. Isn't that right?

R: Yeah, but I think it was ... that's what I was wondering ... if it was the way I had worded it or something.

C: Yeah, let's look at that. I remember that.

R: I called them conditions.

C: Yeah, you see it was a different word.

R: Okay, "You saw today there were four conditions necessary for charging an object by induction. Can anyone remember what the first condition was? I'll let you finish copying it down." "What does that mean, condition?" "Oh, there's four conditions. Can you think of a condition?"

C: Yeah, do you see what's happening there?

R: Yeah. So they just ... 'cause I used a different word.

C: Yeah, it was a different word suggesting a different idea.

R: Uhm hmm. Well you just called them four steps. To me ... I guess that's the thing. To me it seems like the same word. But I know what I'm talking about. It's not the same word.

C: Well, to my mind, what the difference between step and condition is ... "condition" describes four things that exist at the same time, whereas "step" suggests a sequence. Condition does not.

ANALYTICAL COMMENTS

Colin's initial interpretation is that S2 didn't know the "conditions."

Rosie proposes that the problem may have had more to do with the way she worded the question. Perhaps the word "condition" was problematic for the students.

Rosie reviews the transcript.

To Rosie, "condition" meant the same thing as "step." However, she realizes that students cannot be assumed to take the two words as being equivalent. Her statement, "But I know what I'm talking about," suggests that she is aware of the difficulty one sometimes has choosing words for expressing ideas. She has "reframed" the problem in terms of the meaning students attach to the word condition.

Colin elaborates, pointing out the meaning "condition" has for him.
R: Yeah.

C: So when you used that word, I thought to myself, "That suggests in my mind something slightly different than the word step." But in your mind condition might have meant that.

R: Yeah, I guess that was the first word that kind of fit. I didn't have it clear or something . . . how to present it, so . . .

C: Well, I guess what it illustrates, though, is that condition is certainly a more complex word than step, so there are more complex words like induction and conduction that you want them to know. But, other than that, it is probably wise to use as short and simple words as possible. But the problem I think in that case was not that they didn't know the four steps, but that they weren't sure about what you meant by condition.

R: Oh yeah. Because I sort of led them back to what they were doing . . . and sort of had to . . . long windedly . . . and then they came out with it.

Colin reviews the initial "framing" and the "reframing" of the problem: the initial frame was that the students didn't know the four steps. As the problem was reframed, the students weren't sure what Rosie meant by the word condition.

Rosie provides evidence for the reframed problem from a later part of the lesson. (Notice that she is aware of her long utterances, as illustrated in the remainder of Lesson 2, below. As discussed in the analysis presented in the text, this characteristic of her teaching changed significantly through her practicum.)

R: I'm thinking of what (C) did today with the electrophorus. He said that there were four steps . . . four conditions that were needed to charge it by induction. Okay, I'll give you the first one. First of all, you need to bring a charged object close to a neutral object. So in the case of the electrophorus, what we saw today was . . . we had a record that was charged negative. And we brought the disk . . . (draws) . . . okay, we'll make it a thick disc so you can see all the charges. Okay, before we bring it close, all the charges are random . . . okay, so . . . then what would be the next condition, or the next step? (S8), can you think of what the next condition was for charging? (C) did special trick.

S8: Ground it.

R: Okay. So we bring them close . . . so we'll pretend that we've brought them close here . . . (draws) . . . ground the charged object . . . sorry, ground the neutral object . . . okay, so ground it. Now, when I brought this disk close to the charged
record ... what happened to all the charges inside? (S26)?

S26: They moved to the bottom and to the top.

R: Okay, which one's would have moved to the bottom?

S26: The negative.

R: Okay, so the record's negative ... the negative charges in the disk would also move to the bottom?

S26: (silence)

S: They move to the top.

R: (S23)?

S23: The negative ones would move from the bottom of the plate to the top of the plate.

R: Okay, so our negatives are then lined up at the top of the plate and our positive's are on the bottom ... now we're grounding the neutral object ... so what's happening to all the negative charges?

S22: They're leaving.

S21: They're going out.

R: Okay, (S22), the negative charges are going to the ground. So then in the third step, if we remove the ground ... (writes and draws) ... okay, we've still got negative charge on the record ... and what would happen to the disk? (S25)? I've brought the disk close to the record ... the charges have separated ... and I've grounded the disk ... now, when I remove the ground off the disk ... when (C), once he took his finger away, what's left on the disk?

S: (silence)

R: Okay.

S6: Positive.

R: Positive ... okay, can you explain that (S6)?

S6: Well, it's the only way because you've got to have positive to attract it to the electroscope.

R: Well any charge will ... if you have an excess of charge it'll make the electroscope move. But you're right, it's positive. Okay, what happens in this step ... when you're grounding the neutral object, you have all these negatives on the top that are being grounded. And they want to get as far away from the negatives on the record as possible. So they're all going to the ground. So all these negatives are going to the
ground. So when you take away the ground, then more positive are left. So the fourth step (writes) ... then you separate the objects, and they now have opposite charge on them. (pause)

Okay, and we saw examples. Okay, what were the two examples we saw in class there? (S6)?

S6: How it made the electroscope move . . .

R: Okay, the electrophorus . . . and then the one we saw yesterday was the banana. Okay, now we've just got a couple of minutes left. I'd like to talk about the quiz for tomorrow. Yeah, I'll give you back the journals at the end of class. I just want to go over what's going to be on the quiz. Okay, first of all is the atomic model (writes). Then the electrostatic series. Uh, don't memorize it. Okay, you don't have to memorize it, but I want you to understand how it works and how it operates.

S6: Like the electrostatic?

R: The electrostatic series . . . that was the list we had with fur, ebony, and all those materials.

S6: Just know what's positive . . .

R: Just know how to use the list, okay? You don't have to memorize where everything is. Pardon?

S6: Will we have the list?

R: Yeah, I'll give you the list. Or part of the list . . . on the test. Okay (continues) charging by conduction . . . and charging by induction . . . and the two types of charge. And how they interact. Now this is a quiz . . . it'll be about 20 minutes, okay? So study for it, but it's not a major test. How-they-interact (writing). Okay, so for tonight . . . study for you quiz, uhm, finish up your journal . . . so you have to do the main points. In this journal . . . the last journal you did, you didn't have to do a summary. But this journal . . . I'd like you to do a summary . . . uhm, a paragraph . . . two paragraphs long . . . just saying what you learned . . . down in a nut shell in this journal. And your journals. I'll just put up an overhead and tell you how I marked it, and then at the end of class you can just come and all pick them up. And I've got the worksheets as well. You can include the worksheets in the journal for tomorrow.

S: You know those notes you just gave us on the disk and everything? Do we use that and like our . . .

R: Well, this is all part of the debriefing so you don't have to redraw any pictures in the summary. The purpose of the summary is just to write a paragraph . . . two paragraphs on what you learned. Just to sum it up. Yes (S10)?

S10: Uhm, do you have to do the questions on page 13 and 14.
R: No. Okay, there were some questions assigned... number 1 to 6. You've already done 1 to 3. So you don't have to do... don't have to do number 4 to 6.

S: You don't have to do 4 to 6. Did you hear that (to another student)?

(the period ends)
Rosie put three problems on the board at the beginning of Lesson 4:

1. Use 1 battery to light the bulb.
2. Use 2 batteries to light the bulb.
3. Use 2 batteries to light the bulb so it shines just as brightly as it did in #1.

Students were instructed to work in groups of two or three, and each group was given a bulb (in a bulb holder) and two batteries. A large box of wires with alligator clips was put at the front of the classroom.

Throughout the lesson, Rosie and Colin circulated among the students as they worked on the problems. Several groups of students were video-taped by the investigator. After school, when Colin and Rosie discussed the lesson, they viewed the video and discussed how one group of three girls went about solving problem #3. The supervision dialogue that transpired appears below in the left-hand column. The students' discussion appears throughout, with diagrams of their apparatus. Analytical comments appear in the right-hand column beside the supervision dialogue.

SUPERVISION DIALOGUE

C: I thought that this little sequence of events was so interesting. I hope the sound quality is good. About today's activity . . . it was kind of an interesting thing . . . uh, one of the things . . . they found the first simple circuit fairly easy. Why do you think they might have done that? Why did they find the first task easy?

R: Well, 'cause it is.

C: 'Cause it is easy?

R: Yeah.

C: Anything else? Any other reason?

R: Well . . .

C: Well, what sort of mistakes might you make in that very simple series circuit?

R: Well, it's hard to make a mistake 'cause you only can go two places. I mean you could not hook up . . . you

ANALYTICAL COMMENTS

Colin prepares the video-tape for viewing.

Speaking generally about the lesson, he notes that the students found the first problem to be quite easy; they were required to construct a simple circuit using one battery and one bulb. On the previous day they had done something similar in one of Rosie's stations on current electricity. There they had connected a simple circuit, lighting a bulb using a small voltaic cell made from fruit.
could hook both wires on to one terminal.

C: Yeah.

R: But other than that . . . there's not really much you could do.

C: Well, uh . . .

R: The way those little lamps are set out with the two connections, I think it makes a difference. Like I'm just thinking back to those drawings that they had in that learning in science book. When you were just given a light bulb, without the connections attached to it, I think it would be a little harder. But having those two screws there makes a difference, I think.

C: Uh, I think that there were other things. One is that there was a simple circuit they were setting up with the fruit. So they had some experience.

R: Yeah, that's true.

C: The other is that . . . I agree that hooking both wires to one terminal. Uh, I've seen that as something that's occurring. Uh, the other thing is that sometimes they don't realize to hook it on to the metal part. And you had dealt with that in the introduction. Remember you were describing conductors and insulators.

R: Uhm hmm.

C: Sometimes they make a mistake trying to hook it on to . . .

R: Well yeah, because they [the cells] have these little red caps on them that they would have had to take off.

C: So they don't take the caps off. My point is there that . . . that could have been part of the lab. But that was all right. Now, one of the things that occurred to me was that because they found the first two

Rosie formulates two reasons why students could have difficulty with constructing a simple circuit: (1) they could hook both wires on to one terminal, and (2) they might not know which parts of the bulb casing to touch with the wires, had they not been supplied with bulb holders.

Colin suggests that one of the reasons why students found the first problem easy was that they'd had some experience in making a simple circuit on the previous day.

He suggests that another source of difficulty for students would be their not realizing that the wires must touch the metal part of the terminals.
tasks easy, you think, "Oh, gee they really understood." Well, the last task was extremely difficult for them. They had all kinds of bizarre and interesting solutions. And this one here, for example, the one on the tape . . . I thought they understood it. And I looked at the diagram and I thought, "Oh, the diagram doesn't look quite right because the negatives and positives were marked wrong." The reason I had them do it for me was I was not sure whether they knew what they were doing because of their diagram. Otherwise I thought that they knew.

R: Well, (S6) and (S24) . . . it looked kind of right because they had the right brightness and they had the two batteries and it was positive and negative . . . but all they had done was they cheated just to try to pull one over. What they did was they hooked it up, the one, in series and then they just looped the wire in around . . . and shorted out, and never had it connected. And (S5) and (S8) . . . they had their parallel circuit set up but for number two. They didn't know that they had set up a parallel circuit.

C: Did you think that that was a useful stage? Do you think it was useful to spend time on having them do that as sort of a broad problem?

R: Yeah. I think so. Like I think that I'd do it again.

C: Because what we've done is . . . rather than . . . I'm mean here's a very fundamental difference between . . . I mean I think this is the crux of what we mean by constructive and transmission. I could have said, "The way you connect a parallel circuit is you connect the like poles together and then you connect . . ."

R: Well some of them still did that. It was because they read the battery. But it's a little bit different because it's . . .
C: But do you see what the transmissive mode means here? Uh, now what we have done is we've given this to them as a problem. We say, "We want you to construct a solution to this." The idea, I think, here is that now they've had a bit of play time and figuring the problem . . . what we're trying to claim, I think, is that when they go to the next step now they're ready to have this problem solved because it was a real problem for them. They haven't been able to solve it. They struggled in a number of ways. Some of them have worked their way through. But now we build it up to the . . .

R: "This is what you did."

C: Yeah. And the idea is that the raw experience . . . well, just like we were having a discussion about how the what-happens section fits into the debriefing. The raw experience first.

R: Yeah, it took them longer than I thought it would. Like you said, I was watching the clock and I thought that I don't want to cut them off. Then it was getting to five minutes left in class and I just wanted to get something down for the diagrams, but I almost could have left them for the whole period.

C: Well, were they generally involved with the problem do you think?

R: Yeah.

C: I wonder why.

R: Well, they were really interested in it. The materials were simple. I don't know. I guess, too, that a lot of them don't really have any experience with electrical stuff?

C: Do you think that . . .

R: They thought it was kind of neat to try.

Colin's teaching approach stems from his belief that learning is based on experience and depends on students' existing knowledge. Thus, students were given the three problems on circuits before any teaching occurred. Colin notes that the third problem was particularly difficult for them: to light a bulb using two batteries such that the bulb lights as brightly as it does with one. His idea, as seen expressed here, is that after students have struggled with the problem for a while, they are in a position to learn about parallel circuits.

By providing the problem first, students are given what Colin refers to as "raw experience," that is, experience they can later make sense of at the time when the actual teaching, or "debriefing" occurs. In the meantime, the experience of trying to solve the problem may indeed be perplexing for them.

Colin probes the way in which Rosie conceptualizes the students' involvement with the problem. (Again, his style of supervision mirrors his teaching style,) Her reasons for student involvement include genuine interest, simple materials, and novelty of the task.
C: But was it a real problem . . . they were really puzzling to solve it?

R: Uhm . . . not for all of them. Some of them. Like for (S24) I don't think it was. And for . . .

C: Well, what do you mean?

R: Well, for (S24) I don't think he was really interested in it, but I think part of that was . . . he knew how to do it already. Well, the first two he knew anyway. He knew how to do it really easy and so he thought "Well, this is boring . . . simple circuit." Uhm . . . but those girls, (S23) and (S26), they were. And these girls [S1, S10 & S12] were. And (S5) and (S8) were. (S2) and (S3), I'm not sure.

C: There's quite a significant number who were really working away trying to solve the problem. As a matter of fact, one of the things that interested me was that they didn't, you know, when I was there . . . there was no need to cut this off. They're so involved with trying to solve this, it would be a crime to do that.

R: Yeah, well, it took longer than I thought.

C: Keep it in mind.

R: Anyways let's watch it. Yeah, it's channel four.

Colin’s curiosity about the nature of the students' puzzlement with the problem prepares the way for viewing the video and sets the stage for the remainder of the supervision conference.

Again, he probes the way in which Rosie conceptualizes the character of the problem for the students.

Colin’s comment about it being a crime to cut off the problem solving activity further emphasizes its importance to him. Indeed he was somewhat bewildered that Rosie had taken the last five minutes of the period to have a few students put the drawings of their solutions on the overhead projector, displaying them to the rest of the class.

LESSON

S12: Okay, first we attach the negatives, and then you tip it over . . . and touch the positives and the negatives together . . . and they work . . .

. . . and then you can do it to the other side . . . and it works again.
And if you use both of them, it doesn't work.

**SUPERVISION DIALOGUE**

C: Do you know why?

R: I don't understand what they're doing. Are they going positive to positive?

C: No. What they're doing is they've got . . . they're shorting the cells out. So it's the cells are connected like this (draws). And it doesn't work.

R: Okay.

C: And then what they do is when they separate this, they're using this cell and when they break this connection they're using this [other] cell. But when they put both in it doesn't work.

R: But then they flipped it around, and that's when you thought that they understood what was going on.

C: Well, I go through this and I thought, "Now why isn't it working?" I suggested they connect this battery with the opposite terminal. And then the first time it doesn't work, and then it does. And then they develop it to continue on beyond that and identify the number of circuits and then figure out why it's working. That's the beauty of it. It's not just that they get it to function. They come out with an explanation. The interesting thing was that right there I thought they had it and I was wrong.

**ANALYTICAL COMMENTS**

Colin stops the video and asks Rosie if she knows why the girls' circuit didn't work using both batteries. When she is unable to explain why, he uses circuit drawings to show her.

Colin provides an overview of the remainder of the video-tape. Throughout the sequence, the girls will not only solve the problem; they will also undergo a significant change in their understanding of electric current and the concept of circuit. At this point Colin is visibly excited, particularly over the fact that his initial understanding of what the girls understood was wrong. What he models for Rosie throughout their dialogue is a keen sense of inquiry into the nature of the girls' puzzlement over the problem.
LESSON

C: You know the third problem was to use both of them...

S10: ... to make it as bright...

C: ... to make it just as bright as #1. Did you do that... that set up?

S12: We did... that's...

S10: That's as bright as #1.

S12: 'Cause we can make it brighter by using another cable.

C: Have you tried all the possibilities that are there?

S12: (begins to disconnect the bulb)

C: No, no... don't disconnect the bulb... but the way you're touching the cells together. Have you tried everything that you could?

S1: Try using the positives again.

S12: Okay.

Yeah.

'Both together... and they don't work. Okay.

C: Is there any other way that you can try?

S1: Positive and negative.
S10: We did that before though.

S12: Keep it on that.

'Just sec . . . (bulb lights) Well, these are two negatives (surprised). This is bizarre.

And there's two positives touching there. The only difference is like the wire isn't attached. That's like the same thing that's been happening. So I guess it isn't that the opposites are working . . . as long as one doesn't have a wire attached to it, it's going to work. (pause) So let's see . . . what else can we use? So it would be like positives and negatives . . . that's what would be doing it, but . . .

S1: Well, it still must be that way . . . because . . . this is positive . . . what am I thinking of here? (pause) No 'cause this is positive . . . no, this is negative and so it's going to the bulb . . . and this is going from the bulb to the positive . . . (laughs) I don't know . . . 'cause . . .

SUPERVISION DIALOGUE

C: Do you know what she's saying there? That what you need is this situation. I've seen this one before. That if this is attached to the negative and that's attached to the positive, it should work. You go from positive to bulb to negative, and you don't have to form a complete path. And she says, "I don't understand why that doesn't work."

LESSON

S12: And . . . and . . . but you see it's
not doing anything, right? And then
... so when you try ... even the
negative ... (bulb lights). Oh, just
a second ...

Okay, what could be happening is like
we're getting an all positive charge
'cause there's like all of that going
into there ... just a second. If you
touch that side and that side (the two
positive terminals) there's all this
positive going into there. And if you
touch this to this (the two negative
terminals) there's all this negative
going into there (the bulb).

So if you go back to what we originally
had ... with two positives or something
... and you touch ... (bulb lights)
well, why does that work? Just a second.
Because there's (laughs) we got ourselves
confused.

SUPERVISION DIALOGUE

R: Okay, she closes the circuit just with
the wire that's attached to the other
battery. I wonder how they got on
the idea of turning them
up-side-down to begin with. You
know what I mean, because they're
kind of locked into that.

C: I thought it was a neat idea.

R: Well, (S17) was doing that over here
too.

ANALYTICAL COMMENTS

At this point in the video, Rosie
recognizes how the girls are able
to light the bulb with the
up-side-down battery: the circuit
is closed by the wire attached to
the top cell's terminal, the
connection being made by the
touching terminals.

LESSON

S1: Did you try ... does it work if you put
the two ones without the cable on?
S12: No.

S1: No.

S10: No, because it only works if there's one cable.

S12: (tries again) No, it doesn't work. It's only if one has a wire on it and the other doesn't have a wire on it. That's like... the basic thing that works. So why is that?

S1: It doesn't work with two wires?

S10: No... well, did we try that?

S12: It works... no it doesn't.

S10: Okay.

S12: Okay... one with a wire and one without a wire.

S1: (takes one wire off the cell)

S10: Wait a minute... that was on positive, right?

S12: Uhm hmm.

S10: Okay... so try this out. Keep that on positive...

and put the two wires together. (bulb does not light) Ooops.

S12: Remember we tried that before? 'Cause we found that it's not the positives and negatives.

SUPERVISION DIALOGUE

R: (S12) said something about the positives and negatives, so is she thinking the terminals?

ANALYTICAL COMMENTS

Rosie begins to take the lead in sorting out what the girls could have been thinking.
C: She explains that. This is that theory, you know, where ...

R: That you have positive things ... well, you sort of do, but you have positive electrons and negative electrons.

Rosie recognizes that the girls seem to have the idea that there are two kinds of electricity: positive and negative.

C: Yeah. They come ... one from one pole and one from the other.

LESSON

S10: Okay.

S12: Okay, so it's just the wire.

S10: A wire with no wire.

S1: Put two wires together ... and have it ...

S12: We did that I think.

S1: No, no ... but if we do it won't work because you have all positives going there (from one cell to bulb) and positives going there (from other cell to bulb) ... and there's no negatives. I have no idea what I'm talking about. No ... uhm, I don't know. (pause)

S12: I don't understand ... why is the wire that is ...

S1: That's what's conducting it to the light bulb.

S12: Yeah ... 

S10: But why do the two wires not work then?

S1: Because ...

S12: Okay, I can maybe understand if ... you have like one wire is on like a positive ... and then you touched it to a wireless positive ... cause then all this positive stuff is going into it, you
know what I mean . . . and it's making it work. Or if you do that, you know, with the negative, right? But when it's a positive on a wire . . . why does that work because wouldn't that even it out?

SUPERVISION DIALOGUE

R: (laughs) I'm trying to follow her logic.

C: Oh, the positives cancel the negatives. That's her theory of why this set up didn't work. The positives and negatives feed in and they cancel.

ANALYTICAL COMMENTS

The idea that the positive and negative cancel each other is an extension of the two-types-of-electricity theory.

LESSON

S1: (tries another arrangement)

S12: Except . . .

S1: Hey, look. Okay, that works and that's a lot brighter.

SUPERVISION DIALOGUE

R: They think there's something special about the wire.

ANALYTICAL COMMENTS

Rosie formulates an hypothesis about the girls' reasoning as the video-tape continues.

LESSON

S10: That's brighter . . . what are you doing?

S1: And that is a positive and a negative without a wire.

S10: We didn't try that before . . . oh, that's strange.

S12: (tries the same arrangement) And that works really well.

S1: Uhm hmm.
S12: Okay . . . 'cause I was just thinking that . . . okay, what was it?

C: When you had it . . . when you had it connected the way you did just a minute ago . . .

S12: (repeats the arrangement)

These two?

C: Can you describe the order in which it was connected?

S12: Okay (puts cells down) . . . this is the negative (points).

C: And where does it go from there?

S12: Negative goes into there (follows wire to bulb). And this is positive (points to the other cell) and it goes into there (follows wire from other cell to bulb) . . . and this is a negative (without wire) and this is a positive (without wire).

S1: So it's connected . . . it's just making a circuit. It's like when you put these together, it's like having that other cable that we had joining these two (the two terminals without a wire attached).

SUPERVISION DIALOGUE

C: You see, there's the "Ah ha!" Right there. Did you see that? That is the first "Ah ha!" right there. You know, I just thought that was such a terrific event. She just sees it like that.

ANALYTICAL COMMENTS

Colin displays as much excitement in his voice as S1 did on the video when she conceived of electricity flowing through a continuous circuit.

LESSON

S12: Right, yeah . . . okay.

S10: Right, okay.

S1: So that's making the same amount of light coming out of there as when we had the cable.
S12: Yeah, that's what I was thinking before.
Yeah, I just sort of connected them, right?
And then when you have a negative and a
positive . . . okay, right . . . a negative
with a wire and a negative without a wire
.

It will work because it goes . . .

S1: It goes there (to bulb) and comes out there
(back to same cell).

S12: Yeah, so it goes in and out, right (traces
through both cells). It goes all the way
around.

S1: It's not using this battery when it does
that. That's what it's doing because you're
making the wire connect there (negative
on terminal with no wire).

SUPREVISION DIALOGUE

C: You see, that's a good insight there.
She's really got it.

ANALYTICAL COMMENTS

S1's realization that the top bat-
tery was not being used supports
Colin's notion that she correctly
understands the concept circuit
now.

LESSON

S12: I see. Probably why it wasn't working
before is because if you touch these two
(negative with wire to negative without wire)
you're forgetting about one of them not being
connected into it.

S1: Yeah, it's not working here.

S12: That's it . . . the circuit just stops.
So that's why the . . .

S1: The only way is if the circuit . . .

S12: Either two without a wire . . .

S1: Look. Because this . . .

is the same as . . .
C: That's very good. I like your line of reasoning too. There's one other thing that you can do ... just the way you've got it connected ... one way in which you haven't tested it yet.

S12: You mean switch it?

C: Just leave the wires where they are.

S12: Okay.

C: There's one particular pattern that you haven't tried yet. Can you figure out what it is?

S12: We've tried these two (B and C)

S10: ... and these two (A and C)

... and these two (B and D)

... and these two (B and C).

S1: Have we tried these two (A and D)?
S10: Yeah.

S12: 'Cause we know that those two wires don't work.

C: (moves wire) Put that one over there

... is there any kind of connection that you can make?

S1: (attempts an arrangement)

C: What is happening there?

S1: Ah, the positive ...

C: Where is the circuit now?

S1: It's going (follows with finger) ...

S12: And out through there ... so it's all going around.

C: What is ... where does the circuit go? Can you just explain it to me?

S1: It's positive and it's going into there (the bulb) ...

C: ... all the way around ...

S1: Coming here ...

S12: ... and then it comes up through there (negative) into the other one (the other cell).
C: Okay, good. What is this cell here doing (points)?

S1: Nothing. (laughs) I don't know.

S12: Oh yeah, and that's not being used.

C: If you're not using that cell, then what are you using?

S1: (begins to disconnect wire from one cell)

C: Don't disconnect it.

S1: (tries touching both sets of terminals)

S12: Both of them are touching?

S1: Now they are. (bulb doesn't light)

S12: Okay, well try switching them around.

Wait a second . . . this isn't right because two wireless ones are touching and they're not working.

S1: I know. That's because we switched the terminals.

S10: That's a negative and that's a negative.

C: I think . . . I think I got you a bit mixed up here. Let's see what . . . you've got the one cell . . . and to bypass the other cell really makes it strange. Let's try it this way (moves wire).

See if you can do anything with that.
SUPERVISION DIALOGUE

C: That was a mistake on my part. That's when I realized that I had given them the wrong clue.

LESSON

SI: Let's see ... we touch that one to that one ... (touches both sets of terminals)

(touches one set of terminals)

(touches other set of terminals)

Or ...

(turns top cell around)

(tries other set of terminals)

C: Is that brighter ... or ...
S's: That's brighter.

S1: So that's with them both (both cells).

S10: Without a wire.

C: Okay, now make it the same brightness as with one.

S1: The same brightness as with one cell?

C: Using two cells, you want to make it the same as if it's ... 

S1: ... one.

C: ... the brightness of one.

S1: (sigh)

S12: I thought we had done that.

S1: We did that, yeah.

C: Actually, you just did it a minute ago.

S1: (turns top cell around again)

C: Watch carefully.

S1: That's one touching.

S12: Yeah.

C: Does that solve the problem? Are you using both cells?

S1: (pause) Oh, I see what you're saying.

SUPERVISION DIALOGUE

C: This is another "Ah ha!" Right here.

ANALYTICAL COMMENTS

Colin guides Rosie's observations, alerting her to a significant event coming up.

LESSON

S12: Negative to negative ...
S1:

There ... I'm touching both.

S12: Are you touching both?

S10: Why does that work?

S12: You are touching both. I don't know, why is it working now?

S1: Because the circuit is using both batteries.

S10: We're going positive to positive . . .

S10: Of course. If this goes with this it works (negative, cell A with positive, cell B), and if that goes with that it works (positive, cell A with negative, cell B), and both of them work together.

C: If you get some more wires, could you connect something that did the same as that . . . as what you just did?

S's: Yeah.

C: How about doing that? How many do you need?

SUPERVISION DIALOGUE

C: What I was trying to do here . . . they had the solution, but I wanted to pull it apart . . . separate it.

R: Yeah, it's really hard to see it.

C: I knew they needed two, but I wouldn't tell them.

ANALYTICAL COMMENTS

Although the girls had the solution to the problem, their technique of touching the two batteries together would have made it difficult to show the concept of "parallel circuit." Colin had them separate the batteries and connect them up again using additional wires.

LESSON

S12: One more . . . yeah, I think so . . . one more.

S1: (gets another wire) What, connect these two?
S12: Yeah.
S10: That's too bright.
S12: Oooh.

SUPervision Dialogue

C: See, this is where (S12) realized they needed another wire.

LESSon

S1: Oh, so we need another one.
S10: I know . . . switch this to there.
S1: If we had another wire and go . . .

S12: Yeah, work it on that one. Okay, good. But then this isn't using the whole thing.
S10: 'Cause we need another wire.
S12: 'Get another wire?
S10: Just a second . . . wait . . . yeah.

C: How many other wires do you want?
S12: One.
S10: And put it there . . . you know what I mean?
S1: (gets another wire)

There ... it's the same.

S12: Now, what do we have here?

S10: Okay, we have . . .

S1: Okay, we have (traces) positive to bulb to negative . . .

S12: Positive to . . .

S1: Positive to positive . . . and positive to . . .

S10: . . . negative.

S1: Wait a minute . . . what did we do here?

S10: That doesn't make sense.

S1: That doesn't make sense. Okay, look . . . negative to negative, (moves wire) positive to positive, positive to bulb and negative to bulb.

S12: And that's, like, even better for, like, the light.

S1: Yeah.

SUPERVISION DIALOGUE

C: You see, they solved it themselves. And now they get into the discussion about why it works.

ANALYTICAL COMMENTS

Colin shows a great deal of pride in his students. He notes the up-coming shift in activity: the girls are about to learn the difference between series and parallel circuits.

LESSON

C: How many circuits do you have here? Let's try to keep it straight. Can I just move this one over here . . . 'cause it's the same as . . .

How many circuits do you have?
S's: (count the wires) One, two, three, four.

S1: I think it's all one circuit you know.

S12: But we have four wires.

S10: It goes from here to here (traces).

S1: And this goes through here (cell B) and then comes from here to here. It's one.

S10: Two. It's two because these aren't connected. It goes from here to here.

But then it splits and goes from there to there.

C: What do you mean that it splits?

S10: Well you have two . . .

S1: But it goes through the battery.
(uses hand to connect the terminals)

S12: Yeah, but . . .

SUPERVISION DIALOGUE

C: Did you see what happened there? Up to now they've been treating the inside of the cell as not being part of the circuit. The positive pole is

ANALYTICAL COMMENTS

Colin explains the significance he sees in S1 putting her hand across the terminals of cell B.
an origin of something, the negative pole is an origin of something, but they haven't got the idea that it's complete right through inside the cell. So they're missing that idea of a circuit. You have separate supplies. When she puts her hand across there . . . that's really an insight. Did you see that? She puts her hand across.

R: To signify that it's part of the circuit.

Although there is some evidence to suggest that S1 may have had the correct conception of circuit earlier in the lesson, Colin makes a point of "reading" the use of the hand over the cell terminals as signifying an "Ah ha!" experience.

LESSON

S1: Because if we had it like this . . .
   (disconnects wires)

No . . . like this . . .

Then we'd say that this is one circuit.

C: Right.

S1: Even though that's split in here (two terminals) this is on the same battery.

S10: Yeah.

S1: So if we put this one on . . . and this one on here . . . why should it make a difference?

S12: But why do we bother having . . .

C: But if you disconnect . . .

How many circuits are there?
S12: One.

C: All right. And the other one that (S1) just had . . .

. . . which was this one here . . . How many circuits?

S's: One.

C: Are they the same?

S12: Yes.

C: They do the same thing.

S12: They do the same thing, but they're not the same.

SUPERVISION DIALOGUE

C: Do you see what the response was there?

R: They do the same thing.

C: I said, "Are they the same?" What I meant was, "Are they the same circuit?" What she said meant was that they are like each other. So I was using "same" as identical, and she was using "same" as similar to. That's why I said, "It does the same thing."

R: Uhm hmm. So you wanted that they weren't the same.

C: I wanted them to realize that they were not identically the same circuit . . .

R: But that they did the same thing.

C: But that they did the same thing. And when I used the word "same" she interpreted it differently than I meant it when I asked the question.

R: Uhm hmm.

ANALYTICAL COMMENTS

Colin uses the familiar approach of inviting Rosie to explain what she sees in the phenomenon.

The matter of interest to Colin is how S12 interpreted his use of the word "same." The point he wants Rosie to appreciate is that S12's interpretation of "same" led her to a different answer than the one Colin expected. For her, the two circuits were the same, while for Colin, they were different, but did the same thing.
C: I picked that up. That's one of the things that I picked up.

LESSON

S10: They're not the same.

S1: It's a different battery, that's all. And you're just making the wires longer.

S12: I know, but wouldn't you say that it's another current going over to the battery to go over to the light ... like I mean, you can't ... if you have two different objects ... you know ...

S1: Look ... take this one away.

S10: That's one.

S1: That's one circuit.

S12: That's one 'cause it's only going through one battery.

S10: When you have two batteries, it goes through that one too. So it's two.

S1: No, because the one you had before was this one.

And that's only using one battery.

S12: Yeah.

S10: But then you have to get this one (cell A) to charge with ... those to charge together.

S1: But are those two the same?

S12: Are what two the same?
S1: The ones if we just have those two together (the two negatives) and those two together (the two positives)?

S12: Yeah, if you just use this one battery it works, and then you just use this battery (the other battery) it works . . . it's the same thing. But when you use them both together . . .

S1: Then it's different.

S12: Then there's two currents, right?

S1: Yeah.

S12: That means you have two circuits.

C: There's an advantage to using both. The light is just as bright, so what might the advantage be?

S1: That you can use it for a longer period of time.

S10: 'Cause it works on one . . . then if this one gets used up . . . it can still have this (other) one.

C: Well, that's exactly right. If you use one or you use two like this . . . one of the arrangements would last a lot longer. Which one?

S12: This one using two.

C: Yeah, you're dividing the work.

S12: 'Cause there's two circuits. Right.

C: And when they were in the other arrangement, that is they were . . . uh . . . made the light shine brighter . . . uh, what do you think about how long they would last? (pause) Would it be the same as one, or would it be longer?

S's: The same as one.

S10: Because you're using the whole . . .

C: There they're not dividing the work; they're adding it up.

S10: Yeah.
S12: Yeah.

C: This here is called a parallel connection, which means that these wires...

... are parallel to these.

Or, this one (cell A) is beside this (cell B). There are actually two circuits. They share the load... and they last twice as long.

In the other case, where there's just one path through... uh... this first one that you had... can you show me? (the students make the arrangement)

There's one circuit.

S12: Yeah, it's going in a continuous circuit.

C: When you connect all of these elements... that is this one (bulb), that one (cell A), and that one (cell B)... one after another in the same circuit... it is called a series of things, so this is called a series connection.

S12: Yeah.

C: And what is its advantage?

S12: It's that it makes it brighter. It adds more volts. That's pretty cool.

C: What you want is a drawing of the parallel connection.
S1: ... of the parallel one.

C: Maybe you can connect it up again?

(students have no difficulty connecting the parallel circuit again)

SUPERVISION DIALOGUE

C: I like that. There's so many things that are there. One of the things is that it takes a bit of practice ... like the question of "same" ... it takes a bit of practice to pick up things like that. I mean, you pick up more than you would without practice.

R: It's sort of a matter of listening for it.

C: Yeah. Well, what it is though ... I remember when I first started dealing with things like that ... there were things that kids were coming up with that had never occurred to me. And after a while you begin to recognize patterns. For example there were a lot of new things in that [video]. The new things were this idea that ... they're not thinking of a circuit, really. They don't have a clear idea that the cell is part of the closed path. That the circuit is a closed path. Actually, that is something new in my mind. I hadn't quite dealt with that before, so I was learning somethings. Now, actually, the satisfaction that I gained out of it was just that I was lucky enough to recognize the situation enough that when they became bogged down, I actually made quite a small suggestion. Then they just took off. But it wouldn't have worked unless they had been ready for it. I mean it took ... I was sitting here watching what they were doing. I was very frustrated because they wouldn't touch the two [terminals] together. "I'm not going to say anything, I'm not going to say anything." I was really itching. But in a way, because I was involved

ANALYTICAL COMMENTS

The concluding dialogue is quite interesting for a number of reasons. First, Colin surfaces his own confusions about trying to figure out what the students were thinking as they tried to solve the third problem on circuits. He admits that it takes practice to "pick up" things like this, and that he has learned some new things himself today. Second, he notes that "after a while you begin to notice patterns," alluding to the idea that a teacher builds up a "repertoire" for recognizing patterns and dealing with problems encountered in teaching. Third, he displays a genuine enthusiasm for inquiring into the ways in which students make sense of the subject matter of science. He is really thrilled with the "discoveries of the day."
with these kids for fifteen minutes, I knew what they were trying and I got a very clear idea of where they were going and why they were failing. Uh, but there was tremendous satisfaction in being able to intervene. It was really . . . I felt so good that it had gone so well . . . you know, you really think that there was real genuine learning that's happened here. Uh, there is a consideration. What I would do in a situation like this is . . . you see, you can't do that for every kid all the time. But if I could do that once with this group and another time with that group . . . even if they have a sense of . . . I think that's what learning is. If they have a sense of that once, they begin to take ownership and they begin to do that themselves. I mean, did you see the puzzlement, and then at the end, the satisfaction? I mean, in my view at least, I thought there was such great achievement there.

R: And then tomorrow when I go up there it'll be, "Oh yeah, that makes sense, that makes sense." Not, "Okay, we draw it like this."

C: Even if . . . you see some of the kids are puzzled. But you've got to take them out of their puzzling situation. If they're not puzzled . . . if you've just drawn something . . . it's not a real problem for them. If they say, "Gee, I'm stuck on this and I can't figure out why this damn thing doesn't work," well then you're solving the problem. It's a real problem. I think this is where one becomes . . . I mean, you talk about developing skills. I think this is the question of becoming reflective in one's teaching. That is, that . . . you know, you just don't recognize it at first. You begin to recognize it here and there and you develop a repertoire of particular instances, but also a pattern. One of the things you do . . . just because a kid uses the same word that you do, like "same," they don't necessarily mean the same thing . . . to you as it

Colin differentiates between "just drawing something" (such as a circuit diagram), and allowing students to become puzzled with a "real problem." The general idea is that meaningful learning is based on experience, particularly in situations that are puzzling for students. But Colin's comments about "becoming reflective in one's teaching" are particularly interesting: you just don't recognize it at first. You begin to recognize it here and there and you develop a repertoire of particular instances, but also a pattern.
does for them. And if you miss that, you miss the opportunity. I mean, I think words ... vocabulary is really quite significant.
PUBLICATIONS


