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ABSTRACT

TEACHERS' BELIEFS ABOUT STUDENTS' LEARNING PROCESSES: A DESCRIPTIVE STUDY

By

Robert E. Hollon

The beliefs about students' learning processes, the teachers' role in promoting learning, and the influence of the teachers' beliefs on their judgments about important information and information-gathering strategies were investigated from a conceptual change framework for a sample of 13 junior high school science teachers. The teachers' beliefs and judgments were related to their ability to learn from experience.

The teachers were observed as they taught units about photosynthesis, cellular respiration, and matter cycling. Clinical interviews focusing on resources and classroom activities were conducted at the start of the study and after each unit.

Three different orientations toward teaching and learning were identified. The <u>conceptual development</u> orientation was characterized by (a) an emphasis on learning as accommodation in which students changed their thinking about important concepts, (b) curricular goals focusing on students' developing meaningful understanding of a few important concepts, and (c) monitoring students' ideas and helping them change their thinking. The <u>content understanding</u> orientation was characterized by (a) an emphasis on learning as assimilation in which students added new concepts and information to existing knowledge, (b) content-oriented curricular goals emphasizing students' understanding of an integrated body of scientific knowledge, and (c) communicating important science content in a clear

manner and monitoring students' understanding of important details of the content. The fact acquisition orientation was characterized by (a) an emphasis on memorization of isolated facts contained in available resource materials, (b) curricular goals determined by the nature of existing materials and (c) emphasis on managing activities and improving students' motivation and emotional state.

Each orientation was characterized by a system of self-reinforcing beliefs based on interactions among the teachers' knowledge and beliefs, judgments about important information, and information-gathering strategies. For the conceptual development and content understanding orientations, the systems acted as open loops, enabling the teachers to learn about their students' scientific thinking from experience. The fact acquisition teachers' knowledge and beliefs interacted to produce "developmental dead-ends", closed loops in which the teachers did not develop knowledge of their students' thinking or engage in teaching strategies that would have provided the information necessary to develop that knowledge.

The results of the study suggest that both subject matter knowledge and basic knowledge of psychological processes related to learning may be fundamental to teachers' ability to learn from experience and their ability to successfully teach for conceptual change. These knowledge bases should be developed within a framework emphasizing students' understanding of science content as a primary instructional goal. Additional research should seek to identify sources of teachers' beliefs about students' learning and key influences on their development.

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CHAPTER ONE

The increased utilization of scientific knowledge is steadily reshaping society and creating an increasingly technological environment. As a result, individuals need increasingly sophisticated and technologically-oriented knowledge is needed in order to be considered scientifically literate (National Science Teachers' Association, 1982). People are expected to make decisions about scientific issues ranging from the value of genetic engineering, nuclear energy, or space exploration to the safety of microwave ovens or irradiated food. Making these decisions intelligently requires both a sound base of scientific knowledge and the reasoning skills to use that knowledge.

In contrast to the need for increased scientific knowledge, students seem to be learning less. Performance on standardized measures of science achievement has been decreasing (National Science Foundation - Department of Education, 1980). Enrollment in science courses has decreased (Hueftle, Rakow, & Welch, 1983). Further, present science education goals related to everyday life or societal decision-making receive little attention from educators or teachers (Harms, 1981). As a result, students leave science classes with little meaningful understanding of important disciplinary concepts or their relationship to the real world.

Several major reports such as A Nation at Risk have called for increases in the amount of time devoted to science instruction in the elementary schools and the number of science courses required for high school graduation. However, increasing science requirements alone is not the answer, for this approach fails to address a much more fundamental problem in science education: Students didn't learn very much of what was already being taught (Anderson, Sheldon, & Dubay, 1985; Bishop & Anderson, 1985; Hollon & Anderson, 1985). Increasing the amount of unsuccessful instruction would, in all probability, only marginally increase the scientific knowledge that students actually acquire. Thus, improving students' understanding of science must involve improvements in the quality of instruction as well as increases in the amount of time devoted to teaching science.

Improving the quality of science instruction is not an easy task. Teaching is a cognitively complex activity demanding that teachers draw on a variety of knowledge bases in order to develop and teach lessons to students whose view of the world is much different than that of the teacher (Anderson & Smith, 1985; Shulman, 1986). Thus, teachers must not only be committed to helping students understand important concepts, they must also understand the content to be taught and how students think that content, and be able to carry out strategies that have the potential to help the students learn successfully. It is the nature of teachers' knowledge and beliefs about students' learning that is the subject of this dissertation.

Theoretical Perspectives

The theoretical perspectives for this study were drawn from cognitive psychological research based on a model of people as "boundedly rational" and thus limited in their ability to perceive information from their surroundings (Shulman & Cary, 1984; Simon, 1982). As a result, they selectively perceive and process information to construct new knowledge (stored in memory as schemata) based on already-existing knowledge (Frederickson, 1984; Resnick, 1984; Simon, 1957, 1982; Sternberg, 1982).

An important feature of this model is the link between perception and knowledge. As limited information processors, humans potentially spend much of the time in a state of information overload. However, the overload is reduced or avoided through selective perception, in which some information is perceived as relevant to a situation, while other information is ignored. The information perceived from any given event depends on the nature of the individual's existing knowledge. New information is compared to existing schemata and is either processed or rejected as irrelevant. Some available information is never perceived in the first place. Thus, while existing schemata may act to reduce information overload and enable thinking processes to proceed, they also limit perceptions of important information. This can result in the development of a "closed loop" between knowledge and perceptions in which the individual engages in "self-reinforcing behaviors." These behaviors limit individuals' abilities to perceive alternate forms of information and ultimately their potential for learning from experience.

Improving the Quality of Teaching Through Research

A large body of research exists in which the purpose has been to identify variables related to student learning (c.f. Brophy, 1979; Doyle, 1978; Duncan & Biddle, 1974). Much of this research has addressed issues related to elementary school instruction but has recently been extended and replicated in junior high schools and high schools (Brophy, 1979). Prior to 1975, most studies were based on a process-product model, in which relationships among teachers' behaviors and students' behaviors (and ultimately student learning) were investigated (Brophy, 1979; Clark & Peterson, 1986).

Process-product research has provided important contributions to the question of improving science teaching. In particular, it served as the background for the emergence of questions about the nature of the cognitive processes underlying teachers' observable actions (Clark, 1977; Clark & Yinger, 1979; Morine-Dershimer, 1979). These studies, collectively referred to as studies of teachers' thinking (Clark & Peterson, 1986), have addressed both the nature of teachers' thoughts while actually teaching, as well as the decision-making, knowledge, and beliefs that form the basis for their actions.

Studies of teachers' thinking represent a very new field of inquiry. In a review of studies teachers' thinking in the Third Handbook for Research on Teaching published in 1986, Clark and Peterson noted that most studies had been published since 1976. That such a review was included in the handbook is in itself notable, for the Second Handbook of Research on Teaching published in 1973 did not include any reference to such studies.

Studies of teachers' thinking have been based primarily two theoretical models: the teacher as decision maker and the teacher as a processor of information (Clark, 1978; Clark & Peterson, 1986). Studies based on the decision-making model have typically addressed teachers' thoughts in situations where there was time for deliberation, such as in studies of planning activities. In this model, the teacher is viewed as assessing alternatives, processing information related to the alternatives, and arriving at a decision which forms the basis for later classroom actions.

Studies based on the model of teachers as information-processors have focused on questions concerning events actually occurring during instruction. The teacher is viewed as processing information within innate limitations, and constructing simplified cognitive models of classroom events which guide the flow of events during the lesson. Research conducted within this framework has addressed the nature of the cognitive models relied on by the teachers during instruction, and the types of knowledge and beliefs that form the basis for their judgments during teaching (Clark, 1978; Clark & Peterson, 1986).

The results of studies of teachers' thinking suggest that individuals depend on a set of individually-held beliefs about student characteristics, teacher roles, and subject matter that guide their judgments and decision-making during planning and teaching. However, the studies seldom focused on the <u>substance</u> of teachers' beliefs about students' learning, nor did they address the <u>learning processes</u> by which the teachers had developed their beliefs.

Conceptual Change as a Framework for Improving Science Teaching

Other researchers have sought to improve the effectiveness of science teaching using a conceptual change model of learning (Posner, Strike, Hewson, & Gertzog, 1982). Research based on conceptual change has identified a variety of misconceptions or alternate patterns of knowledge and reasoning about scientific phenomena that interfere with individuals' learning of science concepts (see reviews by Driver & Easley, 1978; Driver & Erickson, 1983; Gilbert & Watts, 1983).

Efforts to improve science teaching using conceptual change as a model for learning and instruction have been encouraging. There is considerable evidence that the style of teaching developed through conceptual change research is instructionally effective. Researchers have shown that it is possible to design materials and instruction in ways that help students overcome misconceptions and develop meaningful understanding of concepts (Anderson, 1985; Anderson, Sheldon, & Dubay, 1985; Hollon & Anderson, 1985; Minstrell, 1985; Smith & Anderson, 1984). However, teaching for conceptual change is also cognitively demanding for teachers. In particular, successful conceptual change teaching requires that teachers understand and monitor how their students think about natural phenomena. Thus the understanding the nature of teachers' knowledge and beliefs and the processes by which they develop is central to efforts to improve science teaching.

The staff of the Science Teaching Project at Michigan State University have engaged in a research program investigating a variety of ways to improve students' understanding of important science themes.

The program has been grounded in the assumption that conceptual change is a necessary process for students to develop meaningful understanding of important science concepts (Anderson & Smith, 1986; Anderson et al, 1986). An important aspect of that research has been efforts to identify the substantive nature of the knowledge bases needed for successful conceptual change teaching (Anderson & Smith, 1985; Smith & Anderson, 1984; Smith & Lott, 1983). They have have argued that teachers often are unsuccessful <u>because they lack important knowledge</u> needed to help students overcome their misconceptions (Anderson & Smith, 1985; Smith & Lott, 1983). For example, Anderson and Smith (1986) reported that successful science teachers possessed different knowledge about their students and used that knowledge in different ways than less successful teachers. They suggested that effective teachers need two different types of knowledge, including a general orientation towards conceptual change teaching, and specific knowledge of three types, including (a) <u>knowledge of science content</u> and how it is translated into curricular goals, (b) <u>knowledge of students' thinking</u> and the specific misconceptions that are likely to influence their understanding of important concepts, and (c) <u>knowledge of specific teaching strategies</u> that will help students overcome their misconceptions. However, their research has not addressed the processes by which effective conceptual change teachers acquired that knowledge or how teachers' knowledge and beliefs about teaching and learning influenced their judgments about important features of curriculum materials and their use of various teaching strategies.

The research presented in this dissertation is based on the assumptions about effective science teaching discussed above. Effective science teaching promotes the development of meaningful understanding of important concepts through the process of conceptual change. Teaching for conceptual change requires detailed knowledge about science content, individuals' learning processes, and pedagogy. Thus, beliefs about students' learning processes, the teacher's role in promoting student learning, and important information-seeking behaviors form a part of the knowledge base needed for effective teaching.

Statement of the Research Problem

The research described above suggests that the orientations toward teaching, and the nature of the knowledge and beliefs teachers bring with them to science classrooms are critically important, influencing not only their teaching behavior, but also their perceptions of classroom events and their ability to learn from experience. This study extends that research by focusing on teachers' thinking about one critically important aspect of instruction: the nature and processes of student learning. The study addresses the following research questions:

I. What is the nature of teachers' beliefs about students' learning processes?

II. What is the nature of teachers' beliefs about their role in promoting student learning?

III. How do teachers' beliefs about students' learning and their role in promoting learning influence their judgments about what information is important and their information-gathering strategies?

In addition, this dissertation examines the processes by which teachers' knowledge and beliefs develop through experience. It was not possible to address this question empirically. Instead, it was considered from a theoretical perspective based on the results of questions I, II, and III.

Overview of the Research Design

The research presented in this dissertation is a descriptive study comprising one part of the Middle School Science Project conducted by the staff of the Science Teaching Project at Michigan State University. The Middle School Science Project investigated the effects of teacher training and specially designed curriculum materials on teachers' use of conceptual change teaching strategies (Anderson et al, 1986; Blakeslee, Anderson, & Smith, 1987), student learning (Smith & Anderson, 1987), and the impact of the treatments on teachers' knowledge and beliefs about teaching and learning (Hollon & Anderson, 1986, 1987). Three major data sets were generated during the study, including student test data, classroom observation data, and teacher interview data. The data used in this dissertation were drawn from the teacher interview and classroom observation data bases.

Overview of the Middle School Science Project. Thirteen 7th grade life science teachers were randomly assigned to three different treatment groups. Group A (n=4) received training about the nature of students' scientific thinking and the ways that students' misconceptions interfere with learning science concepts. Group B (n=5) received teaching materials which contrasted students' misconceptions with scientifically acceptable theories. Group C (n=4) received both training and materials.

One or two classes taught by each teacher were identified as target groups. These classes were observed as the teacher taught units about photosynthesis, cellular respiration, and matter cycling. Narrative observation data and samples of student texts, assignments, and quizzes were collected and coded for at least three lessons during each unit. The students in the target classes completed randomly distributed pretests for two of the three units at the beginning of the school year as well as posttests administered immediately after each unit was completed.

The research questions presented in this dissertation were addressed primarily through a series of clinical interviews conducted at four times during the Middle School Science Project. Each teacher was interviewed at the start of the study and after teaching each experimental unit. The interviews contained a series of tasks that were designed to provide information about each teacher's knowledge of science content, their goals for student learning, their knowledge of students' misconceptions about photosynthesis, cellular respiration, and matter cycling, and the features of teaching resources and strategies they considered most important for promoting student learning.

The interview data were analyzed to develop descriptions that revealed characteristic patterns of reasoning among the teachers and illustrated typical orientations toward teaching and learning. A set of detailed case studies was developed to describe the features of instruction, goals for students' learning, beliefs about students' learning processes and role in promoting student learning, and the information and resources considered most important in planning and teaching each unit typical of each orientation.

The issues and data points identified during the development of the case studies were used to develop a coding system that was used to characterize each teacher's responses to the various interview tasks. The coded data were used in combination with classroom observation data to develop a set of documents describing each teacher's position with regard to important issues that emerged during the development of the case studies, and to summarize the features of curriculum materials and teaching strategies each individual identified as important.

Limitations of the Research

An important methodological issue involves the degree to which the teacher's responses to interview tasks provide valid and plausible evidence of their beliefs (Ericcson & Simon, 1980; Nisbett and Ross, 1977; Nisbett and Wilson, 1978). It has been assumed that the teachers in the study were doing their best to provide accurate descriptions of their learning goals, their use of various resources, and the teaching strategies that they considered most important. To some extent, the consistency between the teachers' statements in the interviews and their actual practices could be validated using classroom observation data, however it was not assumed that the teachers would always act (or be able to act) in accordance with their beliefs.

The sample of teachers involved in the study (n=13) limits statistical power and generalizability, however it is adequate for descriptive research involving case study analyses. No attempt has been made to establish statistical significance for any of the research questions or to generalize beyond the sample of teachers involved in the study.

This dissertation does not address the question of changes in the teachers' knowledge or beliefs as the result of experimental treatments. Although some effects were reported for treatments involving the use of specially designed materials (Anderson et al, 1986; Smith & Anderson, 1987), there were no apparent changes for the treatments involving training, or in those units where the teachers were not supplied with materials.

Although parallel forms of the interview protocols were used for two of the three experimental topics in the study (the photosynthesis protocol was slightly different), they were administered by seven different project staff members. As a result, some inconsistencies exist in patterns of questioning, probing for clarification of responses, and the extent to which the interviewer "guided" the teacher's responses to the questions. However, the interview tasks were sufficiently open-ended to generate much detailed information, thus the overall patterns in teachers' responses could still be identified.

Overview of the Dissertation

This dissertation consists of five chapters. Chapter One has described the rationale for the study, presented a brief overview of the research design, and discussed assumptions and limitations inherent in the study.

Chapter Two includes a review of research related to teachers' thinking and general cognitive processing models. Particular attention is paid to the limitations of existing research as it addresses teachers' beliefs about teaching and learning.

Chapter Three describes the development of the interviews, their administration, and the procedures used to develop case studies and summary documents for each subject.

Chapter Four describes the results of the research. Three case studies are presented to illustrate different orientations toward teaching and learning, including the nature of the teachers' beliefs about students' learning processes, their role in promoting learning, and the interactions among knowledge and beliefs, perceptions of important information, and information-gathering strategies. Models of self-reinforcing beliefs systems are developed for each orientation. The results of the study are discussed and related to existing literature.

Chapter Five summarizes the research results and discusses implications for pre-service and inservice education, and research.

Summary

The preceding chapter presented a rationale for the dissertation research based on the premise that efforts to improve science teaching will be aided by understanding teachers' conceptions about their students' learning processes and their role in promoting learning. The major research questions addressed in the research were described. The methods employed in the research were briefly described, with particular attention paid to the use of interviews to develop descriptions of teachers' conceptions. Data analysis and reporting procedures were summarized, followed by discussion of important assumptions and limitations of the study, and an overview of the chapters in the dissertation.

CHAPTER TWO

This research is a descriptive study of a sample of middle school science teachers' beliefs about students' learning processes, their role in promoting student learning, and the influence of those beliefs on their judgments about important information and their information-gathering strategies.

The theoretical perspectives for this study were drawn from cognitive psychological research. Researchers in this field have adopted an information-processing model to describe knowledge (Newell & Simon, 1972; Posner, Strike, Hewson, & Gertzog, 1982; Sternberg, 1983) based on a constructivist theory of learning. According to this theory, individuals construct meaning from new experiences by using existing knowledge to interpret information perceived from the environment. The learning process may be mediated by features of the environment and/or the nature of the individuals' existing knowledge. Conceptual change learning (Posner, Strike, Hewson, & Gertzog, 1982) includes another dimension in which existing knowledge both facilitates and presents potential barriers to meaningful learning.

Cognitive research addressing the nature of individuals' conceptions of various subject matter topics (see reviews by Driver & Easley, 1978, Driver & Erickson, 1983; Gilbert & Watts, 1983) provides a particularly important perspective for this study. One aspect of that body of research has focused on "knowledge-in-action" (Driver & Erickson, 1978), the constructs that individuals rely on in making sense of everyday phenomena. The perspectives and methods employed by these researchers have provided much insight into the substance of students' thinking. This study extends that research by investigating teachers' "knowledge-in-action". It addresses the substance of teachers' knowledge of one specific domain, namely knowledge concerning the nature and processes of students' learning. It is an investigation of the underlying knowledge and beliefs that influence teachers' perceptions of important information and their information-seeking behavior.

The methods employed in this research involved observing individual teachers as they engaged in various tasks directly related to their teaching, combined with clinical interviews designed to elicit the patterns of reasoning underlying their task performance. These methods were similar to those used in studies of individuals' conceptions of specific knowledge domains such as heat and temperature (Hollon & Anderson, 1985), mechanics (Clement, 1982), changes of state (Osborne & Cosgrove, 1983), or photosynthesis (Anderson, Sheldon, & Dubay, in press). Other techniques such as policy capturing, journal writing, think-aloud, stimulated recall, or grid construction techniques have been used to identify categories of teachers' knowledge or decision making strategies (Clark & Peterson, 1986; Clark & Yinger, 1978).

However, these methods have typically been employed to elicit categories of propositional knowledge about the types of decisions made by teachers, rather than the nature of the underlying knowledge used to make those decisions. Thus, this research has more in common with cognitive psychological studies of memory, comprehension, expert-novice performance, problem-solving, or conceptions of specific subject matter than with studies of teachers' planning (Clark & Elmore, 1979) or interactive decisions (c.f. Housner & Griffey, 1983; McNair, 1979).

In the remainder of this chapter, the literature describing information-processing theory and conceptual change learning are reviewed to illustrate how these models of knowledge structures and cognitive processes provide both a theoretical and methodological framework for investigating teachers' beliefs about learning and their role in promoting learning.

Several bodies of research on teachers' thinking are also reviewed. Substantive and methodological issues which limit their applicability to this research are considered. This research has been extensively reviewed (c.f. Clark & Peterson, 1986; Shavelson & Stern, 1981; Shulman & Elstein, 1976). These reviews will form the basis for describing the nature of the research methods used and questions addressed in those domains and serve as sources for describing some hard-to-find unpublished dissertations. Individual studies focusing on teachers' conceptions of specific domains (e.g. Duffy, 1977; Elbaz, 1981; Munby, 1982, 1983) are reviewed in detail.

Information-processing Theory

Information processing theory has emerged as a model for investigating complex cognitive processes during the past thirty years through the work of Bruner, Miller, Chomsky, and Newell and Simon (Newell & Simon, 1972). During this time, researchers have moved away from studies of general characteristics of groups of people toward studies of particular characteristics of individuals performing specific tasks. Information-processing theory provided researchers with a model of cognition which enabled them to investigate the nature of individuals' thinking rather than accounting only for their behavior. Inasmuch as teaching involves such tasks, the perspectives and methods employed to study other domains of individuals' knowledge are appropriate to the study of teachers' knowledge as well.

Structure of the Information-processing Model

Among the phenomena explained by the information-processing model are perception and memory (Shavelson, 1974). Perception includes those processes in which physical sensory input is translated into cognitive representations, examined to identify salient features, then compared to previously learned structures.

According to information processing theory, information enters the brain through sense organs, is evaluated and manipulated sequentially in short-term memory (STM), and may result in some action on the environment and/or in the transfer of information to long-term memory (LTM) as new knowledge. STM is limited: 5-7 pieces of information can be manipulated at one time.

information processing capacities can be increased through "chunking" in which related pieces of information are processed as a single unit, and by moving information into and retrieving it from LTM (Erickson, Chase & Faloon, 1980).

As a result of STM's limitations, individuals perceive and interpret only a small portion of the information available from the environment. The selection process is based on heuristics, implicit rules used to select information, classify objects or events, or revise knowledge (Tverny & Kahneman, 1974); or attributes, processes in which information from selected sources is used to make predictions about events (Borko & Shavelson, 1978), and other psychological mechanisms (Janis & Mann, 1977; Newell & Simon, 1972; Nisbett & Ross, 1980).

Schema theory as a model of knowledge and learning. Knowledge, which resides in long-term memory, is often represented by schemata (Glaser, 1984; Mayer, 1983; Rummelhart & Ortony, 1977) . Schemata are cognitive networks which represent the way an individual has structured personal knowledge. They may represent characteristics of groups of objects, or prototypical examples of behaviors associated with frequently encountered events (Rummelhart, 1981). Although schemata include many examples or instantiations of concepts, propositions, or rules, they do not represent discrete facts (Glaser, 1984).

Schemata are related to one another through common nodes, forming networks of related ideas in which some relationships are hierarchical and others are not (Anderson, 1984; Posner, 1978). These networks are accessed or activated by two types of control processes. Interpretive processes control the manipulation of information in long-term memory.

Recall, recognition, problem-solving, and other thinking skills are a part of the interpretive processing function. The monitoring system is similar to an index in a book. It keeps track of what we know and don't know, and performs tasks such as instructing the interpretive processing system to analyze questions to determine if relevant schemata exist which might be activated to address the question. This process eliminates blind searches of the entire contents of LTM for information related to each new event.

Rummelhart and Ortony (1977) described the use of generalized and specific schemata to interpret important data. They noted that generalized schemata were useful for recognition and processing of a broad range of data (a direct influence on what is or is not perceived), while specialized schemata (which are content-specific) allowed deeper, faster processing of input but over a much narrower range of perception. Thus, schemata acted as the basis for selecting or perceiving important information from the surrounding environment as well as providing structures for comparing new information to existing knowledge.

Learning as developing schemata. Glaser (1984) described learning in terms of schema theory as a process of developing schemata. In acquiring knowledge, individuals interpreted new experiences in terms of existing schemata, and reorganized schemata to account for the new experience. The reorganization involved assimilation, in which new concepts or information were subsumed into existing schemata, or accommodation, in which schemata were radically changed, resulting in the development of new relationships among concepts Posner et al. 1982). Information inconsistent with existing schemata might be accepted temporarily, modified to better match existing schemata, or ignored.

Schemata also enable individuals to make predictions about recurring events. For these events, the knowledge that is assumed about an event is far greater than the information that can be perceived about it. Thus, predictions can be generated based on the nature of existing schemata rather than through direct perception and processing of information related to the latest occurance of the event.

Mayer (1983) described several different ways in which schemata might change during the learning process, including addition learning, distorted learning, and meaningful learning. Addition learning occurs when individuals attempt to make sense of new information for which no related schemata exist. Because the new information is not related to any existing knowledge, it is ignored or stored in a manner such that subsequent comparisons with other information becomes difficult. Addition learning also could occur if individuals possess appropriate schemata, but the schemata are not activated by new information. As a result, the new information is not linked to existing schemata, thus is stored in isolation, becoming relatively inaccessible, or is forgotten.

Distorted learning occurs when new information activates relevant schemata but is in conflict with those schemata. In order to establish links between the new information and the existing knowledge, features of the newest information are altered or distorted to make it more compatible with existing schemata.

Integrated meaningful learning results when new information activates relevant schemata and is recognized as another instance or application of that idea. Thus, new information is integrated into existing schemata in an organized process without distortion or loss of important details.

Anderson (1984) raised several issues about the use of schema theory as a viable model for explaining the large amount of detail that accompanies comprehension learning. He rejected a "strong schema" orientation in which individuals deductively developed theories based on general principles which produced goal-directed actions in favor of a "weak schema" orientation based on individual's remembering specific cases and developing generalizations based on them. He argued that the weak schema orientation involving reasoning from specific cases to general principles provided a better explanation for individuals' ability to account for a wide variety of loosely related instances of schemata.

Posner (1978) described the information-processing requirements for answering typical classroom or examination questions, suggesting that question-answering was a problem-solving task rather than just retrieval of information. He outlined seven steps involved in responding to questions:

1. The question must be comprehended, which requires knowledge of the subject matter, syntactical structures and and verbal lexicon in order to decode the question (available from LTM) and the use of that knowledge to construct an interpretation of the question.

2. The individual must know what counts as an adequate explanation. The rules for this are also stored in LTM.

3. A decision must be made concerning whether or not the question can be answered and if it is worth answering. These are functions of the monitoring system.

4. If the question is deemed worthwhile and answerable, and the schemata for "explanation" is activated, the interpretive processes scan LTM for relevant schemata.

5. After relevant information is retrieved or reconstructed, it must be manipulated in order to construct an answer (a function of the interpretive processes).

6. The explanation must be encoded into language, again using the lexicon and syntactical rules originally used to decode the question.

7. Motor skills are used to communicate that response.

Different questions required different searches of LTM both in terms of search strategy and the nature of information sought, and different manipulation by the interpretive processes.

Posner's analysis of question-answering illustrates the manner in which information processing models provide structures for thinking about the nature and development of individuals' knowledge. Analysis of individuals' responses to questioning tasks, whether in a classroom or an interview, can provide useful insight into the nature of the knowledge used to solve the question-answering problem and perceptions of information relevant to answer the question.

<u>The role of perception</u>. Perception is an important process which influences individuals' knowledge development. As "boundedly rational" individuals (Shulman & Carey, 1984; Simon, 1957, 1984b), humans are not capable of attending to all the information available for a particular event. Instead, we construct simplified cognitive models of the real event and act rationally in terms of the model (Shavelson & Stern, 1981; Shulman & Carey, 1984). The models are based on selective perception, in which existing knowledge (schemata) forms the basis for perceiving information. Some information is recognized, but is processed without conscious attention. Other information is recognized and processed consciously. Information that fails to activate any relevant schemata is ignored. Thus, while our existing cognitive structures reduce the complexity of information through selective perception (thus enabling

thinking processes to proceed), they also limit our perception to those events about which we already have knowledge. Other potentially valuable information is not perceived because it has no referents in our existing schemata. Selective perception thus restricts learning because the new information perceived is consistently similar to (or at least not too different from) already-existing knowledge. A closed loop between perceptions and schemata may develop, preventing us from perceiving alternate forms of information or activating alternate schemata which might result in changed interpretations of events.

Schema theory provides a framework for considering several issues related to teachers' development of knowledge about students' learning processes:

1. Perception is based on existing knowledge (schemata).

2. Information is perceived or ignored depending on whether or not it activates relevant schemata.

3. Knowledge development depends on the existence of relevant schemata. The absence of related schemata, or the failure of information to activate relevant schemata, makes it difficult for individuals to develop new knowledge.

In the following section, a more recently developed model of learning based on conceptual change is reviewed to provide another perspective related to the development of individuals' knowledge and their judgments about the nature of important information.

Conceptual Change Theory as a Model of Knowledge and Learning

Conceptual change theory emerged from cognitive research addressing memory, comprehension, and particularly novice-expert problem solving in physics (Clement, 1982; Larkin, McDermott, Simon & Simon, 1980). Researchers noted that, while their novice subjects possessed less content knowledge, they possessed well developed ideas and strategies which they relied on to explain the problems. Although not scientifically appropriate, the subjects consistently relied on these ideas to solve the problems. Thus, the differences between novices and experts were not just the amount of knowledge possessed by each group; they also involved fundamentally different ways of thinking.

Conceptual change theorists describe knowledge in terms of "conceptions" which represent the individual's set of central organizing concepts about how the world really exists (Gilbert & Watts, 1983; Hewson, 1980; Posner, 1978). "Conception" and "schemata" are often used synonymously, although "conception" appears to connote a less specific or detailed description of the components and interrelationships than does schemata. Other terms such as "framework" are used as well to refer to knowledge structures (Driver & Easley, 1978; Gilbert & Watts, 1983), however "framework" tends to be used in describing the character of responses by groups of students rather than by individuals. The term "conception" will be used in this study because it is recognized by most readers of literature related to teaching and learning as meaning the substance or nature of individual's set of ideas or beliefs, and because it does not impose the detailed structural descriptions usually associated with using "schemata".

Learning as changing conceptions. The conceptual change model of learning is constructivist in nature (Posner & Strike, 1978; Posner, Strike, Hewson, & Gertzog, 1982). According to this model, individuals learn by constructing new meanings from experience. The nature of the experience determines how information is processed. If new experiences are consistent with existing conceptions, assimilative learning occurs. Accommodation occurs when the experience results in major restructuring of conceptions. The process of fundamental reorganization of conceptions is referred to as "conceptual change." Four conditions are necessary for conceptual change to occur (Posner, Strike, Hewson, & Gertzog, 1982):

1. _There must be dissatisfaction with existing conceptions_. Individuals are not likely to undergo major changes in their thinking until they become convinced that less radical changes will not work.

2. _New conceptions must be intelligible_. The individual must be able to understand a new concept sufficiently well to explore its potential for explaining phenomena.

3. _New conceptions must appear initially plausible_. They should at least appear to have the capacity to help the individual make sense of problems generated or not explainable by previous conceptions.

4. _New conceptions must be fruitful_. The individual should perceive new conceptions as having the potential to be extended to new areas of inquiry.

These conditions do not have to be met in any particular order. In particular, dissatisfaction may not even be possible until the learner has had considerable experience with two competing conceptions. As one conception is used more and more successfully, it "gains status." As another conception is seen to be less successful, it "loses status." Changes in an individual's thinking may occur over a period of time, making the distinction between assimilation and accommodation less clear.

An important aspect of conceptual change learning is that the individual is not assumed to process information in the same form as it is communicated, nor even to perceive it as similar in form to what was communicated. The learner perceives information based on existing knowledge, and processes it according to that knowledge. As a result, the meaning the individual constructs may be quite different from what was intended.

The nature of elicited conceptions. Driver and Erickson (1978) conducted an extensive review of research about students' misconceptions of various science topics. An important aspect of the review was the distinction between studies addressing students' propositional or conceptual knowledge and those addressing students' "knowledge-in-action." Conceptual studies included those whose purpose was to determine the nature of students' conceptual or propositional knowledge about events isolated from the students' everyday context. The data collection and analyses techniques used were based entirely on linguistics, including word association (Shavelson, 1974), free association (White & Gunstone, 1980); or concept mapping techniques (Champagne, 1981; Stewart, 1980). The data enabled researchers to document features of the structure of students' propositional knowledge, but at the risk of misinterpretation, since the data lacked referents to real world events. As a result, the links between propositional knowledge and everyday events remained largely unknown.

Studies involving knowledge-in-action elicited knowledge used to explain real-world phenomena. Studies of this nature involved tasks in which the subject manipulated materials or made predictions about some real-world event or physical system and explained the reasons used to make the prediction or manipulation. The tasks contained important perceptual information that may or may not have been used to respond to the task demands. The subjects' conceptions were then inferred from their responses to the tasks. These techniques have been used to investigate students' conceptions of a variety of topics such as photosynthesis and respiration (Anderson, Sheldon, & Dubay, in press), heat and temperature (Hollon & Anderson, 1985; Erickson, 1979, 1980), light (Anderson & Smith, 1983); chemical change (Hesse, 1986); and the molecular nature of matter (Novick & Nussbaum, 1978).

The substance of the studies of knowledge-in-action described above is not the subject of this research. Their importance lies in the methodologies and the assumptions underlying them. They consistently examined patterns in individuals' task performance, and their explanations for performing those tasks. Typically, the subjects completed clinical interview tasks or paper and pencil tests (Posner & Strike, 1978) in which they made predictions and developed explanations for some familiar event.

An important feature of the tasks was their familiarity to the subjects. By involving the individuals in events common to their everyday existence, and collecting data describing the ways they responded to those events, researchers gained access to the knowledge and thinking strategies actually used by the subjects rather than some set of propositions or theoretical knowledge held but not necessarily used to explain everyday situations.

The questions addressed in this study were also questions of knowledge-in-action. The goals were to describe the knowledge and beliefs about teaching and learning actually used by teachers during planning and teaching, rather than their more general theories about the characteristics of ideal or "effective" teaching. Thus, research addressing students' knowledge-in-action provided a useful framework for examining teachers' knowledge-in-action.

Knowledge and perception: Keys to learning from experience. Several researchers have addressed issues related to the links between teachers' knowledge and their perceptions of important characteristics of curriculum and classroom events (Erickson, 1986; Shulman, 1986; Shulman & Carey, 1984). In general, researchers have suggested that teachers' perceptions of classroom events are based on knowledge developed through experience and that their interpretations of classroom events are limited by that knowledge. Further, teachers' perceptions are bounded both by their innate limitations as information-processors and the conscious and unconscious development of cognitive routines designed to reduce information-processing demands.

Erickson (1986) addressed the link between knowledge and perception in a staff development project investigating the processes by which teachers interpreted classroom events. He described teachers' need for strategies to reduce information-processing demands in their daily teaching, and raised several issues about the factors influencing what teachers perceive or fail to perceive as a result of their innate limitations as processors of information. He suggested that teachers were often limited in their ability to perceive and use alternative teaching strategies because they failed to perceive important information related to classroom events available from sources beyond the immediate context of the event. As a result, the teachers failed to develop important knowledge about their students and their teaching, and as a result, learned little from their ongoing teaching experiences.

Erickson implemented an intervention involving classroom observations by the teachers and researchers, followed by structured comparison of observation notes, in an attempt to help the teachers perceive different forms of information about their students. As the teachers began perceiving information previously unavailable to them, they shifted from what Erickson termed a "snapshot" perspective of classroom events to a perspective in which events were regarded as part of a longer-term narrative. As a result, they were able to develop new knowledge about their students and their teaching.

Shulman and Carey (1984) discussed several models of rationality from which teachers, learners, teaching, and educational research could be considered. The <u>rational model</u>, which Shulman and Carey suggest is the model of human functioning most prevalent among contemporary educators, places humans in the position of being able to reason logically, and to perceive events in the real world as they truly exist. Reasoning capacities are increased through education and experience in the world. The <u>irrational</u> model is typified by the theories of Freud, involving the id, ego, and superego, and the conflict between reason sought by the ego and unreason demanded by the id and superego.

The bounded rational model posits humans as limited in their ability to perceive events in the real world and to process information, thus they construct simplified cognitive models of events in order to reduce information-processing demands. The models are bounded by the limits of the individual's existing knowledge and beliefs. Individuals act rationally with respect to their model rather than the actual event.

The collectively rational perspective expands consideration of the complexity of events based on individually held knowledge to include reasoning as practiced by individuals viewed as members of a societal group. Knowledge and meaning are not idio-syncratic, but are developed and manipulated with respect to varied meanings possible in social contexts. Teaching and learning is interpreted from a group framework, in which members can act as memory, processors, sources of feedback, and monitors.

An important issue for this study is the notion that individuals act rationally with respect to their cognitive models (Shulman & Carey, 1984; Simon, 1984b). As a result, an individuals' actions may not make sense to the uninformed observer, they are reasonable from the point of view of the individual. By developing and making explicit the frames of reference, including propositional knowledge and beliefs, knowledge-in-action (Driver & Erickson, 1983), practical knowledge (Elbaz, 1983), perceptions of important information, and strategies used for gathering information, it becomes possible to develop some understanding of the theories and beliefs underlying individuals' actions, and to consider strategies for influencing those actions.

Summary of Models of Cognition

Schema theory and conceptual change theory provide a theoretical and methodological framework for addressing the research questions of this study. Schema theory accounts for perception, in which limitations on information-processing capacity results in individuals actually processing only a small portion of the information available from the environment. Perception is based on comparisons of new information with existing knowledge or schemata stored in long-term memory. Thus, teachers' ability to learn from experiences are influenced both by the nature of their existing knowledge, which determines how new information will be processed, and by perception, which determines which information from the environment the teacher will actually recognize as important. Learning occurs when schemata or conceptions are changed, usually by adding information to existing structures (assimilation) or by fundamentally rearranging schemata, establishing new links between some schemata while eliminating others (accommodation). The nature of the changes in schemata are determined by existing knowledge and beliefs, and the nature of available information (Posner & Strike, 1978; Simon, 1984b).

Studies of "knowledge-in-action" (Driver & Erickson, 1983) illustrate methods appropriate for investigating the relationship between individuals' responses to real-world tasks and their underlying knowledge. By observing teachers as they engage in various teaching activities and administering clinical interview tasks in which the teachers discuss their activities and apply knowledge about students, it is possible to gather evidence and make inferences about their knowledge and the information they perceive from the teaching environment.

Research on Teachers' Thought Processes

Research on teacher's thought processes typically has been based on a cognitive information-processing model in which the teacher is assumed to be a boundedly rational individual acting in ways to simplify complex problems in a dynamic environment (Clark & Yinger, 1979). Clark and Peterson (1986) summarized trends in the existing research literature related to teachers' thought processes, organizing it into four groups: Teacher Planning, Teachers' Interactive Thoughts and Decisions, Teachers' Attributions, and Teachers' Implicit Theories. They also described a theoretical model illustrating the relationships among the four groups, and the relationships to teacher and student behaviors and the larger contexts of schools.

In an earlier review, Shavelson and Stern (1981) described a decision-making model which illustrates how teachers integrated information about students, subject matter, and the teaching environment during the decision-making process. They did not include a section on teachers' theories or beliefs. They did include a section on teachers' cognitive processes, which focused primarily on the heuristics teachers relied on to select information selection and how the heuristics influenced attributions for students' success or failure (Borko & Shavelson, 1976). Thus, research addressing the nature of teachers' knowledge or beliefs is a very new area of inquiry.

Many of the studies or teachers' thinking have described types of knowledge that influence teachers' planning and teaching. Relatively few have attempted to describe the nature and substance of those knowledge structures or the implicit beliefs underlying teachers' observable behaviors or the process by which the teachers' beliefs develop. The methodologies typically employed involved self-reported data, including stimulated recall, journals, word association and grid construction tasks, and think aloud protocols (c.f. Clark & Peterson, 1986, for a more detailed description of the methods). Some studies of teachers' theories or beliefs (Bussis, Chittendon, & Amarel, 1976; Elbaz, 1981) included clinical interviews and/or classroom observations as primary data sources.

Research on teachers' thinking has focused on understanding the nature of teachers' thinking in a given situation, such as when they were planning a lesson, or when they decided to alter their plan in the middle of a lesson. Thus, the focus of research has been on identifying types of knowledge possessed by teachers and how they use it during teaching activities; few studies have addressed the substance of teachers' knowledge and beliefs, particularly about students. For example, in discussing several studies which compared the interactive decision-making of experienced and inexperienced teachers (c.f. Calderhead, 1981), Clark and Peterson (1986) noted that the studies suggested that experienced teachers possessed better developed knowledge structures than inexperienced teachers. They related the findings to differences in teachers' schemata, and listed a number of different types of knowledge (such as range of students' skills and knowledge, discipline problems, family backgrounds...) but neither the reviewers nor the authors of the studies discussed the teacher the substance of what actually knew about students' skills or discipline problems.

The issue of shared perceptions between researchers and subjects has been raised by several researchers (c.f. Clark & Peterson, 1986; Munby, 1982; Nisbett & Wilson, 1977). Munby (1982) in particular noted that many researchers made the fundamental error of assuming shared perceptions of language and terminology, a problem particularly important in studies using coding systems, rating sheets, and grids containing categories developed by the researchers. Munby argued that it was important to maintain the language used by the subjects in the development of categorizing systems, and to supplement such systems with interviews to place meanings into the subjects' context.

In an earlier article, Nisbett and Wilson (1977) raised the issue of people's ability to directly report the nature of their cognitive processes. They argued that (a) subjects were often unaware of the nature of a stimulus that produced a response, i.e "I don't know why I did that, I just did it". It seemed appropriate at the time"; (b) were unaware that a response had occurred, i.e. "I didn't know that I did that"; and (c) were unaware that a stimulus had affected a response i.e. "I didn't realize that I changed the way I was acting (or thinking)." Nisbett and Wilson proposed that individuals' responses were not based on direct introspection, but were based on implicit causal theories based on the plausibility of a stimulus actually producing some response. They argued that such responses would be accurate in those instances when the stimuli (an interview task, for example) represented recognizable and reasonable events and were related to responses in a plausible manner. If the stimuli and/or response weren't recognizable or reasonable, or weren't linked in a plausible way, the individual's responses would not be an accurate indicator of the nature of their underlying theories and beliefs.

Nisbet and Wilson's argument suggests that the tasks used in the interviews conducted during this study only provide accurate reflections of the teachers' beliefs if the tasks themselves are perceived as reasonable and plausible (reflect events that the teacher believes could have occurred and were reasonable to think about in the first place). Since the tasks in the interviews were based on discussions of questions, tasks, and resources identified by the teacher or observed by the researcher, the criteria of events being reasonable is met. The issue of plausibility might be more difficult to demonstrate if a task required the individual to access knowledge or engage in reasoning that was not possessed. In that instance, responses to tasks might not be accurate reflections of the individual's underlying beliefs (although they would provide some evidence about what the beliefs were not...).

Studies of teachers' implicit theories and beliefs. In their review of research on teachers' thinking, Clark and Peterson (1985) identified only nine studies directly addressing teachers' implicit theories and beliefs. Three studies (Duffy, 1977; Elbaz, 1981; Janesick, 1977) involved classroom observations as a primary data source. Elbaz and Janesick conducted long term ethnographic studies of individual teachers. The other studies relied primarily on stimulated recall, clinical interviews and grid construction techniques. In each case, the results were reported as categories of thought held by the subjects.

A few studies focused directly on teachers' theories or conceptions about teaching. Common to these studies was the idea that teachers' behaviors (both cognitive and active) depend on some personally held set of conceptions, and make sense to the teacher in terms of their conceptions. Clark and Peterson (1985) noted that these systems were not well defined even for the teacher, thus the task of making them explicit was difficult to accomplish in ways that maintained the teacher's viewpoint.

Studies of teachers' perceptions of their own role include those by Janesick (1977) and Munby (1983). Janesick (1977) conducted an extended ethnographic study of the "perspective" of one sixth grade teacher. She defined "perspective" in terms of a reflective interpretation of experience which was socially derived, and which would serve as a basis for action. Janesick found that the teacher viewed himself as a group leader, striving to create consensus and cooperation during classroom activities. The teacher was thus not oriented toward teaching subject matter, but perceived his role as one of managing the classroom environment to develop and maintain group cohesiveness.

Munby (1983) examined the implicit theories of teaching of 14 junior high school teachers. He used a modification of Kelly's repertory grid technique to generate a set of factors relating terms or phrases to teachers' explanations for how the terms were related. The teachers were interviewed to determine their underlying conceptions. He found that each teacher held between three and five different constructs guiding their teaching, including including learning and development, involvement, teacher control, student needs and limitations, and motivation.

Greenfield and Blase (1981) described the role perceptions of secondary teachers in a suburban school, and how those perceptions changed as teachers gained experience. They noted that the primary role for beginning teachers was one of "achieving professional mastery." The beginning teachers were concerned with learning their subject matter and how to teach it, developing management and student discipline skills, and trying to negotiate appropriate social relationships with students who were often close to their own age.

The more experienced teachers, those with three or more years of experience, perceived their roles as more holistic, including concerns related to academic learning, teaching students moral issues such as honesty and integrity, and helping students with personal problems such as family break-ups, drugs, death, and crime. They also perceived their role as one of overcoming job-related barriers that reduced their opportunities to achieve successes with students in the three areas listed above.

Greenfield and Blase presented a picture of teachers' roles that was somewhat more holistic than the secondary subject matter expert described by Brophy and Good (1974). Like most of the studies reviewed in this chapter, their analysis identified student learning as an important issue for the teachers, but the authors did not report what the teachers' perceptions of their role in promoting learning actually were.

Winne and Marx (1982) described a sample of 5 upper elementary school teachers' views of thinking processes for classroom learning. Working from a cognitive mediational perspective, the authors developed a complex coding system for categorizing the teachers' and students' interview responses and observed classroom behaviors. They identified three major categories of processes, including orienting, cognitive processing, and consolidating. Each category was subdivided to capture other features of the teachers' and students' thoughts.

Orienting referred to strategies in which the teacher's intention (or the students' perception of the teacher's intention) was to focus attention on a task or goal to control students' efforts to achieve the goal. Cognitive processing involved identifying the processes students engaged in as the result of teacher directions or as a response to some orienting event. This category emphasized students' mental actions (such as comparing, generating, and reexamining) as opposed to the products of cognitive processes (such as comprehension, attention...). The third class of intended responses were those related to consolidation, or processes that occurred after students comprehended something and were engaging in practice activities designed to promote storage and retrieval of the new ideas.

Winne and Marx concluded that the teachers and students in the study engaged in a large variety of teaching strategies designed to manage students' cognitive processes, but did not assume that all teaching events lead directly to learning. They perceived a variety of actions as setting a stage for learning (orienting) as well as reinforcing and practicing using content already learned (consolidation). However, their analysis focused on the teachers' expectations for their actions (What did you think the students would learn from that) rather than why the teachers thought the action was important to help students learn.

Olson (1981) reported that British science teachers enacted a common curriculum in quite different ways. He attributed the differences in the interpretation of the curriculum to the unique nature of individuals' knowledge and the variance in individuals' conceptions about the nature of curriculum. Even greater differences were found between teachers' perceptions of the curriculum and those of administrators and curriculum developers. These differences were accounted for by differences in the groups' perceptions of curriculum and varying conceptions about the nature of the curriculum enactment process. Thus, the nature of each groups' knowledge resulted in vastly different perceptions of important features of the curriculum.

Elbaz (1981) reported that teachers possess a broad range of practical knowledge which both guides their work and is derived from it. She described an English teacher's use of systematic knowledge in distinct ways to address specific groups of teaching situations, linking the practical aspects of teachers' knowledge to their experiences. However, she was not interested in the particular nature of teacher's knowledge or beliefs but rather in the structure of the types of knowledge.

Shavelson and Stern (1981) summarized the types of information about students that teachers attended to in planning and teaching, including sex, general ability, self-concept, social competence, class participation, work habits, classroom behavior, and independence.

Shavelson, Caldwell, and Izu (1977) investigated teachers' decision making in an experimental study in which teachers were presented with different sets of information about a fictitious student. Information about social class, work habits, intelligence were described.

The apparent reliability of the information was manipulated by casting it as reliable (obtained from parents or standardized tests) or unreliable (obtained second-hand from peers who didn't know the student. The investigators found that teachers were sensitive to the reliability of information received, and were willing to revise estimates of the students' potential when supplied with new information.

Previous research conducted by the Science Teaching Project at the Institute for Research on Teaching (Anderson & Smith, 1986) identified different orientations toward the teaching and learning of science among elementary teachers including didactic, activity-driven, and discovery-oriented teaching.

Didactic teachers approached the task of teaching science as one of organizing and communicating important information to their students. The students' task was to study and learn the information presented. Emphasizing content coverage often resulted in these teachers failing to recognize that students held misconceptions that posed important barriers to learning (Slinger, Anderson, & Smith, 1983).

Activity-driven teachers emphasized activities to be carried out in the classroom, such as text reading, demonstrations, experiments, answering questions, or other activities, assuming that the students would learn through experience. Although the teachers attempted to follow instructions in teachers' guides, their lack of understanding of the importance of the activities caused them to modify or delete important sections making it difficult or impossible for students to learn important scientific principles (Smith & Sendlebach, 1982).

Discovery-oriented teachers relied on numerous activities in their science instruction, but avoided telling students the "correct answer". Instead, they encouraged students to develop their own ideas from observations and experimental data, assuming that students would develop appropriate conceptions by performing experiments and engaging in "scientific thinking". However, because little or no direct information was presented to the students, they interpreted the experiments in terms of their prior knowledge and remained committed to their misconceptions (Smith & Anderson, 1984).

Conceptual change teachers, in contrast to the groups described above, used teaching strategies which involved continually diagnosing students' conceptions, evaluating their progress in the process of conceptual change, and adjusting instruction accordingly. These teachers asked questions that required students to explain phenomena, made students aware of differences between their ideas and more scientifically appropriate explanations, supplied important content information at appropriate times during instruction, and provided students with opportunities to practice applying new ideas to a variety of everyday events (Anderson & Smith, 1983; Nussbaum & Novick, 1982.)

Anderson and Smith (1986) suggested that effective conceptual change teaching requires two different types of knowledge. First, teachers need a general orientation towards conceptual change teaching, in which the teacher understands the cognitive processes involved in conceptual change, and is committed to conceptual change as the only process by which students can effectively learn science. Second, teachers need specific knowledge of three different types, including

1. Knowledge of science content and how it can be translated into curricular goals,

2. Knowledge of students and the specific misconceptions that are likely to influence their understanding of the concepts being taught,

3. Knowledge of teaching strategies that will help students overcome their misconceptions.

This knowledge is acquired by paying attention to much information that is not oriented toward describing science content, but focuses on the nature of students' thinking. However, if teachers' existing knowledge does not also include cues alerting the teacher to the importance of students' cognitive processes, then they will fail to perceive important characteristics of students responses to instruction that might lead to useful insights about the ways that the students are making sense of the material being taught.

Research on Teachers' Expectations and Attributions

Research on teacher expectations has addressed the relationships between teachers' expectations and student achievement (c.f. Brophy & Good, 1974). An information-processing approach to explaining teacher expectation effects would probably find that teachers use expectations the same way that most people do: to interpret the meaning of new information they receive; to anticipate the form that new information will take (thus reducing information-processing demands); and to judge the sufficiency of the information to help reach a decision (Shulman & Elstein, 1975). Thus, although research on teacher expectations itself is not particularly relevant to this study, interpreting the research from an information-processing perspective illustrates how conceptions (in this case about student achievement) influence teachers' perceptions of information available from the environment.

In discussing research on teachers' expectations, Brophy (1983) noted that predicting effects of teachers' expectations was difficult due to their interactions with underlying beliefs about teaching and learning. However, few studies of expectations have addressed the nature of those beliefs about teaching and learning. Good and Brophy (1978, 1980) described two different definitions of the teachers' role in learning and instruction. They noted that secondary teachers often perceived themselves as subject matter experts whose primary role was that of designing and conducting classes oriented around the subject matter. Their classes were aimed at higher achieving students, and were conducted in a very business-like fashion.

The other end of the spectrum was represented primarily by individuals trained as elementary teachers who emphasized student socialization as the primary goal of instruction. These teachers engaged in more social interactions with students, knew them better as individuals, and conducted classes that placed much less emphasis on subject matter than the classes conducted by secondary teachers. Brophy and Good noted that the socialization-oriented teachers were more apt to be susceptible to expectation effects. For those who perceived lower achieving students as able to learn, there were more instances of students receiving extra help to increase achievement. However, for those teachers who perceived lower achieving students as unable to learn very well, more instances were observed of teachers acting in ways that were well-meaning but restricted students' opportunities to learn (Brophy & Good, 1978; Rosenshine & Berliner, 1978).

Another perspective concerning differences in teachers' roles was offered by Brophy and Good (1974). They noted that studies of expectation effects had produced inconsistent results, and suggested that the inconsistencies could be the result of individual differences among teachers, particularly their role definition (which they defined as the degree to which teachers assumed responsibility for student learning), and other personal attributes such as intelligence. Brophy and Good characterized teachers as proactive, overreactive, or reactive. Proactive teachers emphasized thinking about students' characteristics and needs, and possessed well developed ideas about what students needed to learn and how they should be taught. These teachers tended to work in ways that shaped the students' thinking according to the teachers' goals and expectations, rather than relying on external influences and information from publishers, past teachers, and the behaviors of the students. Their success depended on their ability to establish realistic expectations and utilize strategies capable of overcoming various obstacles. In particular, proactive teachers were characterized as having positive expectation effects on low achieving students, however undesirable effects were also possible, depending on the nature of their beliefs about teaching and learning.

Overreactive teachers were characterized as developing stereotypic images of students based on a few first impressions. Expectations are developed based on the stereotypes rather than the nature of the students themselves. Thus, fairly rigid systems of interaction developed in which negative consequences were predicted, especially for low achieving students.

Brophy and Good described most teachers as reactive: they didn't always try to mold students to their way of thinking, but didn't form judgments based only on students' past performances. These teachers were characterized as flexible, and sensitive to changes in students' performance. They adjusted their goals in response to trends in students' performances and other forms of feedback.

Studies of teachers' implicit theories and attributions have addressed issues concerning the causes of students' successes or failures. In general, these studies have addressed the nature of teachers' attributions and the relationships between teachers' attributions and students' performance in the classroom. Studies of teachers' attributions for students' success or failure have generally used some set of categories to summarize the nature of teachers' attributions (c.f. Bar-tal & Darom, 1979; Cooper & Burger, 1980; Frieze, 1976; Weiner et al, 1971). Some researchers generated a priori categories, while others generated categories based on teachers' responses to interview questions or tasks. Although these studies illustrate some important methodologies, much of their interest has been on issues other than relating teachers' attributions of students success or failure to underlying theories or conceptions about teaching or learning.

Summary of research on teachers' thinking. Research on teachers' thinking has provided a rich variety of information and insights into the nature of the cognitive processes underlying teachers' activities. This body of research indicates that teachers rely on relatively few (three to six...) theoretical constructs to guide their teaching and that their underlying knowledge and beliefs about the nature of good teaching provide structures that enable them to cope with the demands of teaching (Clark & Peterson, 1986). Most of the studies of teachers' thinking have involved experienced teachers, and have focused on particular aspects of the teachers' thoughts, such as their decisions during planning, their interactive thoughts, and their beliefs about practice. Little evidence about the nature of the teachers' beliefs about students' learning processes and their judgments about important information exists, nor have researchers addressed the processes by which teachers have developed their knowledge over time. The importance of teachers' knowledge and beliefs about students' learning processes has thus been acknowledged (Anderson & Smith, 1986), but the substance of those beliefs has seldom been empirically investigated (Winne & Marx, 1982).

Summary

The research described in this chapter illustrates a set of relationships among teachers' knowledge and their ability to make sense of their surroundings. As limited information-processors, teachers must use their existing knowledge to interpret their observations of students, the classroom context, and the various forces acting from outside the classroom. However, most current research on teachers' thinking has not addressed the nature of teachers' knowledge and beliefs about students' learning processes or the relationship between teachers' knowledge and what they perceive as important information. For example, Munby (1983) attributed teachers' different perceptions of curriculum to differences in their knowledge and conceptions, but he did not address the features of curriculum that were important to teachers with a particular view of curriculum. In addition, he reported that teachers' beliefs could usually be described using a set of three to five constructs, however he did not describe the substance of any of the constructs.

Similarly, Anderson and Smith (1985) reported that successful science teachers possessed different knowledge about students and used their knowledge in different ways than do less successful teachers. Their work illustrated the nature of the differences that exist in teachers' knowledge of students, but did not address the nature of relationships between teachers' knowledge of students and their perceptions of important information and information-gathering strategies. Thus, the role of teachers' knowledge and beliefs in guiding their practice and judgments about important information have been acknowledged but not empirically investigated.

CHAPTER THREE

This purpose of this study was to describe a sample of 7th grade science teachers' beliefs about students' learning processes, their beliefs about the teacher's role in promoting learning, and how these beliefs influenced their judgments about important information and their information-gathering strategies. The research reported here was conducted within the framework of the Middle School Science Project. Thus, the data collection and analysis strategies described in this chapter were developed for purposes that extended beyond the scope of the questions addressed in this dissertation.

In order to address the knowledge and beliefs the teachers actually relied on to guide their teaching, their "knowledge-in-action" (Driver & Erickson, 1983) rather than propositional knowledge about the characteristics of appropriate teaching, interview tasks were designed which involved teachers in describing how they actually planned and taught units about photosynthesis, cellular respiration, and ecological matter cycling. The tasks addressed teachers' learning goals for their students, their knowledge of students' misconceptions about photosynthesis, cellular respiration and matter cycling, and the features of resources and teaching strategies they considered important for promoting student learning.

The interview data were used in conjunction with data from classroom observations to develop descriptions of the teachers' beliefs about teaching and learning, their judgments about important information, and their information-gathering strategies. The subjects, research design, development of data collection instruments, and data analyses procedures are described below.

Subjects

The initial group of subjects recruited for the Middle School Science Project included fifteen 7th grade science teachers. At the end of the first year, two individuals withdrew. Thus, the subjects for this study included thirteen 7th grade life science teachers (F=7, M=6). All had been teaching at least 10 years. Twelve were certified as secondary teachers. Eight had earned advanced degrees in education. Seven of the teachers were science majors. The others included a math major, a home economics/art major, a vocational education teacher, a social studies major, an elementary education major, and a fire science instructor.

Experimental Conditions Related to the Middle School Science Project

The purposes of this research did not include relating teachers' beliefs and behaviors to any particular treatment included in the larger Middle School Science Project. However, because the treatments did represent potential influences on the teachers' thought and actions, they were considered in the data analysis for this research. The treatments included in the Middle School Science Project are summarized in Figure 1 below.

Figure 1
Design of the Middle School Science Project

	Group A	Group B	Group C
Photosynthesis	Training about misconceptions and strategies	Teacher' Guide Student text Transparencies	Training and Materials
Respiration	Training about misconceptions and strategies	Teacher's Guide Student text Transparencies	Training but no Materials
Matter Cycling	__________	__________	__________

The teachers were randomly assigned to three different treatment groups. Group A (n = 4) received training which provided them with general information about the nature of students' scientific thinking and the ways that misconceptions interfere with students' learning. Group B (n = 5) received teacher and student text and transparencies designed to explicitly contrast students' misconceptions with scientifically acceptable theories. Group C (n = 4) received both training and materials.

The nature of the treatments varied across units. Training and materials were provided for the photosynthesis and cellular respiration units. The matter cycling unit was a transfer unit included to examine the resources and strategies used by the teachers in a context where no materials or training were conducted. Teachers in Group C received training and materials for the photosynthesis unit, but only training for the respiration unit.

Data

Three data bases were developed during the Middle School Science Project, including student test data, classroom observation data, and teacher interview data. The research presented in this dissertation utilized only the interview and observation data. Each type of data is described in detail below.

Teacher interviews. The primary data for this study were transcripts of 39 post-interviews. Each teacher was interviewed at the beginning of the study, and after completing each of the three experimental units. The interviews were designed to provide information about four different aspects of the teachers' knowledge and beliefs, including

(a) their knowledge of science content

(b) their knowledge of students' misconceptions about photosynthesis, respiration, and matter cycling

(c) the features of planning and teaching resources judged to be important

(d) features of teaching activities they regarded as important influences on student learning

The interviews included tasks in which the teachers sorted cards to illustrate important relationships, made predictions about students' responses to test questions, or described important resources and strategies they used in planning and teaching. An important aspect of the tasks was that they were based on activities that the teachers had actually engaged in during the unit, rather than hypothetical teaching tasks. Thus, the knowledge elicited by these tasks was "knowledge-in-action" (Driver & Erickson, 1983) or "practical knowledge" (Elbaz, 1981) rather than propositional knowledge about how teachers ought to act.

The initial set of interview tasks were selected from a pool of potential tasks contributed by the research project staff. The selection of tasks from the pool was based on the notion of academic tasks (Doyle, 1983), and the Middle School Science Project goal of assessing changes in teachers' knowledge as a result of the treatment. An interview protocol was developed to structure the administration of tasks and follow up questions.

Three different versions of the protocol were used during the study. The initial protocol was was revised after the pre-interviews were completed, and again after the photosynthesis interviews. Tasks were added or deleted to obtain better information from the teachers, and to limit the time needed to complete the interview to approximately one hour. Parallel forms of the final interview protocol were used during the respiration and matter cycling units. The tasks included in the final version of the interview are described below.

Task 1: Card sort of unit concepts. The teacher was presented with a set of cards containing the names of various concepts related to the interview topic (see appendix A for lists of the concepts included in each unit). S/he sorted the cards to identify those concepts actually taught during the unit, then organized the cards to illustrate relationships that were important for students to understand. Questions focused on the nature of the relationships used to group the cards, and the teacher's expectations for student learning. This task provided information about the way that the teacher organized content knowledge, and the goals that the teacher had for students' understanding.

Task II: Review of test questions. The teacher was shown a series of cards containing questions from the student diagnostic test. After reading a question, the teacher responded to five questions, including

1. How would your students answer this question before instruction?
2. What might they be thinking about that would cause them to answer that way?"
3. How would you like them to answer it at the end of the unit?"
4. What per cent of the students do you think will be able to answer it correctly?
5. What problems might prevent the others from being able to respond?

The teacher then sorted the cards into piles identifying "questions important for students to be able to answer" and "questions not important". The reasons for classifying each question as important/not important were discussed. This task provided information about the teacher's understanding of their students' thinking about science concepts, particularly their understanding of students' misconceptions. Additional information regarding perceptions of students' abilities, reasons for their failure to learn, and the teachers' goals for student learning were obtained from this task.

Task III: Features of important planning and teaching resources. The teacher was shown a series of cards containing the names of resources typically used to plan or teach a science unit. The teacher sorted the cards into piles identifying resources used and not used, and described why each resource was used, and the features of the resource that the teacher perceived as most important. Reasons for not using resources were discussed to gather additional information about characteristics that the teacher perceived as unimportant.

Task IV: Factors important in promoting student learning. In this task, the teacher was asked to identify the three things (or more) that s/he did that were most important in influencing students' learning of the unit concepts. Additional questions probed the reasons for each factor's importance.

Discussion of actual instruction. During classroom observations of the photosynthesis unit, academic tasks (Doyle, 1983), i.e. any task that the student completed for a grade, were identified. During the interview, the teacher was asked to describe the importance (in terms of its' contribution to the unit grade) and the purpose of each academic task. Additional questions probed the role of the task in fostering student learning, and the teachers' perception of differences between expected learning and actual student learning. This task provided some evidence about the types of activities the teacher felt were important to foster students' learning. It was deleted after the photosynthesis interviews because several teachers had no academic tasks to discuss, making the task relevant only for those teachers who regularly held students accountable for assignments.

Limitations of the interview data. The interview data were subject to several potential biases. Because the interviewers were aware of the goals of the Middle School Science Project, there may have been some tendency to guide respondents' comments. In a few instances, the interviewer rephrased responses to tasks using language inconsistent with the subject's other responses, but consistent with the language used by the researchers. Due to the rotation of interviewers across subjects, systematic biases were minimized.

In addition, the research design included self-reported evidence, thus the potential for response effects existed (Borg, 1983, Gordon, 1980) (and were evident in one case involving a subject who was uncooperative during interviews, and provided short, terse responses to all the interviewer's inquiries).

The use of card sorting tasks, while focusing the interview on specific topics, may also have influenced subjects to construct responses based on their judgments about "plausible explanations for an event" (Nisbett & Ross, 1980). However, because the sorting tasks were based on events that occurred during instruction, the explanations developed should provide plausible evidence of the knowledge and beliefs that form the bases for the teachers' actual practice.

Classroom Observations

More than 150 observations of classroom instruction were conducted as a part of the Middle School Science Project. The data available from these observations included narrative descriptions of actual instruction and coded information summarizing (a) the content addressed during instruction, (b) the use of teaching strategies associated with successful conceptual change teaching, (c) descriptions of all sources of information used during the planning and teaching of the unit, and (d) descriptions of all academic tasks (assignments, tests or quizzes, work sheets) used during the unit. The development of the observation system and procedures for analyzing classroom observation data (Anderson, 1985, Chadwick, 1985) and the results of the analyses (Anderson, et al. 1986; Blakeslee, Anderson & Smith, 1987) were reported separately.

Separate analyses were also conducted to examine the teachers' use of specific teaching strategies associated with conceptual change learning (Smith & Anderson, 1987). The data available from that analysis included

a) frequency of teacher questions including predictions and/or explanations
b) nature of phenomena used during instruction
c) use of conceptual advance organizers
d) use of contrasts between goal and naive ways of thinking about scientific principles

Limitations of the observation data. The classroom observation data were potentially subject to systematic bias. The design of the Middle School Science Project, and the procedures used to code the observation data, emphasized teaching behaviors associated with conceptual change teaching (Minstrell, 1984; Roth, Anderson, & Smith, 1984), thus the observers were potentially more attentive to those behaviors. In addition, the observers did not receive training in classroom observation (although four staff members had extensive observation experience) (Borg, 1983; Slavin, 1984). The impact of these variations was randomized by rotating observers for each unit.

Data Collection

Observations of instruction. Each teacher was observed as s/he taught units about photosynthesis, cellular respiration, and matter cycling using the materials and/or training provided as a part of the Middle School Science Project. Narrative data describing classroom instruction, samples of student texts, assignments and quizzes, and other resources used during planning and teaching were collected for at least three lessons in each unit, resulting in a set of 12 - 15 observations for each teacher.

Administration of interviews. The interview data used in this study included 39 post-interviews completed within two or three days after each unit was taught. The interviews were conducted by the same researcher who observed the teacher's instruction in order to allow particularly interesting or discrepant classroom events to be explored. Observer-interviewers were rotated for each unit in order to reduce biases in both the observation and interview data.

The interviews were conducted by seven researchers from the Science Teaching Project staff. The researchers did not receive any training in conducting the interviews, however, pre-interviews served as practice sessions for the interviewers. In addition, the written protocol provided some structure for administering the tasks and follow up questions. Interviewing procedures were reviewed after the photosynthesis interviews were completed to provide the researchers with feedback regarding completion of tasks, consistency of probing of teachers' initial responses, and the levels of questioning used during the tasks.

The interviews were usually conducted in the teacher's classroom to provide better access to materials usually used during instruction. The interviewer was provided with a packet containing the written interview protocol, cards containing the names of the unit concepts, cards identifying planning and teaching resources supplied by the Science Teaching Project and other resources typically available, and cards containing the questions from the student test. The cards were used to stimulate the teacher's memory about important concepts or resources relevant to that unit, while at the same time defining the task environment by focusing the discussion on a particular topic or question rather than just "talking about teaching." The teacher's responses to questions were probed whenever the interviewer felt it necessary to obtain clarification; no specific guidelines were established for using probing questions.

Each interview was audio-taped. Transcripts were prepared from the tapes and were reviewed by the interviewer to fill in gaps in the recordings and to ensure that all portions of the interview as it was conducted were included in the transcript. Most transcripts were verified for accuracy, however in two instances the quality of the recording was such that the transcripts were of marginal value. In those cases, the interviewer constructed a description of the interview from memory to supplement the data contained in the original interview. As a result, two of the interviews were more reconstructions of conversation than actual interview transcripts.

Data Analysis

Analysis of the interview transcripts required several steps, including initial readings to organize the data and identify patterns of reasoning displayed by the teachers, development of case studies to describe the beliefs about teaching and learning underlying the patterns of reasoning, identification of important issues and data sources from the case studies, and the development and application of a coding system to systematically analyze the entire data set. From the case studies and coded data, a set of charts were developed to summarize the teachers' responses to the interview tasks and to describe patterns in their reasoning and beliefs about teaching and learning. Each step in the analysis process is described below.

Initial organization of data. Transcripts from each teacher interview were read to develop familiarity with the entire data set and to obtain an overall picture of each teacher's responses to the interview tasks. The responses were compared to each other within and across tasks, following a format similar to a constant comparative method (Glaser & Strauss, 1967; Lincoln & Guba, 1985). A set of initial hypotheses about the teachers' beliefs were developed and used to generate predictions about their responses to interview tasks (Hollon & Anderson, 1986). The predictions were then applied to the data in order to determine how well the hypotheses and the predictions matched the teachers' responses. The results of this analysis were used to revise both the hypotheses and the predictions to better reflect the nature of the data.

Identification of orientations and development of case studies. Three different orientations toward teaching and learning were identified during the initial data analysis (Hollon & Anderson, 1986). A set of case studies was developed describing the beliefs, judgments, responses to interview tasks, and teaching activities characteristic of each orientation. The case studies served three purposes:

1. They provided detailed descriptions of characteristic sets of beliefs about teaching and learning held by the teachers in the study.

2. The process of developing the case studies helped identify key issues which could be used as a theoretical structure for comparing teachers and analyzing the larger data set.

3. Key data points were identified. As the case studies were developed, some interview questions became more important; others provided little useful information about teachers' thinking about their students.

The teachers were chosen for case studies based on several criteria, including the degree to which their teaching and interview responses consistently reflected consistent patterns of reasoning about teaching and learning, the presence of particularly interesting behaviors, and the availability of a complete data set for that individual (two teachers' interview data were less reliable due to the recording problems described above). The process of developing each case study included

(a) reviewing all interviews and observation data available for that teacher to develop a better sense of the individuals' approach to teaching;

(b) generating initial hypotheses about the teacher's beliefs about teaching and learning that might account for teaching behaviors and interview responses. These were based on the ideas generated during the initial readings of the transcripts; and

(c) systematic searches of the interview and observation data to determine how well the hypothesis were supported by the data.

The process of generating hypotheses and examining the data continued until hypotheses emerged that generated predictions consistent with the teacher's classroom behaviors and interview responses. In practice, this process was less organized than just proceeding through steps A, B, and C. There was a considerable amount of time spent just "messing with the data" as ideas were formed, tested, and (usually) rejected.

Development of summary charts. During the development of the case studies, interview tasks II, III, and IV emerged as providing the most useful data related to teachers' thinking about their students. Task II provided important statements about the teachers' goals for student learning and their attributions for students' success or failure to learn.

Task III yielded descriptions of the teachers' judgments about important features of various planning and teaching resources. Task IV produced detailed descriptions of the strategies that teachers considered important to promote student learning and why the strategies were effective.

A series of charts were developed to summarize the teachers' responses to each task. The charts served two purposes:

1. They systematically collected all of a teacher's statements about an issue into one place, where they could be examined more critically for patterns in the responses. They also facilitated comparisons across teachers and across topics by reducing 1500 + pages of text into a series of documents which could be compared to one another. The close proximity of a large number of related statements was useful for sharpening distinctions among important theoretical issues.

2. The charts allowed data to be coded more accurately and efficiently. When issues and codes were redefined, adjustments could be made in categorizing statements without having to search through large volumes of text to locate 2 or 3 lines.

For each task, the "question" was used as a loosely defined unit of analysis. Unique responses were recorded once for each question, so that if a teacher repeated the same answer within a question it would not be recorded as two responses. If more than one explanation was offered for a question, each reason was recorded as a separate response. As a result, the number of responses verified from teacher to teacher, and did not match the number of questions on the student test.

The development and use of each coding form is discussed below. The forms and coding instructions are included as Appendix B.

<u>Form A: Failure to learn</u>. The data for this chart were drawn primarily from Task II. Additional statements from other tasks were recorded when they occurred. The recording process consisted of writing

the word, phrase, or sentence used by the teacher to describe students' failure to learn, and the page number where the statement appeared in the interview transcript.

A coding system was developed to categorize teachers' statements about students' failure to learn. The purpose of this process was to identify trends in individual teacher's responses as well as providing a basis for identifying patterns across teachers. The coding categories were developed from patterns in teachers' responses identified during the development of the case studies rather than from an external source. Similar procedures for developing categorization systems have been used by other researchers (c.f. Cooper & Burger, 1980). Frequency distributions and per cent of total responses were calculated for each coding category for individual teachers in each topic.

Form B: Important planning and teaching resources. The data for this task were drawn mostly from interview task III. Each resource identified as used in planning or teaching a unit was recorded in the chart. In addition, each reason given for why it was important was coded according to a set of categories derived from the case studies and modified once during the initial steps in the coding process. Individual statements about the reasons for each resources' importance were recorded for the case study teachers, but were not recorded for the others. Frequency distributions for each code were developed for each teacher.

Form C: Important teaching strategies. The data describing important teaching strategies were drawn mostly from task IV in the respiration and matter cycling interviews, and from the discussion of academic tasks in the photosynthesis interview. The procedures used to record data included writing each statement describing the strategy considered important, the reasons why it was considered important, and the page number where the statement appeared in the transcript. Statements were recorded for all the teachers in each group.

Ten categories describing features of important teaching activities were identified during the development of the case studies. These categories were used to code the teachers statements. Frequency distributions and percent of total responses were calculated for each topic and combined to produce a total distribution for each teacher.

Reliability of the coding schemes. The reliability of the coding categories developed for each task was assessed by having a second individual independently identify and code important statements within the task. Coding discrepancies were discussed and categories were revised to clarify distinctions in the nature of the responses. The final reliability checks for the coding system were 0.7 for task II, 0.85 for task III, and 0.72 for task IV.

Group summary charts. A chart summarizing each teacher's responses to interview tasks II, III, and IV was prepared. The chart contained both qualitative descriptions of the teachers' responses as well as summaries of the coded data. These charts were developed to gather together all the summarized data for each teacher. The charts provided a concise format for reviewing trends in individual teacher's behaviors as well as providing a means of developing clearer distinctions among individuals.

Data Analysis Issues

During the data analysis process, three issues emerged for which the teachers demonstrated large systematic differences in their patterns of reasoning about teaching and learning, including (a) the nature of learning, (b) the nature of the teachers' science curriculum goals, and (c) the nature of important teaching strategies. The relationships among the research questions, data analysis issues, and the interview and observation data are summarized in Table 1 below.

Table 1
Relationships Among Research Questions, Analysis Issues, and Interview Tasks

Research Question	Issue	Interview Tasks	Classroom Observations
I. What is the nature of teachers' beliefs about students' learning processes?	Nature of learning	II-descriptions of students' failure to learn IV-discussion of activities important for promoting student learning	Strategies used during whole-class instruction; Assigned tasks
II. What is the nature of teachers' beliefs about their role in promoting learning?	Nature of teachers' curriculum goals	III-discussion of important planning and teaching resources	Features of sources used for each unit; whole-class instructional strategies; assigned tasks
	Nature of important teaching strategies	IV-discussion of activities important for promoting student learning	
III. How do teachers' beliefs about the nature of learning and their role in promoting learning influence their perceptions of important information and information-gathering strategies?		II-predictions and explainations for students' responses to diagnostic test questions III-discussion of important planning and teaching resources IV-discussion of strategies important for promoting student learning	Whole-class instructional strategies; assigned tasks; sources used

Research question I addressed the nature of the teachers' beliefs about students' learning processes. The data which addressed this question were drawn from task II, particularly the teachers' reasons for students' failure to learn, and from task IV in which the teachers described the activities or strategies they felt were most important in promoting learning.

The discussions of students' failure to learn provided "negative evidence" in the sense that identification of causes for failure to learn also provided evidence of student activities the teachers considered necessary in order for learning to occur. For example, some teachers accounted for students' failure to learn with explanations like "they were still thinking about respiration as breathing" or "they just thought about rabbits eating grass and foxes eating rabbits". These statements about the nature of students thinking suggest that the teacher associated learning with changes in students' thinking. Other statements such as "they didn't remember that plants are producers" suggested that learning involved remembering facts and definitions. Thus, asking teachers to account for students' failure to learn provided useful insights into the nature of their beliefs about the process of learning.

The discussion in task IV of activities important to help students learn provided direct evidence about the nature of teachers' beliefs about learning. The descriptions defined both important aspects of the teachers' role as well as important tasks that the students needed to engage in in order to learn. For example, some teachers described class discussions as important because "they get the kids to think and express their ideas" or "they help the students to clarify what they mean." Statements like these suggest that some teachers believe that articulating and clarifying ideas is an important part of the learning process.

Additional data were drawn from observations of instruction, particularly the whole-class instructional strategies and classroom tasks (Smith & Anderson, 1987). Due to the large influence of the materials used in the interventions, only those data for units in which teachers did not have experimental materials were included in this analysis.

Research question II addressed the nature of the teachers' beliefs about their role in promoting learning. This question was addressed directly by interview tasks III and IV. Additional data were drawn from observations of instruction summarizing the features of the sources and classroom strategies used by the teachers as they taught each unit.

An important issue related to question II was the nature of their science curriculum goals. For some teachers, the major goal was to help students to understand important science content. Other teachers' goals focused on issues other than students' understanding of science content. The nature of the teachers' goals for students provided important insights into the nature of their beliefs about their role in promoting learning.

Research question III addressed the interactions among teachers' beliefs about learning, their role in promoting learning, their judgments about important information, and information-gathering strategies. Data related to this question were drawn from the teachers' predictions about students' responses to the test questions in interview task II, which provided evidence about their knowledge of students' thinking. Tasks III and IV provided evidence of the nature of information they considered important and the strategies they used to gather information from students. Additional data were drawn from the classroom strategies, tasks, and sources used during instruction.

None of the interview tasks directly addressed interactions among the teachers' knowledge and beliefs, perceptions of important information, and information-gathering strategies. The systems of interactions developed to address this question were interpretive in nature, and were based on the theoretical framework developed in Chapter Two.

Summary

In this chapter, the design for the research was described and related to the overall design of the Middle School Science Project. The data bases and data collection procedures were defined and linked to the research questions using three issues, including the nature of learning, the nature of teachers' curriculum goals, and the nature of important teaching strategies. The data analysis procedures developed to analyze each interview task in order to address each research question were described. Limitations on the internal validity of the data and methodology used in the research were discussed.

CHAPTER FOUR

The research presented in this dissertation addressed three questions, including

A. What is the nature of teachers' beliefs about students' learning processes?

B. What is the nature of teachers' beliefs about their role in promoting student learning?

C. How do teachers' beliefs about student learning and their role in promoting student learning influence their judgments about what information is important and their information-gathering strategies?

The questions were addressed using a series of clinical interview tasks designed to provide information about each teachers' knowledge of science content, knowledge of students' scientific thinking, their curricular goals for students, and the teaching strategies they considered most effective in helping their students learn important science content. Additional data were drawn from observations of instruction.

Three key issues emerged for which the teachers displayed large differences in their reasoning about teaching and learning, including (a) the nature of learning, (b) the nature of teachers' curriculum goals, and (c) the nature of important teaching strategies. These issues formed a theoretical framework linking the interview and observation data to the research questions (see Table 1, page 64).

Overview of the Results

One teacher was dropped from the sample as a case of "teacher burnout" who wasn't really trying to do a good job. Three different orientations toward teaching and learning were identified among the remaining twelve teachers. The Conceptual Development and Content Understanding orientations were characterized by the teachers' emphasis on student learning of important science concepts as a primary goal of instruction. These teachers were likely to engage in teaching activities that involved direct instruction and included opportunities for students to apply new ideas to explain real world problems. The Fact Acquisition orientation was characterized by teachers emphasizing learning goals limited to students' recall of information found in texts or other resource materials. These teachers tended to rely on curriculum materials to supply students with opportunities to learn, and tended to avoid asking questions involving predictions and explanations.

Within each orientation, it appeared that the teachers' knowledge and beliefs, judgments about important information, and information-gathering strategies combined to produce self-reinforcing belief systems: What they had learned about their students through instruction and class assignments was consistent with their curricular goals and beliefs about students' learning processes.

Overview of the Chapter

Sections II, III, and IV of this chapter describe the Conceptual Development, Content Understanding, and Fact Acquisition orientations toward teaching and learning. Each section contains four parts:

1. An overview of the beliefs about students' learning processes and the teachers' role in promoting learning characteristic of that orientation

2. A detailed case study of one teacher reflecting that orientation, describing the nature of the teachers' beliefs about students' learning processes and their role in promoting learning, judgments about important information, and information-gathering strategies.

3. A model illustrating the interactions among the teachers' beliefs about students' learning processes and their role in promoting learning, judgments of important information, and information-gathering strategies.

4. A summary discussion comparing the beliefs about teaching and learning of each orientation to the other orientations

Section V includes a summary of the classroom behaviors and responses to the interview tasks characteristic of each orientation. Section VI summarizes the results and discusses limitations on the interpretation of the data.

<u>A Case of Burnout</u>

One teacher was not included in any of the groups, and could best be described as a victim of teacher burnout. This individual was an experienced teacher who held an advanced degree in life science. His responses to the interview tasks, which were obtained with some difficulty, indicated that he possessed the content knowledge, the knowledge of students' thinking, and the classroom experience necessary to teach science effectively. However, his classes typically consisted of a few activities or reading assignments. Students were seldom on task and were often visibly disruptive. Instruction generally lacked organization and enthusiasm, and was continually disrupted by students' off-task actions. The teacher clearly avoided placing demands on students in return for their maintaining a minimal level of appropriate behavior, and would often join in students' social conversations rather than pursue academic tasks. Although the teacher apparently possessed the knowledge, skills and experience to teach science effectively, very little teaching actually took place.

Conceptual Development and Content Understanding Orientations

Eight teachers' instruction and responses to the interview tasks provided evidence indicating clear concern for helping students understand important science concepts. Their beliefs about students' learning processes ranged from clear emphases on learning as accommodation (Posner & Strike, 1978) to beliefs reflecting learning as a process of assimilation.

It was not possible to clearly characterize some individuals as consistently holding one perspective or the other. Only five individuals consistently adhered to one set of beliefs about learning. The other three individuals displayed patterns of reasoning that included characteristics of both the conceptual development and content understanding orientations. The analysis of data thus focused on the beliefs about teaching and learning, judgments about important information, and information-gathering strategies characteristic of each orientation toward teaching and learning rather than attempting to identify mutually exclusive groups of teachers.

The Conceptual Development Orientation

The teachers reflecting the conceptual development orientation were characterized by beliefs that emphasized learning as a process of accommodation in which students had to change their thinking about the natural world. The curricular goals characteristic of this orientation emphasized getting students to apply scientific theories to events in the natural world. The teachers who reflected this orientation tended to ask questions and engage in discussions which provided students with opportunities to apply scientific principles to account for real world phenomena while providing them with information necessary to develop detailed knowledge about their students' scientific thinking.

The conceptual development orientation was also characterized by several important components necessary for successful conceptual change teaching (Anderson & Smith, 1983; Roth, Smith, & Anderson, 1983). The teachers reflecting this orientation emphasized establishing appropriate scientific conceptions in a meaningful way and employed teaching strategies that provided students with opportunities to apply new ideas to a variety of different examples. However, an important aspect of conceptual change teaching was not evident in this orientation: students' misconceptions and prior knowledge were not judged to be important factors <u>interfering</u> with learning. Thus, the teachers reflecting this orientation seldom emphasized teaching strategies which would have enabled students to become aware of their own misconceptions.

The following case study of Ms. Copeland illustrates the beliefs about teaching and learning characteristic of the conceptual development orientation. Although a few aspects of her thinking were not characteristic of the conceptual development orientation, her responses to the interview tasks and classroom activities consistently reflected most of the patterns of reasoning typical of this orientation toward teaching and learning.

Ms. Copeland

Ms. Copeland taught a semester-long 7th grade life science course in a suburban community. She was an experienced teacher who had earned a bachelors degree in social studies and had completed extensive graduate coursework in education. Although she had completed a few undergraduate courses in earth science, she did not have extensive formal training in science or science teaching. Ms. Copeland had been teaching for more than ten years, mostly at the high school level, but had been assigned to the district's middle school for about 3 years. Her classroom was a social studies room containing no facilities for conducting laboratory activities. As a result, her opportunities to conduct laboratory activities were limited to those which did not require extensive equipment or materials.

Ms. Copeland was randomly assigned to the research group that received both training workshops and special teaching materials. She participated in two half-day workshops before teaching the photosynthesis and cellular respiration units. She received teaching materials designed by the researchers for use during the photosynthesis unit including unit goals, a student text and teacher's guide containing information and charts describing students' misconceptions and teaching strategies for overcoming them, and a set of transparencies posing explanation questions and, on overlays, scientific explanations for important photosynthesis concepts. In addition, she received information about students' misconceptions about cellular respiration as well as sheets of goals for the cellular respiration and matter cycling units.

Ms. Copeland's Daily Routine

The students entered Ms. Copeland's classroom in typical fashion, with lots of energy and chatter. They sat down and talked among themselves while Ms. Copeland checked attendance. The lesson described below was the second the photosynthesis unit. The first lesson in the sequence developed in the experimental photosynthesis text had raised the question "What is food?"

Ms. Copeland began with a short review of the previous day's topic:

> T: "We had a major breakthrough yesterday. We argued all day long....even as I tried to get my lunch! What do you think now, Staci?"

Staci, who had been thoroughly convinced that water was food for plants, commented

> "Now I'm convinced. The people I polled say you need food and water to survive....I asked my dad and he said food has to have calories so I believe that."

> T: "Does water have calories?" (several students respond "No!") Is water a food?"
> Staci: "No...but I think it <u>should</u> be a food...

> T: "Look at page four in your text. What they talk about here is <u>how</u> plants get food. Do they need it?"
> S1: Yes....

> T: Why?
> S1: To grow..

> T: Do We?
> S2: Yes

> T: Why?
> S2: to get energy to grow...

> T: Do plants and people get their food in the same way? Do plants have mouths? (one student mentions venus flytraps, an answer that Ms. Copeland ignores).

By this time most of the students had become silent and were looking puzzled by the question. Ms. Copeland pointed out that things "like plant foods and food sticks make it <u>sound</u> like a plant reaches out and munches food."

> T: Turn to the next page. Take a few minutes and write down <u>your</u> thoughts about how plants get their food.
>
> S4: Do we have to hand these in?
>
> T: No, but I want you to keep them....I want to see what progress you make with this...

After allowing the students to work for a few minutes, Ms. Copeland began another round of discussion by reminding the students that they had already decided that plants did need food. When she asked how food moved, the students described food entering through the bottom of the plants, from carbon dioxide in the air and from water in the soil. Ms. Copeland walked to the chalkboard and wrote "For <u>How</u> Plants Get Food" at the top of the board. As the students contributed their ideas, she listed them on the board. After a few minutes, the list included "soil, sunlight, rain, other plants, roots and leaves, and "themselves".

> T: Look at the list up there. If they get it from the soil, is it like there's little "big macs" in there?
>
> S5: It's minerals and nutrients....
>
> T: Do minerals supply energy?
>
> S2: Yah...things like potato peels in the soil gives it minerals..
>
> T: Do plants <u>make</u> the food or are minerals the food? Do minerals supply energy?
>
> S6: Sometimes...

T: Does that mean "just on some days...? Anybody think more on that one?

S7: If they supply energy, they'd be food, right? But wouldn't that be the same as saying water is food?

T: How many calories in minerals? Is food for plants the same as food for people? If that were true, all you'd have to do is give them minerals...

Ms. Copeland spent most of the remaining class time addressing each item on the list in much the same manner, first asking the students to think about their definition of food and decide if the item was or was not food, and to think about how the plant might "eat" it.

After finishing discussing the list, Ms. Copeland asked if any of the items were really food for the plants. A few individuals still insisted that some were: others made comments like "I'm confused...where are we?" One student volunteered "All that stuff just <u>helps</u> the plant make its food." Ms. Copeland repeated the statement, emphasizing the word "help" and "make", then repeated the original question about the plant:

T: Where does it get its food?"

S: (several call out) "they make it."

T: Think about that! You make spaghetti, right? You <u>need</u> a spoon, stove, pans... Are any of these things food? No! Let's look at the board again. We'll call all these things "Helpers."

She wrote "Helpers" on the board next to the list of students' responses and commented that "In the next section they describe a couple of experiments. Hopefully that will help explain this better."

The lesson described above was typical of Ms. Copeland's daily instruction. She spent the majority of time engaged in very energetic discussions with students. The tone of her conversation was usually a good-natured blend of sarcasm, teasing, and laughter (sort of a mixture of Joan Rivers, Rodney Dangerfield and Bozo the Clown...). She often repeated students' statements with a look that suggested "I can't believe you actually tried to tell me that...." Underlying her sarcasm, though, was a warm sensitivity to students as individuals; nobody was singled out or embarrassed by her comments. The students seemed very comfortable with her style and contributed freely (and often chaotically) to the discussion. Throughout the confusion, she encouraged students to think about their answers and relate them to things that they had read or discussed. The discussions were often chaotic, but they addressed important issues in a format that encouraged students to express their thoughts about important unit questions.

Ms. Copeland used many examples and analogies similar to the "Big Mac" and "spaghetti" throughout all three units. For example, in the cellular respiration unit she invented the "blood bus" to get the students to think about food and oxygen being transported to cells through the circulatory system. In the matter cycling unit, she used names like "Fu-Fu" and "Thumper" to refer to consumers and "Bertha Bacteria" to refer to decomposers. The students in turn used the names in describing examples of food webs and in explaining questions asked in class. An "internal vocabulary" developed that both the students and Ms. Copeland often used instead of appropriate scientific terms. She commented that

> "the students liked the "crazy weird way of doing things but that they understood!....they really did, and they could explain how those things were related because they knew what each one's function was."

Thus, for Ms. Copeland, the issue was not vocabulary or definitions or using terms. Her purpose was to help students find ways to understand important relationships among producers, consumers, and decomposers.

Ms. Copeland's Beliefs About Students' Learning Processes

Ms. Copeland's beliefs about students' learning processes reflected the beliefs typical of the conceptual development orientation: She regarded her students as actively interpreting or making sense of instruction. Learning was an interactive process in which the students changed their thinking about important science concepts as they constructed new knowledge through discussions and classroom activities where they applied new ideas.. Application exercises and explanation questions helped internalize important concepts and restructure important relationships with other knowledge. Understanding developed as students become more adept at using important concepts to explain scientific phenomena.

Another important characteristic of the conceptual development orientation was illustrated by Ms. Copeland's knowledge of the nature of her students' scientific thinking. She was very much aware of her students' thinking about photosynthesis, respiration, and matter cycling. She could predict students' responses to our test questions and relate them to their thinking (although her predictions for students' success in answering the questions after instruction were somewhat higher than those of the other teachers taking this orientation).

The major inconsistency between Ms. Copeland's beliefs about students' learning processes and the beliefs characteristic of this orientation was her reasoning about students' failure to learn. She attributed students' inability to respond to the questions primarily as a problem in communication rather than a problem in understanding the content. She cited communication skills more than twice as often as any other cause for students' failure to correctly answer the test questions:

> "You have to look realistically at how often we really ask them to explain anything completely. That's a skill that has nothing to do with learning science."
>
> "They can't write it down as to what you want them to say...they know it in their heads but they can't write it down."
>
> The other reasons Ms. Copeland cited for students' failure to learn generally focused on their thinking, including confusion between everyday ideas and scientific explanations, the absence of changes in students' thinking, and writing "non-answers." For example, in the respiration interview she noted that
>
> "They get confused....and so they go back to what they know best ... they haven't worked through it yet.."
>
> "They still haven't gotten away from the idea that respiration is just breathing...after awhile some, maybe most, will get to the point where they can explain more about the cell part..."

Her response to the same question in the matter cycling interview illustrated both the presence of misconceptions as well as writing non-answers:

> "They just repeat what's in the question...it takes a long time to get them over the non-answer stuff where they write that or whatever they've been told since they were two years old..."

However, Ms. Copeland's comments suggest that the issue she called communication was not merely students' ability to comprehend a question, write a sentence or use appropriate grammar; the issue was more their inability to formulate an explanation. She was sensitive to differences between the explanations her students could provide during discussion and the explanations they were able to write without any prompting.

Ms. Copeland's consistent emphasis on resources containing information about students' thinking such as charts of goal and naive conceptions contained in the Middle School Science Project materials, information from workshops, and the student text illustrated another important characteristic of the conceptual development orientation. She described the chart of goal and naive conceptions in the photosynthesis teacher's guide as important because it helped her understand how students think and provided material to use in discussions:

> "I can gain a lot from seeing those and thinking, o.k. here are some things that I can anticipate and head off."
>
> "So that in my discussion of them I can say so does that mean... whatever the naive conception is. And they'll say no, no... and I know they've got it and if they say yeah..right, then I know we've got a problem."
>
> "the kids like it...I like it..it (the photosynthesis text) was good for discussion since the questions and alternative ideas were right there for them as they read...plus they didn't need any incentive to keep working on it...they just wanted to keep on going..."

Ms. Copeland consistently emphasized discussion as the teaching strategy most important to help students learn the unit concepts. She described discussions of a few central questions as important to focus students' attention on the most important issues, provide her with opportunities to monitor students' thinking, and to challenge them to "think things through and explain why." In the respiration interview, for example, she commented that

> "I kept coming back to those three questions...Why a person dies when their heart stops?...Why do we eat?...Why do we breathe?...especially the first one because they would say "so what? And I kept after them until they could tell me "so what?" And they really had to know the information in these other things to be able to tell me and keep me from badgering them

about why. But if I had not asked them that question, I think they would have just memorized...they would have been able to identify the right words in the right places on the test and not have understood a thing...not understood what this had to do with them or living things or life functions at all."

She viewed the application activities as opportunities for students to practice using new concepts to develop their understanding of important unit themes by explaining real world phenomena:

"they make the kids apply what they have learned about and figure things out rather than just copy stuff down from the book."

"they had to work things through and use what they know about the functions of those things in order to work them out...that's applying all the other stuff."

Ms. Copeland did not emphasize testing her students. She noted that she gave tests primarily because the students had to have grades reported and that the tests were one more chance to express their ideas:

"they need to have some grades and to get a chance to explain some more things. I put in some essays for that..."

She weighted homework assignments and quizzes to make sure that no one thing was too important. Her emphasis on explanations and application activities was still evident in these procedures, though, because those activities were graded for content accuracy, while activities involving vocabulary and definitions were used primarily for discussion and were graded only for completeness.

Ms. Copeland's Role in Promoting Students' Learning

"I'm crazy. I'm not afraid to be crazy. We have a teacher who teaches a ninth grade science class and he gets up on the table and talks to them. He does crazy things too, but the kids love it and they learn and his students do better than anyone else's. But it takes a tremendous amount of energy and willingness...I guess it's your concept of teaching, what you think your job is, and some people come into the job thinking that teachers stay in front of the room and lecture and the room is always quiet and it's always disciplined and all those expectations...those kids do need to learn those things also, but the teachers as people are afraid to be wrong, to be silly, to use imagination..."

The comment above was one of several similar remarks made by Ms. Copeland during all three interviews. It was a reflection of both her view of what teaching was...and was not. She contrasted her view of teaching and learning with

> "teachers who lecture then have them spit it back at you...they see themselves as dispensers of information...their whole expectation of "to know" is a lot different. If the kid can spit it back at you on the test on Monday, then he knows it--NO! I don't think he knows it at all..."

Ms. Copeland's discussion about her role as a teacher clearly illustrates the beliefs about the teachers' role in promoting learning that characterized the conceptual development orientation. Ms. Copeland clearly believed that it was important to be actively promoting students' learning by using teaching strategies that encouraged them to think about important ideas. She clearly did not perceive learning as accumulating information -- or her role as the dispenser of information!

Ms. Copeland's role in promoting student learning of science content focused on two important issues: a) identifying important curricular themes; and b) using teaching strategies that enabled her to monitor students' understanding of important concepts and help them develop more scientifically appropriate ways of thinking about the world.

Identifying important curricular themes. Ms. Copeland often commented that she felt it more important for the students to "learn a few things really well rather than a lot of things not so well." In discussing students' failure to learn, she noted that

> "I have to make some judgments...I feel that if, at the end, they have a good understanding of photosynthesis and respiration and how those things are inter-related to each other, then WHEW!...if they can also understand organic and inorganic, then fine, wonderful....I just try to identify some very basic concepts for them..."

Her curricular goals reflected another important characteristic of the conceptual development orientation: They were very student-oriented. Rather than simply identifying important content and teaching she was concerned with getting students to change their thinking in ways that moved them to a more scientifically appropriate understanding of the themes. It wasn't critical that the students mastered all the details as long as they changed their thinking in a direction she considered appropriate.

Ms. Copeland's concern for identifying a few important concepts in each unit was clearly evident in her teaching. She emphasized a few central questions in each unit, and kept emphasizing them rather than continually adding new information. For example, in the vignette presented above she spent an entire class just introducing the question of where plants get their food. She had the students write down their ideas, collected different individual's answers, then discussed the responses in detail, probing students' answers to get them to clarify their thinking. She could have simply defined photosynthesis or told the students that plants make their own food and gone on to the next topic, but instead she kept coming back to the question and making the students think about it.

In discussing important planning and teaching resources, Ms. Copeland consistently identified the tables of unit goals as important "because they gave me an idea of where things were headed and I could think about how things related to other topics." However, she did not just teach the goals as they were presented. She actively interpreted and modified them to reflect her perceptions of important goals for her students which also fit into the curriculum. In discussing the respiration goals, she noted that

> "As far as respiration goes, I just sort of determined some for myself based on your goals and trying to fit things into my real class and on their real function out there and all that good stuff...so I may not have done all the goals that you have established or may have done some different ones..."

This example was particularly interesting because Ms. Copeland had not taught cellular respiration in previous years. Although she had every opportunity to simply address the goals suggested in the unit outline, she invested considerable time and effort to decide which goals best met the needs of her students and could be successfully addressed within the constraints of the classroom.

In discussing important teaching strategies, Ms. Copeland's emphasis on discussion of a few central questions provided further evidence of her concern for important themes rather than information and vocabulary. Throughout the interviews, she seldom mentioned vocabulary or definitions in isolation from their application to some phenomena. For example, during the matter cycling interview, she noted that

> "some things like producers or consumers were important, because the kids had to know what they were to do the food web stuff."

Thus, although some terms and vocabulary were considered important, they were important because the students needed to use them for some purpose; they were not important to know just as definitions.

Monitoring students' thinking. A fundamental characteristic of the conceptual development orientation was illustrated by Ms. Copeland's emphasis on continually assessing students' their thinking and using teaching strategies to help them develop more appropriate ways of thinking about the real world.

During instruction, Ms. Copeland consistently engaged in activities that provided her with information about her students' thinking. She posed important questions as conceptual advance organizers and used various discussion strategies (such as the listing activity in the vignette) to elicit students' ideas. She emphasized activities in which students wrote down their ideas or applied new concepts to explain real world phenomena. Graded assignments and quizzes included application problems and essays which provided students with opportunities to explain ideas rather than just recall information. Thus, most of Ms. Copeland's instruction addressed the nature of her students' thinking.

In discussing planning and teaching resources, Ms. Copeland emphasized resources such as charts of goal and naive conceptions or information about students' responses to test questions, resources that provided her with information about students' thinking and enabled her to better anticipate their misconceptions about photosynthesis, respiration, and matter cycling. The teaching activities she identified as most important for helping students learn were those which included discussions and opportunities to help students relate new ideas to the real world. Her preference for discussions and application activities rather than recall of information further illustrate her concern for monitoring students' thinking.

Interactions Among Knowledge and Beliefs, Perceptions of Important Information, and Information-gathering Strategies.

The interview tasks provided detailed evidence regarding the nature of Ms. Copeland's knowledge and beliefs about students' learning processes, her role in promoting learning, the information she judged as important, and the information-gathering strategies she considered important for promoting student learning. Her responses clearly illustrated the concerns characteristic of the conceptual development teachers. However, the interactions among these components were not directly addressed by any tasks. The following model is thus a theoretical or interpretive model rather than a descriptive account of the manner in which the components interacted to influence her ability to learn from experience.

Ms. Copeland had clearly developed much detailed knowledge about her students' thinking about science concepts. Nothing in her background suggested that she could possibly have developed it any other way than through experience. How had her beliefs about student learning developed?

Ms. Copeland's beliefs about students' learning were generally consistent with the model of conceptual change learning proposed by Posner, Strike, Hewson, & Gertzog, 1982). She felt it important for students to change their thinking about real world phenomena, and that students needed to apply new ideas to everyday phenomena. In addition, she believed her role to be one of facilitating those changes, rather than providing her students with information. These beliefs lead her to regard information about students' thinking as important and relevant to her teaching.

The discussion and application activities she commonly incorporated into her teaching were consistent with her beliefs and judgments, because these activities generated information from students that she perceived as important. Other strategies such as lectures, or defining vocabulary terms, or watching movies would not have provided that information. Thus, her judgments about important information and her beliefs about teaching and learning influenced her to emphasize those teaching strategies which provided her with information about her students' thinking. By comparing information obtained from students with her existing knowledge of students' potential difficulties, Ms. Copeland could monitor her students' thinking and provide them with appropriate feedback.

The interaction among Ms. Copeland's knowledge and beliefs, her judgments of important information, and the teaching behaviors she used to obtain important information formed a self-reinforcing belief system. Ms. Copeland's knowledge and beliefs about students' learning and her judgments about what information was important lead her to use specific teaching strategies that provided her with information about her students' thinking. The information she gathered was consistent with her beliefs about learning and teaching and could be evaluated successfully using her existing knowledge. Thus, the feedback she received reinforced her beliefs while enabling her to develop knowledge of students' thinking.

An important aspect of this system was that it functioned as an open loop. The interactions among knowledge and beliefs, judgments of important information, and information-gathering strategies were such that each component continued to change over time, while reinforcing the nature of the interactions among components. As a result, Ms. Copeland's knowledge of her students and her judgments of important teaching strategies evolved as she gained experience.

Summary

The case study of Ms. Copeland illustrated the teaching behaviors, beliefs about students' learning processes, and beliefs about the teacher's role in promoting learning characteristic of the conceptual development orientation. The other teachers reflecting this orientation demonstrated knowledge and beliefs were not identical to those of Ms. Copeland; there was considerable variation in the teachers' knowledge of science content, management style, concern for grading, and in their ability to put into practice those ideas they described as important. The issues they considered important, students' learning and development, involvement, were similar to those of junior high teachers (Munby, 1983) and in some cases were similar to the categories of practical knowledge described by Elbaz (1981), in many respects were different from the subject matter specialists described by Good and Brophy (1978).

The paragraphs below summarize characteristics of the conceptual development orientation with respect to the issues described at the beginning of this chapter.

The nature of learning. Although the teachers reflecting the conceptual development orientation seldom used the language of conceptual change, they typically described students' learning in terms of changes in their thinking as a result of instruction or other experiences. Thus, learning was not confined to the assimilation of facts or new concepts, but also involved accommodation (Posner, Strike, Hewson, & Gertzog, 1982) in which students' developed new knowledge as they changed their thinking about everyday events.

Although Ms. Copeland regarded students' inability to respond to questions as a problem in communication, the conceptual development orientation emphasized students' failure to learn as a function of their existing knowledge, including specific misconceptions, failure to perceive important parts of a problem, or lack of important background experiences rather than the difficulty of the material, the students' innate abilities, or lack of interest. The teachers utilizing this orientation acknowledged that variables such as difficulty of the material, students' motivation, or ability influenced learning, however they did not describe them as the primary determinants of students' success or failure.

<u>Nature of science curriculum goals</u>. The conceptual development orientation was characterized by student-oriented curricular goals. The teachers reflecting this orientation identified important disciplinary themes and worked to help students change their thinking towards (but not necessarily mastering) a scientifically appropriate understanding of them. Thus, their goals emphasized shifting students' thinking rather than development or mastery of of detailed knowledge.

<u>Nature of important teaching strategies</u>. Ms. Copeland's emphasis on discussion, use of many examples, extensive probing of students' responses to questions and including written assignments were typical of the teaching strategies found within the conceptual development orientation. While not all of the teachers utilizing this approach exhibited Ms.

Copeland's zaniness, they consistently emphasized two-way communication such as discussions, asking and answering questions, and assessing students' thinking throughout the course of lessons. They actively defined and communicated important concepts to their students, demonstrated appropriate ways of thinking about scientific phenomena, related important concepts to the real world, and monitored students' understanding of important themes. These strategies reflected several important components associated with conceptual change learning (Strike & Posner, 1983).

Although the teachers working within the conceptual development orientation had developed knowledge of their students' misconceptions, they generally did not perceive them as critical barriers to students' understanding of important concepts (Anderson & Smith, 1986). As a result, they did not emphasize teaching strategies which would have helped students become aware of their own thinking. Thus, an important aspect of successful conceptual change instruction (Minstrell, 1984; Strike & Posner, 1983) was missing from their beliefs and their teaching.

The Content Understanding Orientation

The teachers reflecting the content understanding orientation emphasized learning as a process of assimilation in which students integrated new concepts and information into existing knowledge. The curricular goals characteristic of this orientation were content-oriented: they emphasized students' understanding of an integrated body of knowledge describing the structure and function of the natural world. Teachers adopting this orientation tended to ask questions and engage in teaching activities which enabled them to communicate important content and monitor students' acquisition of it. These strategies also provided them with information that enabled them to develop some understanding of their students' scientific thinking. However, information about students' thinking per se was not regarded as especially important. As a result, teachers whose thinking reflected this orientation developed knowledge about their students' thinking, but did not consider it as any more important than other sources of information in making curricular and instructional decisions.

The following case study of Mr. Barnes illustrates the beliefs about teaching and learning typical of the content understanding orientation. His responses to the interview tasks and teaching strategies consistently reflected the "learning as assimilation of content" perspective. He was clearly concerned with individuals' learning of important science content, however he viewed learning primarily as a process in which students acquired new ideas in much the same form as they were taught. He was aware of many of his students' misconceptions, but did not regard them as particularly important factors influencing learning.

Mr. Barnes

Mr. Barnes was an experienced science teacher who had earned a B.S. in biology and had completed extensive graduate course-work. He had taught for 13 years in the same school system, including 10 years at the high school before moving to the middle school to teach 7th grade life science, serve as the computer coordinator and coach basketball and track.

Mr. Barnes was randomly assigned to the experimental group which received only materials. For the photosynthesis and respiration units, he was provided with student texts and teacher's guides containing information about students' misconceptions as well as strategies for helping them change their thinking, and transparencies which presented prediction/explanation questions designed to contrast students' misconceptions with scientifically appropriate conceptions. He also received written goals for all three units. He was not provided with any instructions regarding appropriate ways to use the materials beyond those contained in the teachers guide, but was encouraged to examine the materials and incorporate them into his teaching in any way he felt appropriate.

A Typical Class

When the bell rang at 9:00 a.m., the students entered Mr. Barnes' room in an orderly fashion, talking quietly to each other or to Mr. Barnes. Most went immediately to their seats and got out their materials for the days' lesson. Although the talk was about sports or other school activities, the noise level was quite low. Mr. Barnes never had to mention anything about behavior to the students; they all seemed to know what was expected of them and went about their business.

After the bell, Mr. Barnes made a few announcements about school activities, then began the lesson with a reminder about the day's assignment. After checking to see if anyone had trouble answering the questions, he spent about 20 minutes discussing them with the class. The following exchange was typical of Mr. Barnes' discussion style:

T: (Opening the text to the page with the questions) Respiration has something to do with breathing and also getting energy from food and oxygen in cells. In chapter two it talks about people and respiration. Can you get energy from water?

S1: No..

T: Why can't you?

S1: because it only has hydrogen and oxygen.

T: Did you all have that? (most students raise a hand in response) Can you get energy from vitamins? (a few say yes, most say no). Why not?

S2: It doesn't contain energy...

T: What do they give us?

S3: extra nutrients?

At this point, Mr. Barnes spent about two minutes describing the properties of vitamins, referring to them as catalysts or cofactors that helped the chemical reactions that release energy. He pointed out that "we need them, but they don't give us energy."

The other text questions were addressed in similar fashion. Mr. Barnes asked a student to answer the question, then checked to see how many other students agreed with that answer. In each case, he asked at least one follow-up question, encouraging several different students to respond, after which he summarized the point of the question.

In two instances, he mentioned different ways that "a lot of people used to think" as he provided students with correct answers.

After the last question was discussed, Mr. Barnes read the definition of food on page 5, and emphasized it as an important definition. When he asked "Does all living things include plants?" most students nodded their heads in agreement. "So plants not only make their food, they also use it. Remember from here on that <u>all living things</u> use food."

Mr. Barnes quickly repeated the questions about water, vitamins, and exercise as examples of food and checked to see how many students needed to change answers. He asked another question about why people need to eat. When a student responded that food was needed to get energy, Mr. Barnes commented that that other things like water and vitamins were needed for proper functioning of the body, but that the other substances didn't provide energy.

At this point the focus of the class shifted from students answering questions about the definition of food to a lecture about the processes by which food entered the body, was digested, and then distributed to the cells. Mr. Barnes turned on the overhead projector and showed a transparency illustrating the path taken by food as it entered the body and was transported to a brain cell. He spent the next 20 minutes describing the digestive process in great detail, including information about how food was broken into smaller and smaller pieces by gastric juices, entered the small intestine where sugars diffused into the blood stream and were carried to the liver to be converted to glucose for immediate use or storage as starch (his description...). He interrupted the lecture to describe the "pinch test" and fat storage, then described the movement of glucose to the cells of the body followed by diffusion into each cell (with another break in the action to define diffusion) where the glucose was used to supply energy.

The detailed lecture continued until almost 9:40, during which Mr. Barnes described the passage of waste products through the blood to the kidneys, skin, and lungs, and the production of urea (and its use as a fertilizer but not as an energy source). He concluded the lecture by briefly summarizing major points listed in the text, commenting "That shows what happens to the food, but we also need oxygen." He changed the digestive system transparency for one illustrating the movement of oxygen to the brain and briefly described how oxygen entered the blood stream and eventually diffused into each cell.

By this time, class had almost ended. Mr. Barnes assigned chapter three to be read as homework and described the next day's lesson as a session with "our friend the torso model. Any questions?"

During the lecture, the students were mostly silent. From 9:15 until 9:45 (the end of class) Mr. Barnes asked only two questions about the products of cellular respiration. Although the students occasionally wrote a few notes in their texts (which were consumable materials....), they spent most of the time listening.

The lesson described above was typical of the way that Mr. Barnes conducted his class. In later lessons, he presented the function of the circulatory system and respiratory system in similar detail. Lessons not involving some sort of lab activity were usually divided into two parts: short question-answer sessions during which the students were actively involved and spent much time responding to Mr. Barnes' questions, and "mini-lectures" in which the students sat quietly and listened to Mr. Barnes lecturing or watched filmstrips or movies. Discussions usually took place at the start of class, but sometimes occurred after Mr. Barnes presented some new material. In some instances, there were several rounds of discussion and mini-lecture in a single class.

Mr. Barnes' Beliefs About Students' Learning Processes

Mr. Barnes' beliefs about students' learning processes reflected the assimilative view off learning (Posner, Strike, Hewson, & Gertzog, 1982) characteristic of the content understanding orientation. He viewed his students' as "processors of information" who received information during instruction and manipulated it. Learning was a "knowledge-building" process in which students' assimilated new concepts into their existing knowledge. Clear communication of important information to the students during instruction was necessary in order for students to understand new ideas. Repetition and practice using new information in a variety of different contexts ensured that new concepts were internalized. Individuals possessed different learning styles, including "oral", "visual", or "tactile, requiring much hands-on experience." Effective learning depended on information being communicated to each student in a manner best suited to his/her learning style.

Mr. Barnes' beliefs about the importance of students' misconceptions reflected another important characteristic of the content understanding orientation. He was clearly aware of many of his students' misconceptions about photosynthesis, respiration, and matter cycling. In discussing their incorrect responses to the diagnostic test questions, Mr. Barnes was able to describe what students were thinking that caused them to respond as they did. However, he attributed their incorrect responses to to a variety of causes besides the presence of misconceptions, including the abstract nature of the concepts, the lack of necessary background information (his rationale for including the detailed lecture about digestion), and their inability to deal with problems involving more than a few steps. For example, in discussing students' incorrect responses to a question about the products of cellular respiration, Mr. Barnes commented that

> "...well that's the other 40%. Some of the kids have difficulty relating to abstract things here, and I think that that this unit caused some problems because they couldn't see it, respiration was always breathing to them and they couldn't see the stuff being produced.
>
> I: "Did it end up with some of them still believing that respiration was breathing?"
>
> M.B: "I had some of them saying that down to the bitter end! They still didn't get it. I think its the number of steps along the way, too. You get beyond two or three in sequential thinking, kids, they lose it and go back to the use that they feel is real."

During the matter cycling interview, he noted that

> "After 4-5 years of teaching something, I can predict what they're going to be stuck on, and I plan to cover that thing again because I know they're going to be hung up on it..."

In discussing the charts of goal and naive conceptions in the respiration teacher's guides, he commented

> "I thought a lot of it was obvious things that I would do any way....it looked like a survey had been done with a lot of teachers who came up with the shortcomings that students had had....I kind of know what kinds of mistakes the students are going to make and a lot of times I tell them and I say here is what eighth graders are going to do wrong to begin with."

Thus, although Mr. Barnes had developed knowledge about his students' thinking, he used that knowledge primarily to define areas that needed to be covered with extra care during instruction. He did not regard students' existing knowledge as presenting significant barriers to their learning (Anderson & Smith, 1984).

During instruction, Mr. Barnes occasionally referred to the existence of alternate views, using comments such as "some people used to think that....." or "some of you might believe that....." He had his students complete text activities in the experimental photosynthesis and respiration texts in which students compared pre-instruction and post-instruction responses to questions, but did not emphasize changes in students' thinking during discussions of the activities. Instead, he checked only to see that students corrected their mistakes and wrote the proper responses in their texts. Thus, although Mr. Barnes was aware of the nature of his students' thinking about important science concepts and the fact that many had failed to change their thinking during instruction, he generally regarded students' misconceptions as gaps in their knowledge, but no more important than any other factors.

Mr. Barnes' judgments about important teaching resources further illustrate the role of students' thinking characteristic of the content understanding orientation. He emphasized materials and text features which required the students to engage in reasoning about phenomena or apply concepts to some everyday event. He described the photosynthesis and respiration texts as useful because

> "they focused on the kids' thinking and reasoning ....to get them to think logically about processes."

During the matter cycling interview, he again referred to information processing as an important goal:

> "I would not feel bad as a teacher if they mostly learned how to organize themselves and process information better."

Thus, "information processing" as used by Mr. Barnes seemed to mean learning to organize and remember new information and to become more independent learners.

In discussing important planning and teaching resources, Mr. Barnes emphasized materials which communicated content to students in a clear, unambiguous manner as important influences on students' learning. In discussing his planning procedures for the respiration unit, he described reading through the materials in advance:

> "I try to anticipate their difficulties...to imagine where they might be confused..or where I would be confused if I were them..."

Thus, the resources he judged to be important included features that enabled the students to extract information from them with minimal chance for confusion.

An important characteristic of both the nature of learning and the role of the teacher for the content understanding orientation was illustrated by Mr. Barnes' discussion of important teaching strategies. He identified clear lectures, repetition, questioning, and discussion activities as important for students' learning more often than any other activity. He described these activities as important opportunities for the students to hear other ideas and to practice and develop their own understanding of new information:

"If I can get them to ask questions, I know that they are focused on what's going on....if I could ask or have them asking questions all the time. I think they would learn more".

"Answering kids' questions and asking kids question helps to find out where their head was on a given area. Maybe I should call those discussions afterwards. That's the only way I can get at where they are at, given the time constraint.

In discussing his emphasis on lectures, he noted that

about the material and using illustrations helps make the material more meaningful to them, and I try to see what kids are interested in that this would apply to."

During the respiration interview, Mr. Barnes discussed what he called the "teachable moment" as the most important strategy influencing students' learning. He described the teachable moment as a time when the students were particularly ready to learn:

"....and I do try to stimulate them to ask questions if they don't understand a particular thing. And if they don't understand something, or are not sure about something I would really focus in on that and try to give them-that's what I call the teachable moment.. and to me the teachable moment is more valuable than anything else because that's what they're interested in at the time and they are ready to focus in on that particular item....if I can stimulate them to ask questions, I know they are focused on what's going on."

Similar discussions took place in the other interviews, where Mr. Barnes emphasized "finding out about kids ideas" and "having them hear different perspectives and explanations". Thus, Mr. Barnes regarded questions and discussions as a way for the students to develop their understanding of important concepts, while enabling him to monitor their understanding and interest in a particular topic.

During all the post-interviews, Mr. Barnes consistently identified repetition and practice as important strategies for helping students to learn. He typically described repetition as "useful to get kids to better understand the material by programming the information into them"..."4 or 5 repetitions help the average kid, although the brighter ones need less..."

The importance of practice and repetition was also evident in Mr. Barnes' daily lessons and the organization of units. During the respiration unit, for example, the students were assigned chapters one and two (introducing respiration and the nature of food as the only energy source for people) and the questions as homework for day one. On day two, the questions were discussed in class, followed by a lecture about the digestive system and its role in supplying food to cells, and a brief discussion of the movement of oxygen into the body. On day three, the notion of food was reviewed again, followed by a discussion of the digestive and circulatory systems using a model of the human torso. In each case, the appropriate chapter and associated questions in the student text were assigned in advance without any discussion beyond a brief identification of the next topic. The pattern of reading in advance followed by discussion of questions, lecture to supplement the text accompanied by further review was continued throughout the unit. Thus, important issues were addressed at least three times during the unit.

<u>Mr. Barnes' Role in Promoting Student Learning</u>

Within the content understanding orientation, the teachers' role emphasized strategies that helped students to efficiently acquire the necessary information presented during instruction. This was clearly illustrate by Mr. Barnes' emphasis on helping his students become better learners or "processors of information" rather than just helping them learn science content. When asked to identify diagnostic test questions important for students to be able to answer, he raised the philosophical issue of "important for what?" For him, it was important to consider the larger purposes of schooling as well as the issues related to learning science content. In discussing our goals for the units and identifying questions that he felt students should be able to answer, he talked at length about his role as a teacher and his goals for his students, emphasizing the distinction between larger learning goals and more content-specific objectives:

> "For what purpose...Do you mean what is most important for them in their daily lives...or when they're adults...or just for this unit?"
>
> "My goal is to teach them to work...science concepts are less important than learning to be organized."
>
> "If they can learn to process information and get themselves organized at a time when they are changing in so many other ways....."
>
> "I'd rather turn them on to science than just fill their heads with a bunch of data....."

Thus, one important aspect of Mr. Barnes' role involved helping the students to become better organized, more proficient learners.

Mr. Barnes emphasis on helping students develop organizational and learning skills was also reflected in his classroom management. Students were rarely off-task (at least visibly), began working immediately after directions were given, and usually worked independently without any further reminders. During one class, for example, the students spent most of the period doing a lab activity involving running (in place...) and jumping to investigate the effects of exercise on carbon dioxide production. Throughout the entire class period, the noise level never increased to the point where quiet conversation became difficult. The students worked independently and purposefully until Mr. Barnes reminded them it was time to clean up.

Mr. Barnes' beliefs about his role in helping students learn important science concepts were similar to the "subject matter experts" (Good & Brophy,1978, 1980). They focused on three issues: a) identifying appropriate content for students with differing abilities and learning styles, b) clearly communicating important information to the students using a variety of formats, and c) monitoring their understanding of new information and important concepts. These issues formed the basis for describing the role of the teacher within the content understanding orientation.

Mr. Barnes spent considerable planning time identifying resources which he felt contained important information or illustrated important concepts for the students. In describing important planning and teaching resources, he often referred to student texts as important because they identified important information and vocabulary and provided him with "some sense of the direction the students should be headed". However, he also used old college texts as references to "refresh my memory and think about important ideas." In addition, he evaluated transparencies, movies, and other resources in terms of their information content as well as their ability to stimulate students' interest and provide some variety. Thus, although Mr. Barnes relied on texts as guides for identifying important content for students to learn, he also made conscious decisions to alter that content based on his own background, decisions which ultimately determined the enacted science curriculum.

Mr. Barnes' concern for clear communication was evident in his choices of important teaching resources. He described a lengthy effort to convince the district to adapt a different science text:

> "That the students could read and understand "... not the 11th grade reading level book they had been using. It was no wonder the students' reading scores were low..."

Mr. Barnes also related the use of a variety of resources to differences in students' learning styles. He referred to individual differences in terms of the ways that students received information:

> "I don't think all kids learn the same way...some learn visually, some orally, some tactilly or by touch, and some by doing things ...multimedia affects kid a lot"

During the matter cycling interview, he commented that transparencies were especially useful because

> "the kids get the information visually...a lot of students are visually able to process information better than hearing...they'd have something to key on while I was talking, so while I was orally presenting information, there was also something visual that they could refer to..."

Thus, he felt it important to use a variety of different methods to expose students to important information both for repetition and clarification as well as to accommodate students' individual learning styles.

The third aspect of Mr. Barnes' role included monitoring students' understanding of important information. Mr. Barnes felt it important to closely monitor whether or not students remembered and understood new information. He adjusted his expectations to account for individual differences in ability, noting that

> "The more general concepts are more important than the more technical. It's less important for them to understand things in that much detail"

> "I don't think as a teacher that I should expect all the students to understand all of the concepts"

Mr. Barnes relied heavily on his interpretations of students' responses to questions and their participation in class discussion to monitor their understanding of the more general themes in each of the units. He compared their responses in discussions to the types of responses they would provide on an essay exam:

> ....I'm hoping from the discussions that I can hear some of their ideas that I would hear if I gave an essay question."

Tests were described as as opportunities for the students to demonstrate their knowledge and as extra practice in using important information:

> "I hope that they can read the particular question, can use the information that they've programmed into their head, and can develop an accurate idea about it..."

Although he stressed the importance of understanding the more general concepts or themes, the written tests primarily measured students' knowledge of terms and definitions presented during the unit. For example, the test given at the end of the respiration unit contained 55 items arranged in multiple choice, true-false, and fill-in-the-blank format. The test never required the students to explain any important concepts or apply cellular respiration concepts to explain the function of some living thing. Many of the questions addressed details of the digestive, circulatory, and respiratory systems which were not directly related to the process of cellular respiration.

Interactions Among Knowledge and Beliefs, Perceptions of Important Information, and Information-gathering Strategies

Mr. Barnes' beliefs about teaching and learning were similar to Ms. Copeland's in many respects. Both teachers were clearly concerned with students' learning of important science concepts. Unlike Ms. Copeland, who perceived learning as a process in which students had to change their thinking, Mr. Barnes regarded learning primarily as a process of assimilation in which students added new information and concepts to their store of existing knowledge and learned to use knowledge more effectively rather than changing their thinking about important disciplinary themes.

Like Ms. Copeland, Mr. Barnes' beliefs about teaching and learning and his judgments about important information formed a system of self-reinforcing beliefs. Unlike Ms. Copeland, his beliefs that students' learning was an additive process lead him to perceive information about students' interests and acquisition of new information and concepts as important and to regard his lectures and question-asking as important teaching strategies. The students' responses to the questions provided information about their interests and understanding that were consistent with his existing knowledge and perceptions. These same strategies also provided him with information about their misconceptions, information he had used to develop considerable knowledge about the nature of the students' scientific thinking (Hollon & Anderson, 1986). However, his beliefs about students' learning processes emphasized adding new knowledge about the world to students' existing knowledge. Thus, he perceived students' misconceptions as gaps in their understanding rather than an alternate way of thinking.

Mr. Barnes regarded information about his students' thinking as useful to monitor their acquisition of new knowledge or to identify interesting topics, however information about student thinking per se was not considered important. Thus, Mr. Barnes' judgments about the nature of important information were consistent with his beliefs about student learning and his own role. The information he regarded as important enabled him to monitor how much students understood about the structure and function of living organisms, and provided an indication of how well they were processing information he was providing to them.

<u>Summary</u>

The case study of Mr. Barnes illustrated a set of beliefs about teaching and learning that characterized the content understanding orientation. In many ways, his beliefs appeared similar to those of teachers functioning from conceptual development orientation. However, Mr. Barnes' perspectives differed from those teachers in some very significant ways. The differences between the conceptual development and content understanding orientations with respect to the issues identified in chapter three are summarized below through comparisons of Ms. Copeland's and Mr. Barnes' knowledge and beliefs.

<u>The nature of learning</u>. In contrast to the conceptual development orientation. Mr. Barnes' beliefs about learning emphasized assimilation (Strike & Posner, 1978). Thus, learning was a process in which students developed knowledge by adding new information to their existing knowledge base, a process not requiring fundamental changes in their thinking.

Failure to learn was accounted for by several mechanisms including misconceptions, difficulty of the concepts, inadequate instruction, problem-solving requirements, and lack of prerequisite knowledge. Mr. Barnes did not regard students' misconceptions as any more important than a variety of other factors, but regarded them more as gaps in their knowledge base which needed filling. In contrast, Ms. Copeland emphasized students' misconceptions as a primary cause of their failure to understand important concepts combined with their inability to communicate their knowledge to others.

Nature of curricular goals. Unlike Ms. Copeland, who emphasized getting students to shift their thinking about a few important disciplinary themes, Mr. Barnes' curricular goals were content-oriented, emphasizing students' increasing their understanding of a story containing integrated knowledge about the structure and function of the world. The students' task was to develop some understanding of the major ideas present in the story, combined with a few specific facts about the various characters. The goals were more like the subject matter specialists typical of high school teaching (Brophy, 1983; Good & Brophy, 1978) however, Mr. Barnes also had much training and experience as a high school teacher thus the similarities were not surprising.

Nature of important teaching strategies. Mr. Barnes emphasized teaching strategies such as lectures, clear presentations, repetition, and grading assignments as important strategies. These strategies reflected a commitment to one-way communication of information from teacher to students combined with practice in using new concepts and monitoring students' performance. In contrast to Ms. Copeland's emphasis on getting students to express their ideas and assessing them orally and in writing, Mr. Barnes' strategies provided little opportunity for students to develop any awareness of their own thinking about important concepts.

The contrast between questioning styles was illustrated by the vignettes of Ms. Copeland and Mr. Barnes. Ms. Copeland spent much of her class time discussing the nature of plants' food, involving students by having them generate lists on the board followed by discussion of the items listed to get them to discuss their own ideas. Mr. Barnes also engaged students in discussion, but for limited periods of time. He spent at least 50% of the class time lecturing, time in which the students sat passively listening to Mr. Barnes talk. Unlike Ms. Copeland, Mr. Barnes' questions were designed to assess students' understanding of specific concepts he had presented, rather than to get them to express and refine their own ideas.

The Fact Acquisition Orientation

Four teachers' instruction and responses to the interviews demonstrated patterns of reasoning that were very different from the other eight teachers. The teachers reflecting the fact acquisition orientation consistently emphasized students' memorizing information and facts defined by resources such as the text or the district science curriculum rather than by the teacher. They expressed concern for teaching in ways that made students feel successful in school, but did not emphasize students' understanding science content beyond "getting the facts." Their teaching strategies exposed students to information through reading, movies, completing seat work and in-class activities. Their strategies for monitoring students' progress emphasized checking assignments for completeness and factual accuracy, strategies which provided little information about the nature of students' thinking.

The fact acquisition teachers were generally unaware of the nature of their students' scientific thinking, and in several instances became visibly frustrated when asked to discuss students' knowledge or learning processes. They usually were unable to predict students' responses to test questions with any accuracy, and could not relate students' responses to the nature of their thinking. In several instances, they made errors in identifying correct responses to questions on the diagnostic test.

The following case study of Mr. Armstrong illustrates the beliefs about teaching and learning characteristic of the fact acquisition orientation. Like the other fact acquisition teachers, he was not a science major, but had completed several science content courses.

Mr. Armstrong

Mr. Armstrong taught 7th grade life science in a suburban middle school. He had taught for more than 15 years, primarily in high school vocational education. He had earned a masters degree in education with secondary certification and had completed additional advanced graduate study, including 8 college level science content courses.

Like Mr. Barnes, Mr. Armstrong was assigned to the research group that received only teaching materials. He was provided with student texts and teacher's guides containing information about students' misconceptions and conceptual change teaching strategies for the photosynthesis and cellular respiration units, as well as written goals for all three units. He was encouraged to use the materials in any manner he felt was appropriate.

Mr. Armstrong's students were enrolled in a school program in which the entire 7th grade class (about 110 students) attended some classes as one large group referred to as "the block", then met in small groups for other classes. The lesson described below was the third small group class during the photosynthesis unit. The first two lessons had addressed questions about the nature of food.

A Typical Lesson

At 10:00, the students arrived for Mr. Armstrong's class. They tended to divide into two groups, with most of the girls on one side of the room and the boys on the other (near the door). The students were assigned seats, although Mr. Armstrong seldom made them sit exactly in their assigned spot. Class started about 10:05 after Mr. Armstrong checked attendance:

"I'd like to finish this up. Maybe we'll have a lab tomorrow in block...and a test the next day. O.K. let's do the question and answer and summary on page 18. Who wants to read?"

S1: (reading) "We have seen that energy-containing food for plants does not come from the soil, or from the water, or from fertilizer, or from minerals. Plants do not take in food from their environment."

T: Underline that..."plants do not take in food from the environment." Continue reading."

The student finished reading the page, which described plants' unusual ability to use energy from the sun to change water and carbon dioxide into energy-containing food and emphasized the need for light as a component of the food-making process. Mr. Armstrong made no further comments about important ideas contained in the reading.

Moving to the overhead projector, Mr. Armstrong got out a set of photosynthesis transparencies constructed with overlays enabling the teacher to present a question, then flip the overlay onto the screen to display the correct explanation. Mr. Armstrong chose one illustrating the movement of water in green plants:

T: "I've got some overheads here. We should review what was learned. O.K., here's one on plants and water. What happens to water inside a green plant? Which way will the water travel?"

S2: "It goes from roots to leaves...(gets cut off by Mr. Armstrong).

T: (flipping the overlay onto the projector) "Absorbed by the root hairs...Used in what process? (several students call out "photosynthesis"). Is water an energy-giving food?"

S3: "No, it...(interrupted by Mr. Armstrong)"

T: "Why?...because it doesn't provide energy.."

Mr. Armstrong displayed a different transparency showing a cross section of a root with root hairs:

T: "What do the root hairs do?...they function to absorb water. Do they increase the surface area of the root?"

S4: "They..(only gets one word out before Mr. Armstrong starts talking again)

T: "O.K., the xylem carries water and the phloem carries food. What comes back to the root?

S4: "food?

Mr. Armstrong switched to another transparency showing a growing plant with leaves and containing the question "what happens to carbon dioxide inside a plant?"

T: "Where does the carbon dioxide exist?"

S5: "In the air."

T: "How does the carbon dioxide get into the leaf?" (before students have a chance to respond, he continues..) "What is it used for?"

Several students called out "photosynthesis". Mr Armstrong flipped the overlay onto the screen and read the answer aloud, then replaced the transparency with another showing a cross section of a leaf:

T: What is the stomata (sic) used for?"

S6: "It gets the carbon dioxide into..."

Mr. Armstrong interrupted to describe the movement of water to the leaf and food to the roots through the xylem and phloem:

S4: "Is that like in second grade when we coated leaves with vaseline and the plant died?"

T: "Right. Why?"

S5: "Because the leaf can't get carbon dioxide?"

T: "Right! Remember when you put the celery in colored dye?

Without elaborating, Mr. Armstrong switched to another transparency. He used each one in a similar fashion, reading the question written on the transparency or asking another one, then flipping the overlay to display the answer or adding some other comment. Although he asked many questions, the students seldom had a chance to think about them or provide responses. The questions they actually did answer usually required only a single word or phrase. Those involving longer explanations were answered by Mr. Armstrong before the students could say anything. Eleven transparencies were reviewed in less than ten minutes.

After finishing the transparencies, Mr. Armstrong had the students write answers to the questions on page 19 of their text (the experimental photosynthesis text), which described three situations, including Von Helmot's tree growth investigation, a plant with only one leaf exposed to the light, and water falling on the soil near a plant. Each situation required the students to make a prediction and explain their reasoning.

After about five minutes, he checked students' progress in answering the questions:

T: "Jeff, read your answer. Where did the weight come from?

J: "Excess food."

T: "Someone else?"

S7: "From photosynthesis."

T: "It looks like someone disagrees with you, Jeff. Sarah?

S: "Its making food from carbon dioxide, water, and light."

Mr. Armstrong listened to several other answers without comment, then stated the correct response to the question, noting that "some of you may still have some misconceptions about this."

The discussion shifted to question two, which involved a plant supplied with water but with only one leaf exposed to the light:

T: "O.K. Everything is covered but one leaf. How will it turn out?"

S4 "It will live, 'cause the one leaf can supply enough food for the whole plant."

T: "O.K. Anyone disagree?"

S5: "It will grow but it won't be healthy, because the leaf can't produce enough..

S6: "No, it wouldn't live...it would survive but it wouldn't grow because it couldn't get enough food to grow.

Mr. Armstrong stopped the debate, telling the students that they probably couldn't tell whether the plant would grow or not, and reminded them to think about the food moving from the leaf to the roots of the plants. The third question was discussed in a similar manner, with the students supplying several answers after which Mr. Armstrong stated the correct response.

The remainder of the class was devoted to completing the last five pages of the chapter. The students read paragraphs aloud until they reached an exercise requiring them to write answers to questions. They spent about three minutes writing, then reviewed their answers as a group. Mr. Armstrong solicited one or two answers from students then supplied the correct response. At the end of each exercise, he repeated important information contained in the answers, frequently reminding them that "these are important concepts." By 10:40, the students had read the remainder of the chapter, written answers to five more explanation questions, and filled out a chart comparing food for plants and humans.

Near the end of class, the students completed an exercise in which they examined their responses at the beginning of the unit and wrote any changes they would include to make their answers more accurate. Several students read their answers aloud at Mr. Armstrong's request, but there was no discussion about how their answers changed as a result of the unit. Mr. Armstrong noted that "Some of you may have had some misconceptions about some of this stuff. This helps you to see if you've changed them."

The lesson described above was typical of Mr. Armstrong's classes. Students spent considerable time reading, watching filmstrips or movies, and doing individual or group assignments, after which the answers to questions were checked in class. Laboratory exercises were scheduled during block (when two or three lab sections could meet at the same time).

Mr. Armstrong asked many questions during classes but few which required more than a single word or phrase in response. Although he sometimes solicited several responses to a question, he often interrupted to supply the correct response or to ask another question. Occasionally, he pointed out differences among students' responses, but seldom provided feedback about how the answers could be improved. The students were moderately attentive but often just copied the correct answers to questions without participating in the discussion. They seldom were required to offer explanations or descriptions of important concepts. Mr. Armstrong paid little attention to students who were off-task unless they were disruptive.

Mr. Armstrong's Beliefs About Students' Learning Processes.

Like the other fact acquisition teachers, Mr. Armstrong displayed little knowledge of the nature of his students' thinking about photosynthesis, respiration, and matter cycling. Although he made some predictions about their responses to the diagnostic test questions, he was seldom able to relate the responses to their thinking. Learning was viewed as a process of acquiring isolated facts through exposure or "interacting" with materials or activities. He recognized individual learning styles, describing them in terms of differences in the ways that students perceived information; some did better using audio-visual presentations, others learned better when reading or writing. Learning was enhanced by repetition or working with motivating or stimulating materials. He attributed their failure to learn primarily to innate ability rather than their thinking about science content:

> "It's just that I think kids have certain reasoning power and some kids have the mental capabilities of being able to handle a question or a situation, or a level of learning.
>
> "I just think that about 20% of the kids aren't capable of that. I think it is just the fact that mentally they aren't capable of doing it."

For a question that he regarded as particularly difficult, he noted that

> "I'd usually indicate that the brighter kids, the sharper kids would catch onto that concept, but the other ones wouldn't.....I would pick fewer because they wouldn't understand the relationship, especially the duller kids......I think a lot of it isn't the concept, it's just the ability of the kids through the whole thing. They either have the ability to understand this type of reasoning or they don't. It's like there are smart ones and not-so-smart ones."

Occasionally, Mr. Armstrong attributed students' inability to answer the questions to their failure to remember important information or to the fact that many questions were "open-ended". In many instances, however, he was unable to suggest any reasons why students might not be able to respond.

Another important difference between the fact acquisition orientation and the other orientations was the role of various teaching resources. Mr. Armstrong consistently identified the student text, movies, filmstrips, transparencies, and lab activities as important planning and teaching resources because they contained important information that the students could acquire and they were easy to use. For example, he described the experimental student text supplied during the respiration unit as the most useful resource for teaching the unit "because it was laid out systematically and had some good information in it." However, he also felt that it was too repetitious:

> "...you could take every other paragraph or two paragraphs and end up with what you could teach the kids or maybe one sentence of it that was important, so why deal with the rest?..."

> "For this age group, you have to eliminate as much of the garbage as you can and get down to nothing but the facts. You aren't going to keep their attention long enough to do much else...you are just going to confuse the kids."

Thus, the resources he considered important were those that clearly identified important information but didn't require clarification or interpretation, and which had little potential to generate management problems.

Mr. Armstrong did not identify resources or materials containing information about students' thinking as important. In discussing the experimental photosynthesis and respiration teachers' guides, he noted that

> "I did skim it (the respiration teacher's guide) a bit. What I found was my conceptions on it and that my feelings were on it were about the same as the book, so it wasn't worth my time to go through each area....there wasn't that much variance..."

> "I just felt that I didn't need it (the photosynthesis teacher's guide). I just kind of felt out what the kids were dealing with ...it wasn't that important to me because I didn't spend that much time with them on it. I kind of let them dig into it and get the information out of it (the student text) because I think that in a lot of cases it doesn't make much difference whether they understand the concept or not and whether you are going over each concept and repeating what they have answered."

Mr. Armstrong consistently described reading texts or books, lab activities, and "discussing and interacting" as important activities for helping students' learn. His primary concern was that the students be exposed to the materials or information and have opportunities to "dig out the information." He regarded written questions as opportunities for the students to work with the materials and find important information:

> "I want them to be able to interact with any type of activity...writing or experiments or whatever aren't any more effective than telling and discussing...I don't know how to tell if anyone is more effective."

> "Discussing and interacting with the materials and asking questions...it's always successful when you do that."

> "...and normally what I'd do is I'd want the students to come up with explanations that pretty well match what the correct response would be....basically what I was looking for was the proper explanation."

Although he commented that it was important for them to find correct explanations, he seldom monitored their work or held them accountable for their performances beyond completing the assigned work:

> "I assigned them (grades) if they completed the book (the experimental photosynthesis text) and turned it in....and I could see if anyone was screwing around....they were happy. It was a good part of the text, the fact that they could interact with it and write down their feelings and compare it with what they had said before..."

Thus, although Mr. Armstrong stated that he felt that it was useful for students to articulate their thinking, there was little evidence that he regarded the information about their thinking as important or had learned much about the nature of the students' thinking.

Mr. Armstrong's Role in Promoting Student Learning

Mr. Armstrong's role in promoting student learning was typical of the fact acquisition orientation. It consisted primarily of managing classroom activities to provide students with opportunities to acquire new information. Although he monitored students' completion of assignments and lab activities to some extent, he did not emphasize assessing their understanding of important concepts or helping them change or develop their thinking.

Mr. Armstrong's role as a manager of classroom tasks was clearly illustrated by the structure of his teaching. For example, in the vignette presented above, students repeatedly engaged in a series of tasks including information-finding tasks in which they identified important information in the reading, practice tasks in which they used the information to write answers to questions, and review tasks in which they corrected their answers as Mr. Armstrong described correct responses to the questions. Mr. Armstrong controlled the length of assignments, the pace of the activities, monitored students' progress, and reviewed their results.

This sequence of activities was particularly important because it illustrates both what Mr. Armstrong's role was, and was not. In the vignette, as in most of Mr. Armstrong's lessons, there was little or no direct instruction. Mr. Armstrong seldom, if ever introduced new concepts to the students. Instead, their initial exposure to new content was through an assignment or activity that provided opportunities to identify important information, followed by some practice activities. Mr. Armstrong supplied procedural directions and answered individuals' questions.

Further evidence about Mr. Armstrong's role was provided by the resources he considered important for planning and teaching. He consistently identified texts, movies, filmstrips, or lab activities as important, all of which provided the students with information without requiring specific direct instruction. In addition, he described them as important because they provided information or were "easy for the students to use" rather than as important for him to use during instruction or because they included information about students' thinking.

Mr. Armstrong's emphasis on students interacting with materials and his consistent identification of teaching strategies stressing students' involvement with materials further illustrate the role of the teachers who reflected the fact acquisition orientation. His primary function was that of manager of activities. During the interviews, the only strategy requiring direct teacher involvement that he identified as important was discussion. The others, including reading texts, using movies or filmstrips, computer programs, and lab activities could be accomplished by the students without Mr. Armstrong having to be directly involved in instruction. In discussing the value of various activities, he noted that they were all about equally effective, although he expressed a preference for activities involving audio-visual aids:

> "I think that's the key of getting those concepts over to a lot of these students is visual stimulation...they are very receptive to audio-visual materials, but turned off by text or reading."

> "Filmstrips are as effective as the Power Cell text or anything else...you need a gimmick, though."

Thus, the resources and teaching strategies Mr. Armstrong considered important placed much of the responsibility for learning on the students. They did not require that he actively identify and communicate important science content through instruction.

Interactions Among Knowledge and Beliefs, Perceptions of Important Information and Information-gathering Strategies.

Like Ms. Copeland and Mr. Barnes, Mr. Armstrong's knowledge and beliefs, perceptions of important information, and information-gathering strategies formed a system of self-reinforcing beliefs. However, Mr. Armstrong's beliefs and perceptions resulted in the use of information-gathering strategies that were "developmental dead-ends." Mr. Armstrong's lack of knowledge about his students' thinking suggested that he had not perceived information about their thinking as important to his teaching. Further, his belief that students' learning occurred as the result of their interacting with materials resulted in his using teaching strategies that engaged students in various tasks that provided opportunities to "interact" with materials of various sorts while he monitored their completion of the activities. This approach provided him with information about students' participation, but provided little information about their understanding of the material or the nature of their thinking. The strategies and teaching behaviors were consistent with, and reinforced his beliefs about students' learning and his role in helping them learn. The information in resources he perceived as important, and the information-gathering strategies he used (i.e. checking for completeness rather than accuracy, asking questions without providing students ample time to respond) did not generate information necessary to develop knowledge about the nature of his students' thinking, or even to provide discrepant information indicating that their thinking was an important issue.

The case study of Mr. Armstrong illustrated the large differences in knowledge and beliefs about teaching and learning between the fact acquisition orientation in comparison to the conceptual development and content understanding orientations. The differences between the orientations with respect to the three issues defined in chapter three are summarized below.

The nature of learning. In contrast to the other orientations, the fact acquisition orientation was characterized by teachers' lack of knowledge about individual students' learning processes. For these teachers, learning occurred as a result of students being exposed to important information or through completing activities. They were generally unable to relate specific teaching strategies to students' learning. Thus, in many respects the fact acquisition teachers' beliefs about student learning were similar to those of activity-driven elementary teachers (Brophy, 1983; Smith & Anderson, 1984).

Unlike the teachers reflecting conceptual development and content understanding orientations, the fact acquisition teachers seldom accounted for students' failure to learn in terms of their thinking and displayed little knowledge of just how their students thought about important concepts. They usually could not predict students' responses to questions on the diagnostic test. Unlike Mr. Armstrong, the other fact acquisition teachers did not attribute students' failure to learn solely to their innate ability. Instead, they attributed students' failures to factors unrelated to their thinking or the nature of instruction such as motivation, lack of basic skills, poorly designed tests, or absences.

<u>The nature of teachers' curriculum goals</u>. Unlike the conceptual development and content understanding orientations, in which students' learning of important science content was an important goal, the fact acquisition teachers' curriculum goals were limited to students' memorizing information contained in texts or other resources, or identified in district curriculum guides (one teacher spent considerable class time rewriting the district's behavioral objectives as definitions and had the students copy them onto pieces of paper...). These teachers emphasized issues similar to those considered important by elementary teachers (Brophy, 1983) such as supporting students' emotional needs, classroom management, and motivation, however the fact acquisition teachers did not emphasize student learning as an important (or attainable) goal. They acted in ways that were well-meaning, but in many ways restricted students' opportunities to learn (Greenfield & Blase, 1981: Rosenshine & Berliner, 1978)

Important teaching strategies. In contrast to the conceptual development and content understanding orientations, the fact acquisition teachers did not emphasize teaching strategies which would provide them with information about students' thinking or acquisition of important ideas. Instead, they were more activity-driven (Anderson & Smith, 1984; Smith & Anderson, 1983) and emphasized providing proper learning environments, managing activities, keeping students on-task, using text readings, movies, or audio-visual materials, or conducting laboratory activities. These strategies did not require the teacher to be directly involved in instruction. Both the conceptual development and content understanding orientations were characterized by direct instruction: The teachers took an active role instruction by providing important information, leading discussion, and monitoring students' developing knowledge. In contrast, the fact acquisition teachers seldom engaged in direct instruction. Their questioning strategies enabled them to monitor students completion of activities and acquisition of specific facts, but did not provide information necessary to monitor students' understanding of important disciplinary themes. For example, in the vignettes of Ms. Copeland, Mr. Barnes, and Mr. Armstrong. Both Ms. Copeland and Mr. Barnes spent significant time _teaching_ their students. Mr. Armstrong divided his time between monitoring students' completion of seatwork and providing answers to questions presented in the materials, but spent little or no time exposed in direct instruction or engaging them in discussions which might have revealed more about the nature of their thinking.

The fact acquisition teachers' classroom strategies were similar to the activity-driven teachers described by Smith and Anderson (1983). Both groups relied heavily on activities conducted within the classroom, activities that often were modified in ways that made them less effective. The fact acquisition teachers' criteria for successful instruction (completion, student involvement and enthusiasm, and recall of information) suggest that socialization may have been these teachers' primary goals (Brophy, 1983; Brophy & Good, 1978) and a determinant of their perceptions of success or failure, however it was not clear whether or not the teachers' stated concerns were the result of proactive choices or were due to their inability to perceive alternatives.

Comparisons Among the Conceptual Development, Content Understanding, and Fact Acquisition Orientations

The case studies of Ms. Copeland, Mr. Barnes, and Mr. Armstrong illustrated three different sets of beliefs about students' learning processes and the teachers' roles in promoting learning. In addition, systems of self-reinforcing beliefs were developed to account for the interactions among their knowledge and beliefs, judgments about important information, and information gathering strategies. During the development of the case studies, three issues emerged in which large differences in the teachers' reasoning were apparent, including (a) the nature of learning, (b) the nature of teachers' science curriculum goals, and (c) the nature of important teaching strategies. The beliefs characteristic of each orientation toward teaching and learning with respect to those issues are summarized in Table 2 below.

Table 2

Issues Related to Teachers' Beliefs About Students' Learning and the Teachers' Role in Promoting Learning

Issue	Conceptual Development	Content Understanding	Fact Acquisition
The Nature of Learning	Learning occurs as students change the way they think about the world; failure to learn attributed to continued reliance on old ways of thinking	Learning involves acquiring new ideas or knowledge about the subject; failure to learn attributed to missing information, complexity of tasks	Individual students' learning processes not known/not considered important; failure to learn attributed to lack of basic skills, motivation, unable to account for learning
Nature of Science Curriculum Goals	Mastery of important disciplinary concepts and their applications to the real world	Understanding of a body of knowledge describing how living things function in the real world	Mastery of important ideas and skills defined by the district curriculum or science text; emphasis on goals related to students' social or emotional development
Nature of Important Teaching Strategies	Monitor students' thinking; help to develop scientifically appropriate ways of viewing the world	Clearly communicate nature of subject matter; check for understanding of important details	Manage classroom to provide students with activities; use a variety of teaching resources to maintain interest; support students' emotional needs

In this section, the beliefs about teaching and learning, judgments about important information, and information-gathering strategies characteristic of the conceptual development, content understanding, and fact acquisition orientations toward teaching and learning are further illustrated through examination of patterns in the coded responses to the interview tasks and classroom observation data. These data provide additional evidence concerning the nature of the <u>characteristic behaviors</u> associated with each orientation.

The data reported in this section were limited to those individuals whose teaching activities and responses to the interview tasks consistently reflected one particular orientation. As a result, three teachers were not included in this part of the analysis because their responses to interview tasks and classroom actions indicated that they relied on patterns of reasoning characteristic of both the conceptual development and content understanding orientations.

The quantitative data must be interpreted conservatively. Variations in the consistency of interviewing techniques resulted in some tasks being addressed in more detail than others. The coding system developed for the interviews, while sufficiently reliable to illustrate large systematic differences between teachers, was less sensitive to more subtle differences in the teachers' responses.

The classroom strategy data were coded according to specific behaviors associated with conceptual change teaching and learning (Smith & Anderson, 1987; Anderson, Smith, Roth, Hollon, & Blakeslee, 1986). Thus, these data reflected some aspects of actual instruction, but not others. For example, teacher questions were coded only if a student actually responded to the question. An important feature of Mr. Armstrong's instruction, namely asking questions without allowing students opportunity to respond, was not reflected in the coded classroom strategy data. In addition, the ability of the teachers to put into practice those things they believed to be important was subject to a variety of contextual influences and their own willingness to participate fully in the study. Thus, it was not expected that classroom activities would closely correspond to the teachers' beliefs in all cases.

Responses to the interview tasks. The teachers' responses to the interview tasks provided evidence concerning their knowledge about students' thinking, the nature of their curricular goals, and the strategies they considered important in order to promote students' learning. The qualitative nature of the teachers' responses to the interview tasks are summarized in Table 3 below.

Table 3
Teachers' Responses to Interview Tasks

Behavior	Conceptual Development	Content Understanding	Fact Acquisition
Discussion of students' responses to test questions (Task II)	Detailed predictions related to the nature of students' thinking, communication	Detailed predictions related to available information, students' development, complexity of learning tasks	General predictions related to attitude, attendance, basic skills, Few responses referring to students' thinking
Discussion of features of resources used to plan and teach (Task III)	Provide information about students' thinking, supplies examples, promotes discussion	College texts and resources to choose important themes; provide variety; stimulate interest, appropriate reading level	Provides clear examples of content, identifies goals, easy to use, motivates students
Descriptions of important teaching activities (task IV)	Discussions, helping students express ideas, clear presentations, practice and repetition	Lectures, clear examples, questions, using many different ways to provide information, practice, repetition	Using movies, filmstrips, "hands-on" activities, reading text, showing concern, enthusiasm, few references to discussion or content accountability

The characteristics of the teachers' responses to the interview tasks are presented in greater detail below and related to the research questions and data analysis issues identified in Table 1 (see page 64).

Teacher and student tasks. The tasks that the teachers and students engaged in during instruction provided evidence concerning the nature of information available during instruction, their information-gathering strategies, and the activities that they considered important to promote learning. General trends in the teachers' behaviors during instruction were reported separately (Anderson et al, 1986). In addition, classroom strategies associated with conceptual change teaching and learning were also compiled (Blakeslee, Smith & Anderson, 1987). These data indicated that the fact acquisition teachers consistently used fewer classroom teaching and questioning strategies involving predictions, explanations, and opportunities for students to express their thinking than either the content understanding or conceptual development teachers. The nature of the teaching and questioning strategies, and student tasks characteristic of each group are summarized in Table 4 below.

Table 4
Teacher and Student Tasks during Instruction

Behavior	Conceptual Development	Content Understanding	Fact Acquisition
Teachers' activities during instruction	Promoting discussion, contrasting naive and scientific views, using everyday examples, summarizing important content	Presenting detailed information, explaining phenomena, using every-day examples, contrasting naive and scientific ideas	Reading aloud from text, monitoring seatwork, showing movies, videos, presenting facts and definitions, correcting worksheets and homework
Questioning and other information-gathering strategies	Questioning strategies emphasize predictions and explanations of reasoning, two-way discussions, assignments require students to construct explanations	Questioning strategies monitor understanding of details of content, assignments require students to supply information or explain important details of processes	Questioning strategies monitor students' recall of important facts or definitions; assignments emphasize recall or search for facts contained in texts
Student tasks during instruction	Student-student inter-actions; expressing and developing ideas; listening to other students; writing explanations	Teacher-student inter-actions; listening; writing information; responding to teacher questions	Student-material inter-actions; reading aloud; watching movies; completing activities; defining terms and stating facts

The following sections address each of the three major research questions of this study using the data described above. Additional details about the nature of the teachers' responses to interview tasks and classroom behaviors are described and related to the nature of learning, the teachers' curriculum goals, and the nature of important teaching strategies to further illustrate characteristics of the teachers' beliefs about teaching and learning.

Question I: What is the Nature of Teachers' Beliefs about Students' Learning Processes?

The primary issue related to question I was the <u>nature of learning</u>. Data addressing this issue were drawn from teachers' discussions of students' failure to learn in interview task II, their descriptions of important teaching strategies in task IV., and from the features of instruction based on the classroom observation data.

<u>Explanations for failure to learn</u>. The teachers' explanations for students' failure to learn were addressed by interview task II. Their responses to this task are summarized in Table 5 below.

Table 5
Reasons for Students' Failure to Learn
(per cent of total responses)

Reasons	Conceptual Development (n=4)	Content Understanding (n=1)	Fact Acquisition (n=4)
Nature of students' thinking about concepts	29	26	5
Failure to remember important concepts or information	15	13	4
Reading and Writing Skill	16	13	27
Students' innate ability or intelligence	2	0	8
Content not matched to students' skills/reasoning	6	36	11
Attitude, Motivation	6	8	10
Unable to account for students' failure	10	0	20
Other[1]	16	0	14

[1] Includes the prediction that no students would fail to learn

The responses to task II clearly illustrated both the importance of students' thinking well as the emphasis on students' learning science content characteristic of the teachers reflecting the conceptual development orientation. Twenty nine per cent of their responses to this task included references to specific misconceptions or to inaccuracies in students' thinking. Fifteen per cent of the responses referred to students' failure to perceive important relationships or information. Typical responses to this task included

> "They only think that plants give off oxygen, they don't think that they use it too"

> "They still think that plants only do photosynthesis and people have respiration.."

Sixteen per cent of the responses indicated that students' communication skills were a cause for their inability to respond accurately to the test questions. However, the coding system did not adequately distinguish between students' basic reading and writing skills and their ability to formulate and/or write an adequate explanation. Thus, the actual number of responses addressing students' ability to read and write were probably less than 16%.

The responses to task II characteristic of the content understanding orientation were similar in some respects to those of the conceptual development orientation. Twenty six per cent of the responses included references to students' misconceptions' or the nature of their thinking. Thirteen per cent referred to students' failure to understand important information. However, the teacher reflecting this orientation also perceived students' failure to learn as a developmental issue. Thirty six per cent of the responses to this task included references to the idea that students had not yet developed the necessary reasoning skills to be successful. Some typical responses to this task included

> "it's really difficult for these kids to follow these ideas because they involve a lot of steps"

> "they haven't learned that water isn't food"

> "they didn't remember what we said about plants using oxygen as well as carbon dioxide".

These explanations suggest that the important issue was the details students had not acquired rather than the content of their existing conceptions.

In contrast to the conceptual development and content understanding orientations, the teachers reflecting the fact acquisition orientation did not emphasize students' thinking in their responses to task II. Only 9% of their responses referred to students' thinking or understanding of important science content. Instead, they attributed students' failure to learn to numerous factors such as lack of basic reading and writing skills (27%), inappropriate materials for the students' ability (11%), and motivation (10%). Typical responses to this task by these teachers included

> "if they don't get it this time around, they'll get it again later and then maybe they'll understand it better"

> "if they don't get it the first two times, they're not going to get it no matter what, so there's no sense keeping after them about it."

> "The words here will throw them..like relate..they don't know what those words mean..."

> "They can't read...they can't write...and they probably don't want to try very hard anyway..."

These responses suggested that the content of students' ideas about important concepts did not form the basis for their thinking about learning. Their responses emphasized issues over which they had little or no control.

The fact acquisition teachers had difficulty making predictions about students' responses to the test questions. Twenty per cent of their responses to task II included statements indicating that the teacher was unable to predict students' answers to the test questions. In one case, the teacher expressed frustration with the task, exclaiming "I don't know!...and I wish you'd stop asking me about it!"

The responses to this task clearly illustrated an important difference among the three orientations: The teachers who were characteristic of the conceptual development and content understanding orientations had developed considerable knowledge of their students' thinking about science content and could use that knowledge to explain students' learning difficulties. In contrast, the fact acquisition teachers' responses indicated that they had developed little knowledge of students' thinking. Further, the reasons they cited for students' failure to learn suggested that they had not perceived information about their students' thinking as important to their teaching.

Nature of important teaching strategies. In task IV, the teachers were asked to discuss three strategies they thought were most important in helping the students learn the unit concepts. Their responses provided evidence concerning the nature of the tasks that the teachers thought were necessary for students to engage in if successful learning were to occur. The teachers' responses are summarized in Table 6 below.

Table 6
FEATURES OF IMPORTANT TEACHING STRATEGIES
(per cent of total responses)

Strategies	Conceptual Development n=4	Content Understanding n=1	Fact Acquisition n=4
Discussion, written assignments, asking and answering questions	49	28	14
Direct instruction or communication emphasizing specific concepts	23	21	15
Practice, repetition, accountability for lesson content	21	21	7
Movies, filmstrips, reading assignments, videos, experiments, "Hands-on activities"	7	28	43
Displaying enthusiasm, acting as role model, demonstrating concern for students' welfare	0	2	19

The conceptual development orientation was characterized by an emphasis on monitoring students' thinking as a particularly important teaching strategy. These teachers' responses to task IV referred primarily to discussions, questioning, and written assignments in which the students became more aware of their own thinking (49%). Other responses to this task included direct instruction focusing on specific concepts (23%) and holding students accountable for lesson content (21%). Some typical comments characteristic of this orientation included

"Discussions...so they can practice their thinking"

"Asking questions and answering questions....so I know where they're at any given time.."

"Having them write down their answers so they can see how they changed"

"Doing the pages (in the Power Plant text) together...I could see what they were saying as we went..."

The teachers' emphasis on discussions suggested that learning involved more than just acquiring new information: Students were also expected to be actively thinking about the new content being presented in class. Learning also involved retaining important information, but memorizing facts was not regarded as particularly important.

The content understanding orientation was characterized by a balanced emphasis on a variety of strategies, including discussions and assessing students' thinking (28%), movies, filmstrips, and laboratory activities (28%), and practice and repetition (21%). These responses indicated that the teacher reflecting this orientation judged strategies besides discussions as equally valid in helping students learn important concepts. These same strategies enabled him to provide his students with a important content using variety of formats and monitor their use of that information. The emphasis on using a variety of ways to communicate important ideas to students suggested that learning involved acquiring many new concepts and facts about the natural world and being able to relate them to one another.

In contrast, the teachers reflecting the fact acquisition orientation emphasized strategies that did not involve direct instruction. Only 14% of their responses to this task emphasized discussions or activities in which students displayed their thinking. Forty three per cent of their responses emphasized strategies such as reading, written review assignments, "hands-on" activities, watching science movies or filmstrips, or videos, while 19% referred to displaying enthusiasm or concern for students needs. These teaching strategies enabled them to manage classroom activities and provide students with opportunities to learn without requiring them to actively define or present important science content. Some responses typical of this orientation included

> "enthusiasm...they'll notice that if the teacher is watching the film it must be important, so they watch too"

> "things that get their attention like drawing a weird picture"

> "the project they did...the drawings of the cycles of matter. They really enjoyed that..."

The strategies they emphasized provided them with little information about the nature of their students' scientific thinking. However, they were consistent with reports that individuals who don't perceive academic success as an attainable goal emphasize socialization goals in order to enhance their feelings of success as teachers (Greenfield & Blase, 1978).

<u>Features of instruction</u>. The beliefs about students' learning processes characteristic of each orientation were further illustrated by teacher and student activities observed during instruction (see Table 3).

The <u>conceptual development</u> orientation was characterized by an emphasis on strategies involving two-way communication with students. Teachers taking this orientation typically incorporated much discussion into each lesson, focusing on explanations for everyday events. Their questioning strategies, assignments, and quizzes emphasized having students make choices or predictions and develop explanations for their predictions. The students spent considerable time expressing their ideas and discussing them with the teacher and other students. Activities and assignments required writing predictions and explanations for events, or tracing steps on diagrams rather than listing definitions or facts.

The content understanding teacher emphasized presenting information to students in a clear, understandable format. Thus, lectures were frequently a major component of instruction and were often used in conjunction with movies or filmstrips. Lab activities were conducted in order to illustrate and reinforce important concepts. Although distinctions between students' ideas and scientifically appropriate thinking were identified, the students spent little time articulating their own thinking. As a result, the flow of information was primarily from teacher to students much like high school classes (Brophy, 1983). The questioning strategies characteristic of this orientation focused less on the nature of students' thinking and more on their understanding of the content presented during class. The students' primary activities involved listening, writing notes, and responding to questions. During lab activities, they worked in small groups to complete both procedures and summary questions, but spent little time outside of lab activities in content-oriented discussions with each other. Their responses to questions usually included identifying examples, supplying important information, or explaining specific details about important content.

The *fact acquisition* teachers' classroom strategies were similar to those of activity-driven elementary teachers (Smith & Anderson, 1984). They frequently read aloud or presented information directly from the text, identifying important phrases and definitions. They used many movies and other audio-visual materials, worksheets, and often assigned seatwork occupying much of the available class time. However, the actual contribution of any activity to students' learning was not clear (Brophy & Good, 1978; Rosenshine & Berliner, 1978)

The fact acquisition teachers spent relatively little time engaged in direct instruction, thus the primary form of interaction was between students and materials. Their questioning strategies focused on checking students' progress with tasks and their recall of information. They seldom required students to make predictions or develop explanations for events or express their thinking. Assignments were graded primarily for completion or accuracy of terms and definitions. The students spent much time reading, watching movies or filmstrips, or completing worksheets. There were few discussions or other opportunities for students to express their ideas or hear the ideas of others. Their responses to questions usually emphasized key words of definitions in the text rather than explanations of important content or everyday events.

Classroom strategies associated with conceptual change. Further evidence concerning the beliefs about students' learning characteristic of each orientation was drawn from an examination of the teachers' use of classroom strategies, student tasks, and sources associated with conceptual change teaching and learning (Smith & Anderson, 1987).

Classroom strategies associated with conceptual change included prediction and explanation questions, teacher probes of students' responses, explicit contrasts between misconceptions and scientifically appropriate conceptions, teacher explanations, and use of everyday events. The teachers reflecting the conceptual development and content understanding orientations were similar in the use of these strategies, with means per observed lesson of 14 and 12.6 respectively for those units in which the teachers did not use experimental materials. In contrast, the fact acquisition teachers' use of those strategies was only 5.8 per observed lesson, indicating that they spent much less time engaged in teaching activities that provided them with information about students' thinking or enabled students to become aware of their own thinking.

Question II: What is the Nature of Teachers' Beliefs about their Role in Promoting Learning?

Two issues emerged as important in describing teachers' beliefs about their role in promoting learning, including the <u>nature of science curriculum goals</u>, and the <u>nature of important teaching roles</u>. Data addressing these issues were drawn from the discussions of important planning and teaching resources in task III and from the descriptions of teaching strategies important for promoting student learning in task IV. These issues are discussed below.

<u>The nature of teachers' science curriculum goals</u>. Interview task III provided evidence about the resources the teachers considered important to help students learn the unit concepts, and the reasons they thought the resources were important. The teachers' responses to this task are summarized in Table 7 below.

Table 7
Nature of Important Planning and Teaching Resources
(per cent of total responses)

Reasons	Conceptual Development n=4	Content Understanding n=1	Fact Acquisition n=4
Provides information about students' thinking or promotes discussion	23	11	8
Identifies important curricular goals	24	6	23
Provides content or examples for students	24	23	31
Provides reinforcement or practice	13	17	15
Hands-on, motivation "easy-to-use"	7	28	16
Other	9	11	8

The conceptual development orientation was characterized by an emphasis on goals related to shaping students' understanding of important disciplinary themes. These goals were clearly illustrated in the nature of the planning and teaching resources identified as most important. Three fourths of the responses to this task included references to important content or to the nature of students' thinking, including identifying important curricular goals (24%), providing examples of important content (24%), information about students' thinking (23%). Some typical responses to this task included

> "The sheets (of goal and naive conceptions) were good because I could see where they might be going wrong"

"The text was good because the students could see how their thinking had changed...they were really embarrassed..they couldn't believe how they could have written those things at the beginning.."

In discussing important teaching strategies (task IV), the teachers reflecting this orientation also emphasized discussions and activities which provided information about students' thinking (49%) and direct instruction of important concepts (23%) (see Table 6), responses consistent with the belief that students' learning processes involved changes in their thinking about important concepts. Thus, the teachers' emphasis on resources and teaching strategies that provided information about their students' thinking clearly illustrate the nature of their goals for students' understanding of important content and their role in helping them change their ideas.

In contrast, the teacher who reflected the content understanding orientation emphasized resources as important for a variety of reasons, including identifying and providing examples of important content (28%), providing hands-on or motivating experiences (28%), and reinforcement and/or repetition (17%). Typical responses to this task included

"I use the college text to refresh my memory and think about important ideas"

"Their text is important to see where the unit is headed..."
"I looked at the charts (of students' misconceptions supplied in the experimental respiration text) and decided that maybe you had done a survey of teachers or something...but I already knew that they had trouble with that material"

These responses suggested that resources were used to help make decisions about important content and keep track of what additional information students might need in order to understand the unit concepts. Thus, the resources he relied on were important because of their content orientation rather than because they provided information about students.

In responding to task IV, he again emphasized a variety of strategies, rating discussions (28%), direct instruction (21%), practice and repetition (21%), and using movies, filmstrips, and videos (28%) as almost equally important (see Table 3). These strategies enabled him to communicate important information to his students in a variety of ways to ensure that each student had maximum opportunity to understand it. Thus, the information, and resources, and teaching strategies identified as important and most effective were those that facilitated the identification and transfer of important information to the students.

The teachers reflecting the fact acquisition orientation identified a variety of resources (texts, films, activity sheets, their own knowledge) as important, primarily because they identified important curricular goals (23%) or provided students with important science content (31%). The response frequencies seemed similar to those of the other groups of teachers. However a closer examination of their responses to this task suggested that they relied on these resources for different reasons than the other two groups. The differences are illustrated by the comments below:

> "Lab manuals give them some of the basic ideas..."
>
> 'The text is the core of things..it generated the information"
>
> "The text, it explains it for them again...they see it and get an explanation for it..."

In contrast to the conceptual development and content understanding orientations, teachers reflecting the fact acquisition orientation judged resources as important because they included statements of important curricular goals and served as resources students could use to find information for themselves. Thus, the fact acquisition teachers did not rely on their own knowledge to make curricular decisions. Their goals were resource-oriented: the teachers adjusted their expectations to correspond to the content and skills contained in the resources and activities they could successfully manage in their classrooms.

The science curriculum goals described above were further supported by the teaching strategies the fact acquisition teachers identified as important in task IV. Forty-three per cent of their responses emphasized activities such as videos, movies or "hands-on" activities. These strategies enabled them to manage their classrooms to expose students to information contained in various resources, but required little direct instruction (16%). The teachers seldom engaged students in discussions or activities in which they might become aware of their thinking. Thus, the data clearly illustrate the fact acquisition teachers' role as managers of resources and activities.

Conceptual change tasks and sources of information. Similar patterns existed in the nature of the tasks assigned to students and the features of sources of information used during the units. Examples of features of tasks and sources associated with conceptual change learning included those in which students were asked to make choices and/or construct explanations, those which elicited misconceptions, and tasks in which students contrasted naive with scientifically appropriate conceptions.

The use of tasks associated with conceptual change were much higher for the conceptual development and content understanding orientations (19.9 and 27.0 per unit respectively) than for the fact acquisition orientation (7.1 per unit). The use of conceptual change strategies in the sources assigned to students were also much higher for the conceptual development and content understanding orientations (2.4 and 7.0 per unit respectively) than for the fact acquisition orientation, where sources including conceptual change strategies were rarely used (0.3 per unit).

The conceptual change strategies, tasks, and sources of information associated with with each orientation were consistent with the nature of their responses to the interview tasks. The strategies used by the teachers reflecting the conceptual development and content understanding orientations provided information about students' thinking and the nature of science content. Those same strategies and sources of information were not used by the fact acquisition teachers, and in cases where they were available as the result of the experimental treatments, were still not judged to be important. Thus, these data provided additional evidence consistent with assertions about the nature of the teachers' knowledge about their students' thinking, their judgments about important information, and their information-gathering strategies.

Question III: How do Teachers' Beliefs About Students' Learning Processes and Their Role in Promoting Learning Influence Their Judgments About Important Information and Their Information-gathering Strategies?

The case studies of Ms. Copeland, Mr. Barnes, and Mr. Armstrong illustrated three different self-reinforcing belief systems demonstrated by the teachers in this study. In each case, the teacher's knowledge and beliefs about teaching and learning resulted in their perceiving specific types of information about students as important to monitor the progress of their teaching. Each teacher engaged in information-gathering strategies that provided information consistent with their existing knowledge and beliefs, but which did not provide information inconsistent with those beliefs. The following sections further develop the systems of self-reinforcing beliefs to illustrate the interactions among the knowledge and beliefs, judgments about important information, and information-gathering strategies of the conceptual development, content understanding, and fact acquisition orientations toward teaching and learning.

Conceptual development orientation. The beliefs about students' learning processes associated with the conceptual development orientation were consistent with the accommodation view of learning (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1978). The teachers consistently emphasized the importance of students' changing their thinking about important science content. The teachers' role in promoting learning emphasized monitoring and shaping students' thinking in ways that promoted the development of scientifically appropriate ways of thinking about the world. As a result, the teachers adopting this orientation judged information about the nature of students' thinking as fundamental to evaluating the progress of their instruction.

The importance of information about students' thinking was evident in the teachers' responses to the interview tasks and the nature of their teaching. They consistently emphasized resources that contained information about students' thinking, such as the charts of goal and naive conceptions in the experimental teachers' guides, resources they could use to make decisions about important disciplinary themes, or resources that they could use to generate discussions among students. The teaching strategies, student tasks, and student sources of information they used during instruction promoted two-way communication, and provided opportunities for students to make predictions and develop explanations for everyday events. The features of resources and the teaching strategies they identified as important in helping them plan and teach the units were those that provided them with information about their students' thinking and/or had the potential to generate feedback from students about the nature of their thinking. They did not emphasize teaching strategies such as lectures or reading assignments, videos, and movies, strategies that would have provided content information for the students, but would not have generated information about their thinking.

The information-gathering strategies used by these teachers were consistent with their knowledge and beliefs, and reinforced them, because they provided information that could be evaluated in a meaningful way based on their existing knowledge. The information acted as additional examples that supported their beliefs about the importance of students' thinking and their beliefs that their role was to shape that thinking. Thus, the interaction of knowledge and beliefs, judgments about important information, and information-gathering strategies were self-reinforcing in nature.

The interactions among the knowledge and beliefs, judgments about important information, and information-gathering strategies formed open loops enabling the teachers to learn about their students' thinking from their experiences. This was evidenced by their ability to describe their students' responses to the questions on the diagnostic test, and relate the responses to patterns in the students' thinking. This suggests that, for these teachers, expectation effects (Brophy, 1983) would be minimal. The conceptual development teachers' knowledge and behaviors indicate that they were engaging in self-adjusting processes that would result in accurate yet flexible expectations (Brophy and Good, 1978).

Content understanding orientation. In contrast to the conceptual development orientation, the content understanding orientation emphasized learning as a process of assimilation in which students added new ideas to their existing knowledge. The teacher's role in promoting learning emphasized communication of important content to the students in a variety of formats whole ensuring that new ideas were presented clearly. As a result, information about students' understanding of important details of presentations or assignments was perceived as important, while information about the nature of their thinking was not perceived as particularly important.

The content understanding teacher emphasized a variety of teaching strategies such as question-answer sessions, hands-on activities, discussions, repetition, and direct instruction as important. The students completed assignments and used resources that incorporated both information about their thinking and presented important ideas in a variety of different formats, while including questions and activities that generated information .pa about students' thinking and their understanding of specific details of important material. These teaching strategies and resources enabled the teacher to communicate information clearly, while monitoring students' understanding of it.

The resources and strategies the content understanding teacher considered important provided him with information about the nature of the students' thinking, information that was perceived as useful to monitor their understanding of the content presented during lessons. However, his beliefs about the additive nature of students' learning processes resulted in only the information about their understanding of details being perceived as important. Information indicating the presence of misconceptions was interpreted as evidence of gaps in their understanding that needed filling or correcting, rather than as alternate ways of viewing the world. The information he perceived as important reinforced his existing beliefs about student learning, and supplied feedback regarding his success in communicating important content to the students, while accounting for the presence of potentially discrepant information.

The content understanding teacher's system of self-reinforcing beliefs also acted as an open loop enabling him to learn from experience. Like the conceptual development teachers, he had developed significant knowledge about the nature of his students' thinking. However, his beliefs about learning as an additive process resulted in his failing to perceive information about his students' thinking as inconsistent with his beliefs. Instead, that information was reinterpreted as gaps in the students' understanding, an interpretation more consistent with his beliefs about teaching and learning.

Fact acquisition orientation. The fact acquisition teachers' knowledge and beliefs, judgments about important information, and information-gathering strategies also interacted to form a system of self-reinforcing beliefs. Unlike the other teachers, though, the fact acquisition teachers' system of beliefs were developmental dead-ends. Their beliefs about teaching and learning had not developed in a way that enabled them to learn about their students from experience. Unlike the conceptual development and content understanding teachers, the fact acquisition teachers' beliefs about teaching and learning emphasized recall of discrete information, and often addressed goals other than students' learning of science content. Their beliefs about their role emphasized managing activities to provide students with opportunities to learn from the materials used in class, or engaging in activities that enhanced students' social or emotional development. As a result, they considered information about students' recall of information, completion of activities, and feelings of success as important to their teaching.

The fact acquisition teachers' responses to the interview tasks and their teaching activities were consistent with their beliefs and judgments about important information. The features of resources they identified during the interviews emphasized provided information about content and curricular goals; information about students' thinking was not identified as useful. The teaching strategies they identified as important included reading, movies and filmstrips, hands-on activities, and displaying enthusiasm. The teaching strategies and resources used during instruction, particularly those associated with conceptual change learning, seldom included teaching strategies or student tasks involving students in discussions, making predictions and explanations, or completing assignments in which they displayed their thinking. Instead, their teaching focused on management or providing students with opportunities to acquire information. The questions they asked provided information about students' recall of information or completion of activities. The information they gathered from those strategies was consistent with their beliefs, but did not provide them with information about students' thinking. Thus, the teachers reinforced their existing beliefs about teaching and learning because the resources and information-gathering strategies they perceived as important did not provide any information inconsistent with what they already knew.

The fact acquisition teachers' inability to predict their students' responses to test questions and their lack of knowledge of students' thinking indicated that they had not perceived information about individual students' thinking as important to their teaching. When provided with curriculum materials such as the experimental teachers' guides containing information about students' thinking (information that the other teachers identified as important or at least consistent with their own knowledge), these teachers consistently ignored that information in favor of other statements defining important ideas. In addition, the teaching strategies they considered most important did not provide them with information they would need in order to become more aware of the nature of their students' thinking. Thus, for these teachers, the combination of knowledge and beliefs, judgments about important information, and important information-gathering strategies were developmental dead-ends.

Summary

In this chapter, the conceptual development, content understanding, and fact acquisition orientations toward the teaching and learning of science were described. The conceptual development orientation was characterized by (a) an emphasis on learning as a process of accommodation in which students changed their thinking about the natural world, (b) curricular goals focusing on students' developing meaningful understanding of important concepts, and (c) emphasis on monitoring students' thinking and helping them change their thinking. The teaching strategies characteristic of this orientation emphasized two-way communication with students, including the use of teaching strategies involving explanation questions, discussions, providing students with opportunities to apply scientific principles to account for real world phenomena, resulting in the teachers developing detailed knowledge about their students' scientific thinking.

The content understanding orientation was characterized by (a) an emphasis on learning as a process of assimilation in which students integrated new concepts and information into existing knowledge, (b) content-oriented curricular goals emphasizing students' understanding of an integrated body of knowledge about the structure and function of the natural world, and (c) emphasis on communicating important science content in a clear manner and monitoring students' understanding of important details of the content. The teaching strategies characteristic of this orientation included one-way communication from teacher to students' using lectures, audio-visual materials, and application activities. Questioning strategies emphasized monitoring students' understanding of important content details. Teachers reflecting this orientation developed knowledge of the nature of students' thinking, but judged it as no more important than other information in making curricular and instructional decisions.

The fact acquisition teachers approached the tasks of teaching and learning science from a fundamentally different view compared to the other two groups. These teachers perceived science learning as a process of memorizing facts and information, and generally emphasized understanding of science content less than other issues such as improving students' emotional state, motivation, and maintaining classroom management. They relied on teaching strategies exposed students to information or ideas defined by the text or district curriculum. Their strategies for monitoring students' progress emphasized checking assignments for completeness and monitoring acquisition of isolated facts and definitions. They did not perceive students' scientific thinking as important, thus had learned little about the nature of their students' thinking. The teaching strategies they emphasized as important would not have provided them with much information about their students' scientific thinking.

Each orientation toward teaching and learning was characterized by a system of self-reinforcing beliefs that developed as the result of interactions among the teachers' knowledge and beliefs about students' learning processes and their role as teachers, their judgments about important information, and their information-gathering strategies. For the conceptual development and content understanding teachers, the systems acted as open loops, enabling the teachers to learn from experience. In contrast, the fact acquisition teachers' knowledge and beliefs interacted to produce "developmental dead-ends", closed loops in which the teachers did not develop knowledge of their students' thinking or engage in teaching strategies that would have provided the information necessary to develop that knowledge.

CHAPTER FIVE

The purposes of this study were to (a) describe a sample of teachers' beliefs about students' learning processes, (b) describe their beliefs about their role in promoting learning, and (c) examine the influence of their knowledge and beliefs on their judgments about what information is important, and their information-gathering strategies. Teachers interpret information and experiences in terms of their existing knowledge and beliefs, thus their ability to develop new knowledge from classroom experiences, and ultimately their ability to teach successfully, depends on the nature of the knowledge base that they bring to the tasks of teaching.

The theoretical assumptions for this study were based on a constructivist model of learning (Posner, Strike, Hewson, & Gertzog, 1982; Sternberg, 1984b) in which learning occurs as individuals use existing knowledge (stored in long-term memory as schemata) to perceive and process information. The learning process may be mediated by features of the environment and/or the nature of the individuals' existing knowledge. The boundedly rational model (Shulman & Carey, 1984; Simon, 1957, 1984b) further assumes that individuals are innately limited in their ability to process information from the environment. As a result, they construct simplified cognitive models of problems in order to reduce the information-processing complexity of real-world events. These cognitive models are based on selective perceptions (Shavelson and Stern, 1981) which are limited or bounded by the individual's existing knowledge. The models make sense to the individual, but do not accurately represent the nature or complexity of the real-world problem.

A potential implication of the bounded rational perspective is that a closed loop between perceptions and schemata may develop, resulting in failure to perceive alternate forms of information or failure to activate schemata which might have resulted in changed knowledge and beliefs. As a result, knowledge growth is limited to reinforcing existing ideas rather than developing new ideas (Erickson, 1986). Thus, existing cognitive structures reduce the complexity of perceived information through selective perception, but may also limit perception to those events about which knowledge already exists. Other potentially valuable information is not perceived because it has no referents in existing schemata.

The model of humans as boundedly rational underlies recent research examining the nature of teachers' thinking (Clark & Peterson, 1986; Shavelson & Stern, 1981). This body of research has shown that teaching is a cognitively complex task in which teachers rely on different types of knowledge derived from multiple sources (c.f. Clark and Lampert, 1985; Clark and Peterson, 1986). In general, these studies indicate that teachers' actions and decisions are based on knowledge developed through experience and that their perceptions of classroom events are constructed on the basis of that knowledge.

A few studies of teachers' implicit theories and beliefs have been conducted, primarily involving elementary teachers. These studies suggest that teachers hold a wide variety of beliefs about characteristics of students, teacher roles, and subject matter (Clark and Peterson, 1985; Elbaz, 1983; Greenfield & Blase, 1981; Janesick, 1977; Munby, 1983; Olson, 1981, 1982; Winne and Marx, 1982). While these studies illustrate the variety of topics,and the diverse vocabulary used to describe teachers' theories and beliefs, there are presently too few studies to provide systematic evidence regarding teachers' beliefs about teaching and learning, especially with respect to secondary teachers or science teachers at any level. In addition, few researchers have addressed the substance of teachers' beliefs about students' learning processes or the processes by which those beliefs develop.

Available evidence indicates that teaching based on <u>conceptual change</u> holds much promise as a model for improving students' understanding of science content (Anderson & Smith, 1985; Minstrell, 1984). Researchers have demonstrated that it is possible to design curriculum materials and instruction that help students overcome their misconceptions. However, conceptual change teaching is also cognitively demanding. Teachers must possess both detailed subject matter knowledge and knowledge of how students understand and think about those same natural phenomena. Thus, the nature of their beliefs about students' learning is an important component influencing not only their ability to successfully engage in conceptual change teaching, but also their ability to learn about students' thinking from experience.

Anderson and Smith (1985) suggested that effective conceptual change teaching requires two different types of knowledge including (a) a general orientation towards conceptual change teaching, in which the teacher understands and is committed to conceptual change as the only process by which students can effectively learn science, and (b) specific knowledge of three different types, including knowledge of science content and how it can be translated into curricular goals, knowledge of students' learning processes and the specific misconceptions that are likely to influence their understanding of important concepts, and knowledge of teaching strategies designed to help students overcome their misconceptions.

The research described above suggests that the knowledge and beliefs that teachers bring with them to science classrooms are critically important, influencing not only their planning and teaching behavior, but also their perceptions of classroom events and their ability to learn from new information. Thus, understanding the nature of teachers' knowledge and beliefs and how they develop is central to efforts to improve the quality of science instruction. The goals of this research were to build on and extend existing knowledge of teachers' thinking about one critically important aspect of instruction: the nature and processes of student learning. The purposes of the study were:

A. To describe a sample of middle school science teachers' beliefs about the processes by which students learn science concepts

B. To describe the teachers' beliefs about their role in helping students learn science concepts

C. To describe how the teachers' beliefs about students' learning processes and their role in promoting learning influence their judgments about what information is important and their information-gathering strategies.

In addition, the issue of how teachers' beliefs influence their ability to learn from experience was addressed through the development of theoretical models illustrating interactions among knowledge and beliefs, judgments about important information, and information-gathering strategies.

Research Procedures

Subjects. The subjects in this research were thirteen experienced 7th grade life science teachers participating in the Middle School Science Project, which was an investigation of teacher training and curriculum materials as alternatives for providing teachers with information about students' misconceptions and influencing their use conceptual change teaching strategies (Anderson et al, 1986).

Data collection. The data bases used in this research included teacher interviews and observations of instruction conducted during the Middle School Science Project. Student test data were also available, but were not included in the analysis for this dissertation.

The teachers completed a pre-interview and post-interviews after the teaching of each unit. The interview tasks were designed to provide information about teachers' knowledge of science content, their knowledge of students' misconceptions about photosynthesis, respiration, and matter cycling, and information about the curriculum materials and teaching strategies that teachers judged as effective in promoting student learning. An important aspect of the tasks was that they were based on the materials and activities that the teachers had actually used to plan and teach each unit. Thus, the tasks focused on the knowledge and beliefs that formed the basis for the teachers' actual practices, which has been described as "practical knowledge" (Elbaz, 1983), or their "knowledge-in-action" (Driver and Erickson, 1983).

Each teacher was observed as s/he taught units about photosynthesis, cellular respiration, and matter cycling. Narrative data describing classroom instruction, samples of student texts, assignments and quizzes, and other resources used by the teachers were collected for at least three lessons in each unit. Observer/interviewers were rotated for each unit in order to reduce bias in both the observation and interview data.

Data analysis. The data analysis process followed a format similar to the constant comparative method (Glaser and Strauss, 1967; Lincoln and Guba, 1985). Transcripts from each teacher interview were read to develop familiarity with the entire data set and to obtain an overall picture of each teacher's responses to the tasks. Similarities in responses to tasks within and across teachers were identified. A set of initial working hypothesis about the teachers' knowledge and beliefs was generated from reading the interview transcripts and from observations of instruction. The hypotheses were used to develop a set of predictions about teachers' responses to the interview tasks and their classroom behaviors. The predictions were applied to analyze interview and observation data to determine how well the hypotheses and predictions reflected the teachers' actual responses to the interview tasks and their classroom behaviors. The results of the analysis were used to revise the hypotheses about teachers' theories and predictions about their classroom behaviors and responses to the tasks. The goal of this process was not to establish a clear set of criteria for classifying science teachers. Instead, the purpose was to identify patterns in the teachers' responses to the tasks and characteristic approaches to the teaching of science (Hollon and Anderson, 1986).

During the initial analysis procedures, several areas in which large differences in teachers' knowledge and beliefs became apparent, including (a) the nature of learning, (b) the nature of teachers' science curriculum goals, and (c) the nature of important teaching strategies. These issues provided a conceptual framework linking the research questions, interview tasks, and classroom observation data.

A set of three detailed case studies was developed to illustrate characteristic approaches to teaching and learning identified during the first stage of data analysis. The case studies described characteristic features of the teacher's instruction and responses to the interview tasks, and included detailed descriptions of characteristic beliefs about teaching and learning held by the individual. In addition, developing the case studies helped to sharpen distinctions among key issues which could be used as a theoretical structure for comparing teachers and analyzing the larger data set, and highlighted particularly important data points.

A coding system was developed to further characterize the nature of the teachers' responses to the interview tasks. The purpose of this system was to systematically examine all the interview data in order to develop detailed descriptions that revealed patterns of reasoning among the teachers in order to better illustrate the nature of their knowledge and beliefs about teaching and learning.

Results

Three different orientations toward teaching and learning were identified among the teachers in the study, including the conceptual development, content understanding, and fact acquisition orientations. It was not possible to characterize several of the teachers as consistently adhering to just one orientation because they demonstrated patterns of reasoning that had characteristics of both the conceptual development and content understanding orientations. Thus, the data analysis focused on describing the beliefs, judgments, and teaching strategies characteristic of each orientation rather than trying to classify teachers into groups.

The conceptual development orientation. The teachers reflecting the conceptual development orientation viewed learning as a process of accommodation in which students had to change their thinking about important concepts. Therefore, they were most likely to ask questions and use teaching strategies that provided them with information about students' scientific thinking. These teachers could predict students' responses to the questions and relate them to patterns in their thinking. They typically described students' failure to learn in terms of failure to change important ideas. Their discussions of important teaching strategies emphasized the role of discussions, explanations, and helping students express their ideas and use them to explain everyday events.

The features of instruction characteristic of the conceptual development orientation included an emphasis on two-way communication involving discussions, explanations, and extensive questioning in which students expressed their ideas and listened to the ideas of other students. A variety of strategies associated with conceptual change learning, including probes of students' responses, extensive use of real world examples, and contrasts between naive and scientific conceptions of important concepts (Blakeslee, Anderson, & Smith, 1987) were consistently used by these teachers. The students' tasks included explaining their thinking, applying concepts, and writing explanations for everyday events.

<u>The content understanding orientation</u>. The content understanding orientation was characterized by an emphasis on learning as assimilation of new concepts and information into existing knowledge bases, a process not requiring students to undergo fundamental changes in their thinking. Teachers reflecting this orientation could predict students' responses to diagnostic test questions and relate them to patterns in their thinking. However, students' incorrect responses were usually attributed to <u>missing</u> information or explanations rather than the actual content of their thinking, thus misconceptions were explained as gaps in knowledge rather than alternate ways of thinking.

The content understanding orientation was also characterized by an emphasis on one-way communication strategies such as lectures, showing many examples, and using a variety of formats to convey information, and asking questions as important teaching strategies. These strategies conveyed important ideas to the students and provided information necessary to monitor their understanding of important details. The use of strategies associated with conceptual.change learning by teachers reflecting the content understanding orientation was similar to that of the conceptual development teachers. However, information about students' thinking per se was not considered important, thus strategies that helped students become aware of their thinking were not characteristic of this orientation. The students' tasks during instruction involved listening and writing information, or responding to questions, activities conducive to identifying and remembering information but not requiring active interpretation of new content.

The fact acquisition orientation. In contrast to teachers taking the other two orientations, the teachers reflecting the fact acquisition orientation displayed little knowledge of individual students' learning processes. For these teachers, learning occurred as a result of students being exposed to important information or through completing activities. Although they made some predictions regarding students' success or failure to answer diagnostic test questions, they seldom could relate students' responses to the nature of their thinking. They attributed students' incorrect response to factors unrelated to their thinking or the nature of instruction such as motivation, poorly designed tests, or absences. The teaching strategies they judged as important (movies, reading, using hands-on activities) provided students with opportunities to identify and remember information, but did not require active instruction by the teacher. In addition, they provided little or no information about the nature of the students' thinking.

During instruction, the fact acquisition teachers were observed reading aloud, showing movies, writing and reciting facts and definitions, and monitoring seatwork. Their questions monitored students recall of facts. The students' tasks emphasized using materials of various sorts, reading aloud, completing worksheets, and responding to knowledge-recall questions. Thus, the information they were asked to recall, and the activities they completed, provided little opportunity for them to become aware of their thinking about important science concepts. Further, the activities did not generate information that the teachers would have viewed as inconsistent with their existing beliefs.

Within each orientation, it appeared that the teachers' knowledge and classroom behaviors were the result of different patterns of learning over time. These patterns were based on systems of self-reinforcing beliefs: What they had learned about their students was consistent with their beliefs about students' learning processes and their role in promoting learning. The beliefs held by teachers taking the conceptual development and content understanding orientations resulted in their using teaching strategies that enabled them to learn about students' thinking from their teaching experiences. The fact acquisition teachers' belief systems were developmental dead-ends: They did not enable the teachers to develop knowledge about their students or engage in teaching practices that would provide them with the information necessary to develop that knowledge.

Conclusions

The three orientations toward teaching and learning described in this study can be interpreted within the context of the bounded rational model proposed by Shulman and Carey (1984). Each orientation was characterized by teachers developing cognitive models of teaching and learning that enabled them to simplify cognitively and socially complex environments in a way that enabled them to function in that environment. The nature of the models was determined by the knowledge and beliefs characteristic of each orientation.

From the perspective of the conceptual development orientation, students learned via a variety of different experiences, and could be counted on to attend to some information, ignore other information, and transform instruction into new ideas that weren't necessarily desirable. The teachers reflecting this orientation organized instruction and engaged in information-gathering strategies that enabled them to monitor the progress of students' thinking. In doing so, they also engaged in selective perception, ignoring some information in favor of other, more salient clues. However, the information they did perceive was consistent with their beliefs. The nature of that information formed the basis for the knowledge about students that these teachers had developed through experience.

The teachers reflecting the conceptual development orientation were best prepared to teach for conceptual change (Anderson & Smith, 1985; Smith and Lott, 1983). They possessed the commitment to helping students change their thinking, had developed considerable knowledge of the substance of students' thinking, and generally taught in ways that encouraged students to undergo important changes. However, an important aspect of conceptual change teaching, namely the understanding that students' misconceptions often form critical barriers to learning (Anderson, 1984), was not evident in the beliefs about students' learning processes characteristic of this orientation.

The beliefs typical of the content understanding orientation reflected a boundedly rational view of the learner, but perhaps a more rational model of the teaching process (Shulman and Carey, 1984). The emphasis on transmitting content to students in an effective, nondisruptive manner, combined with the emphasis on helping students learn to "process" information suggested that students were viewed as actively manipulating new information, but limited in their ability to interpret new experience. In addition, students were not perceived as actively reinterpreting instruction in view of their existing knowledge. Thus, these beliefs were more characteristic of a rational model of instruction.

The fact acquisition teachers' teaching strategies were, in some respects, characteristic of the rational model described by Shulman and Carey. Their approaches to teaching involved establishing and maintaining an environment in which students were stimulated (both in the social and cognitive sense) by materials and other components of the classroom experience. Thus, their role was consistent with the idea of constructing "delivery systems" (Shulman and Carey, 1984, p.507) that transmitted important information to the students while they managed the system to try and avoid disruptions and/or breakdowns. The analogy here is not complete, for the rational model assumes that the teacher possesses a body of knowledge to be communicated to the students; for the fact acquisition teachers, it is not clear that they possessed that content knowledge. None of the teachers were science majors; they made errors in identifying correct responses to items on the student diagnostic test and had difficulty identifying relationships between concepts (addressed in interview task I). Thus, although they could describe some important content information, their knowledge was probably not integrated in a manner similar to the knowledge possessed by the other teachers in the study.

The teachers described in this study relied on constructs similar to those reported by other researchers in discussing their beliefs about teaching and learning (Bussis, Chittendon, Armand, 1976; Munby, 1983; Winne and Marx, 1982). The conceptual development and content understanding orientations were characterized by an emphasis on issues involving student learning and involvement in classroom events, while the fact acquisition orientation was characterized by concern for issues related to motivation, students' needs, and limitations on their innate ability. Thus, there seemed to be some consistency across subject matter and grade level in the constructs that teachers employ to think about their own practice.

The beliefs typical of the conceptual development orientation were consistent with those of proactive teachers (Brophy and Good, 1974), and similar to, but less content-focused than the secondary subject matter experts reported by Brophy (1983). Although the teachers reflecting this orientation had clearly organized content and instruction in ways that emphasized students' understanding of important concepts, they were not rigidly bound to a particular level of mastery of the content. Instead, they set more flexible goals involving helping students to shift their thinking toward a more scientific understanding of important concepts.

The beliefs about teaching and learning characteristic of the content understanding orientation were also similar to the secondary subject matter experts described by Brophy (1983): They were highly content-oriented. Classes were organized in ways that maximized the transmission of information from teacher to student, and were conducted in a very calm, purposeful atmosphere. It was not clear whether or not instruction focused on higher achievers (Gallagher, 1986; Brophy, 1983), however the emphasis on content was consistent with descriptions of classes where that was the case.

The fact acquisition teachers, in contrast, reflected more of the socialization emphasis characteristic of the elementary teachers described by Brophy (1983). Like most elementary teachers, the fact acquisition teachers were not science majors. There were also discrepancies between these teachers' statements in interview situations, and their actions during instruction, during which they attempted to address important content, but often failed to focus on important content issues, and thus were unable to help students learn science in a meaningful context. Thus, for these teachers, emphasizing social and emotional development issues may have been the result of their inability to perceive curricular alternatives oriented toward the development of content knowledge or their lack of knowledge about the structure of the discipline needed to place particular concepts into a larger framework that made learning reasonable for the students (Anderson, 1987).

This research did not address the question of changes in teachers' beliefs as a result of the experimental treatments used in the Middle School Science Project primarily because visible changes did not take place. The teachers' belief systems appeared very stable and resistant to change. The experimental treatments produced a few specific changes in the teachers' behaviors and responses to the interviews when materials were involved (Smith and Anderson, 1987). However, the overall patterns in their responses remained the same even in the matter cycling interviews, when no teaching materials were supplied. This suggests that differences in the teachers' knowledge and beliefs resulted in their interpreting specially designed materials and feedback from students in different ways, but that a few contacts with discrepant information were insufficient to cause lasting changes in deeply ingrained beliefs for any of the teachers. Thus, the experimental treatments appeared ineffective in shifting the teachers' beliefs in a direction consistent with conceptual change models of teaching and learning, even for those teachers taking the conceptual development orientation, who possessed detailed knowledge about their students' thinking and used teaching strategies consistent with conceptual change models of teaching (Anderson and Smith, 1985; Minstrell, 1984).

Attempts to change teachers' beliefs through short-term interventions may not be appropriate for experienced teachers. In order for them to change deeply-ingrained beliefs which are consistent with other aspects of their role as teachers, experienced teachers must undergo a process of conceptual change with respect to their beliefs about teaching and learning. In order for this to occur, the criteria of intelligibility, plausibility, and fruitfulness of new beliefs about teaching and learning must be established while existing beliefs about teaching and learning must be judged to be unsatisfactory (Hewson & Hewson, 1984; Posner, Strike, Hewson, and Gertzog, 1982). It can be argued, both intuitively and based on the examples provided by studies of students' misconceptions, that such changes are not apt to occur within a short time frame.

Long term interventions such as those currently under investigation by Erickson (1985) may provide a more plausible model for inducing changes in experienced teachers' beliefs. It may be necessary to provide teachers with long term guided experiences working with alternate ways of observing and thinking about instruction as well as the time necessary for new beliefs to develop to the point where they provide useful models for the teachers. The long term impact of the treatments was not addressed in this dissertation or in the context of the Middle School Science Project. However, materials containing information about students' thinking may influence teachers' thinking during during yearly or semester planning, in which teachers address broader issues related to student learning (Clark & Yinger, 1978; Elmore, 1983).

Potential confounding variables. Three of the four teachers reflecting the fact acquisition orientation worked in the same inner city junior high school. The other fact acquisition teacher worked in a high SES suburban school in which there was much emphasis on students' learning. While this suggests a potential influence due to the nature of the teaching setting, one of the teachers who reflected the conceptual development orientation, and who was a college biology major, also taught in the inner city school. At best, the issue of the influence of the setting remains unclear.

The evidence suggesting an influence due to content knowledge is more convincing. None of the fact acquisition teachers were science majors; in contrast, six of the eight teachers taking the conceptual development and content understanding orientations had earned degrees in science. Although the teachers' content knowledge was not specifically addressed within the context of this study, the fact acquisition teachers were the only ones who made content errors in discussing students' responses to the diagnostic test (Hollon and Anderson, 1986). In addition, their descriptions of important goals for student learning suggested that they had little awareness of the nature of important relationships between concepts (Hollon and Anderson, 1986).

Implications

The interactions among teachers' knowledge and beliefs, perceptions of important information, and information-gathering strategies suggests some important implications for teacher education. For preservice teacher education, it seems clear that one important goal should be to develop in prospective teachers an orientation toward teaching that emphasizes students' understanding of science content as a primary goal. This goal should be developed in combination with specific knowledge about students' thinking and learning processes and the development of teaching strategies that enable the teacher to make use of curriculum materials and feedback from students to monitor their thinking about important concepts. More importantly, though, is that the knowledge and skills be developed within a framework relating specific knowledge about students' thinking and teaching strategies to larger issues involving orientations toward teaching and learning. Otherwise, beginning teachers might at best end up functioning from a conceptual development orientation: They would develop knowledge and teaching skills consistent with conceptual change models of instruction (Anderson & Smith, 1985; Nussbaum and Novick, 1982) but lack the orientation toward learning as conceptual change that would enable them to more effectively use their knowledge.

The results of this study also indicate that knowledge of subject matter and students' thinking, while important, is not sufficient to enable teachers to successfully engage in conceptual change teaching. The teachers reflecting the conceptual development and content understanding orientations used more strategies associated with conceptual change than did the fact acquisition teachers. However, they did so pretty much unaware of the important role played by students' existing knowledge. For teachers like these individuals, inservice policies encouraging collective reflections on practice (Erickson, 1984, 1986; Shulman and Carey, 1984) combined with appropriate resource materials such as the teachers' guides developed in the Middle School Science Project, would provide resources and a structure in which teachers could engage in self-diagnosis of instructional problems and develop strategies to remedy those problems. Such activities might involve peer observation and interpretation of instruction, small group seminar/discussions of research issues related to instruction or curriculum development, or peer presentations of individual classroom problems.

For teachers like the those reflecting the fact acquisition orientation, inservice models encouraging collective deliberation and self-reflection and development may not be successful, for these teachers apparently lack important knowledge of the structure and function of the science curriculum necessary to perceive curricular alternatives. They clearly lack knowledge of students' learning processes that would help them use teaching strategies in ways that promote meaningful understanding of science content. As a result, they would not have the necessary tools to perceive alternatives to their existing beliefs about teaching and learning. For these teachers, professional development should include the development of disciplinary science knowledge and knowledge of the basic psychological processes involved in learning. Such a knowledge base may be necessary to perceive and interpret alternate forms of information that would lead to the development of new knowledge about teaching and learning through experience.

Implications for Research

The research presented in this dissertation illustrated three different sets of beliefs about students' learning processes and the teachers' roles in promoting learning and how those beliefs influenced the teachers' judgments about important information and their information-gathering strategies. The beliefs and judgments were related to different patterns of learning from experience. However, many additional questions exist. One important set of issues not addressed in this study involves the origins of teachers' beliefs. It is not clear just how or when teachers develop a particular approach to teaching and learning. The existence of three different perspectives in a group of experienced teachers indicates that the perspectives are not developmental stages, but it is not clear how they did develop.

The issue of the origins of beliefs generates a series of questions of particular importance for preservice teacher education. Do beliefs about teaching and learning stem from preservice education? Do they develop during the first few years of teaching and become relatively stable? Do beliefs about teaching and learning take a back seat to worries about management and discipline during the first few years of teaching, then evolve as the teacher gains confidence and time to think about those higher level issues? What beliefs about teaching and learning are held by students before they enter teacher education programs? How do those beliefs (if they exist) influence their perceptions of preservice training?

Longitudinal studies tracing the knowledge and beliefs of teacher education students and beginning teachers would provide important insights into the nature of the processes that occur as teachers' beliefs about teaching and learning evolve. The impact of specific teacher training experiences on preservice teachers' beliefs could be traced in order to identify components of teacher education and initial teaching experiences that promote the development of beliefs about teaching and learning consistent with those advocated by conceptual change theorists (Posner & Strike, 1982; Anderson & Smith, in press). The results of these studies would provide significant insights for those involved in preservice teacher training and program development.

Another set of research questions involves the influence of teachers' subject matter training on their beliefs about teaching and learning. The teachers in this study who had extensive subject matter training clearly demonstrated different beliefs compared to those who lacked such training. However, at least one teacher was able to overcome the lack of subject matter training and had developed extensive content knowledge. This suggests that other factors such as the teachers' larger role perception

(Greenfield & Blase, 1981; Shavelson & Stern, 1981) play an important role in the teachers' ability to learn from experience. Thus, studies of the differences in beliefs held by individuals with and without extensive content knowledge would provide additional insights into the influence of these variables. Other research should focus on the influence of specific subject training. Do the beliefs of teachers trained in fields such as chemistry or physics, which contain extensive quantitative components, differ from those of teachers trained in fields such as biology or earth science? How does such training influence their judgments about important information and their beliefs about their role in promoting learning?

Additional research could address the influence of prior training and career experiences on teachers' beliefs. Relatively few junior high science teachers were trained as junior high teachers; few programs exist for such training. Thus, teachers at the junior high level are, for the most part, trained as elementary teachers, or as subject matter secondary teachers. In addition, some teachers work in junior high schools by choice; others were forced to accept a junior high assignment or not be employed. The training and career paths of these teachers might exert significant influences on the beliefs about teaching and learning they bring to the classroom.

An important staff development issue for research involves investigating ways to help experienced teachers alter their perceptions of important information, thus breaking the cycle of self-reinforcing beliefs and shifting teachers' perceptions in a manner such that they begin to learn more from their experience. Some researchers have begun to address this issue (Erickson, 1985), but further studies differentiating among those who already hold beliefs similar to those of the conceptual development teachers and those more like the fact acquisition teachers might prove more beneficial to both groups.

This study has not addressed issues related to the influence of contextual variables such as the influence of the teaching setting, interactions with colleagues (especially for those teachers who functioned in a team-teaching situation), or administrator and parental expectations for learning. Ethnographic studies of individual teachers or classrooms might result in a much different account of the role of teachers' beliefs about teaching and learning in their daily activities, the links between their beliefs about learning and their larger role perceptions, and the social and cultural variables that shape their beliefs.

Summary

The research presented in this dissertation addressed the nature of teachers' beliefs about students' learning processes and their role in promoting learning, and the influence of those beliefs on teachers' judgments about important information, their information-gathering strategies, and their ability to learn from experience. The conceptual development, content understanding, and fact acquisition orientations provided one set of answers to those questions. The results of this research were not meant to be generalizable to all teachers everywhere; indeed they apply only to the teachers who participated in the study. However, the results of this study were consistent with other research examining the cognitive lives of teachers, thus they add to the growing body of knowledge about the tasks of teaching.

Appendix A

MSSP INTERVIEW PROTOCOL

MATERIALS NEEDED

tape recorder with 90 minute cassette (check batteries)
the single-page list of concept cards and test questions
list of information sources, concept cards, and question cards
unit calendar
completed academic task forms with copies of the tasks
blank cards and marking pen
clip-board and blank writing paper

The following pages contain the protocol for the respiration and matter-cycling interviews. NUMBERED STATEMENTS are procedures such as sorting or arranging cards. *STATEMENTS IN ITALICS* are comments and initial probes to be used during the interview.

All the questions are important for the project, and for my interest in what teachers know about students. I have put asterisks by those that are particularly important for my purposes. Please try extra hard to make sure that they get included.

INTRODUCE THE INTERVIEW

This interview is like the others that you've done for the project. It has two parts. The first part focuses on what you think students ought to understand about _________. The second part focuses on how you actually planned and taught _________ to your students.

TASK I: CARD SORT OF UNIT CONCEPTS

1. Give the set of concept cards to the teacher.

   A. *Here is one possible set of concepts which are related to ______. I would like you to sort them into two piles, one with all the concepts you taught during your _________ unit and the other with those concepts you didn't teach during the unit.*

(AFTER FIRST SORT)

2. Put aside the cards which do get taught.

   A. *We'll discuss those cards in a few minutes. Let's start with the group of concepts which you didn't teach as a part of the unit.*

   B. *You have identified __C__, __C__,... as concepts which you did not teach in this unit.*

   C. *Do you teach any of these in some other unit?*
      If yes--where?

      What do you expect your students to understand about __C__?

      If no--Why don't you include them?

4. Give the teacher the cards identifying concepts which were taught.

   A. *I'd like you to put the cards into groups or somehow arrange them to show the relationships that you think are important for your students to understand. When you've finished, we'll discuss the arrangement of the cards, and your reasons for organizing them the way you did.*

(AFTER TEACHER COMPLETES TASK)

5. <u>Make a diagram</u> of the arrangement of the cards.

   A. *As we discuss the groups of cards, let's try to focus on the relationships that exist among groups of cards, and what you expect your students to know about them. Later in the interview we'll discuss how you actually taught ________.*

*** B. *What overall strategy did you use to sort the cards the way that you have them here?*

- *Were there other ways of organizing the cards that you thought of but didn't use?*

*** C. *BETWEEN GROUPS: What do you want your students to know about the relationship between (group) and (group)?*

*** D. *FOR EACH GROUP: What do you expect your students to know about this group of cards?*

TASK II: REVIEW OF TEST QUESTIONS

1. Show the teacher the question cards.

*** A. *Here is a set of questions about concepts related to __________. I would like you to read each question aloud (for the tape), then describe how you think your students might answer it before you taught the unit?*

*** B. *What might the students be thinking that would cause them to answer that way?*

*** C. *How would you like them to answer it after you've taught the unit?*

*** D. *About what per cent of you students would you really expect to answer this way?*

*** E. *What problems might keep the other students from learning to answer it correctly?*

(repeat for each question)

2. Have the teacher sort the question cards into important/not important piles.

A. *I'd like you to sort the question cards into two groups, one with all the questions that you think are really important for your students to be able to answer, and the other with questions that aren't so important.*

(FOR EACH IMPORTANT QUESTION)

B. *I'd like you to read the question aloud (for the tape) and then describe why you think its important for your students to be able to answer it correctly.*

*** C. *What would you think if many of your students were unable to answer it?*

(FOR THE UNIMPORTANT QUESTIONS)

A. *Why aren't these questions important?*

Task III: IDENTIFICATION OF IMPORTANT PLANNING/TEACHING RESOURCES

1. Have the teacher sort the stack of resource cards into resources used/not used.

   A. *This set of cards includes several different types of resource materials that are available for teachers to use in planning and teaching. I'd like you to sort the cards into piles containing resources that you used for planning or teaching the _____ unit and resources you didn't use.*

AFTER CARDS ARE SORTED

1. Read the group of resources used cards aloud (for the tape).

*** *A. How did you use each of these resources in your planning and/or teaching?*

*** *B. Which resource(s) had the most influence on your teaching o the _____ unit?*

PROBE FOR DETAILS!!

FOR PROJECT RESOURCES NOT USED

A. *You didn't include_____. Do you have any comments about them?*

TASK IV: DISCUSSION OF THREE MOST IMPORTANT LEARNING ACTIVITIES

*** A. *I'd like you to describe three things that you did in this unit that you think were the most important in terms of helping the students learn* about _____.

*** *B. Why was each one important?*

TASK V: COMPARISON OF PAST, PRESENT, AND FUTURE TEACHING

*** A. *How does the way you taught _____ this year compare to the way you taught it last year (or at some previous time)?*

*** *B. Do you think that the unit was more successful this year?*

*** *C. What changes would you make for next year (or the next time you teach it)?*

TASK VI: GENERAL COMMENTS

A. *We've talked about several topics which we feel are important. Are there other topics (things that you think about, factors which affect your teaching...) that you feel are important for us to know?*

AFTER THE INTERVIEW........

1. Put the unit calendar, lists, copy of card arrangement, and academic tasks (and whatever else) in the unit folder for that teacher.

2. Make sure that the tape gets turned in to be transcribed.

3. When the transcript is ready, staple lists and diagrams to it and place in the unit folder.

APPENDIX A

Page with the unit goals, concept cards, and unit questions on it

APPENDIX B

A FEW INTERVIEWING TECHNIQUE SUGGESTIONS

(from Gordon, Interviewing: Strategy, Techniques, and Tactics
and comments from our first analyses of transcripts....)

1. Avoid summarizing information that the teacher has volunteered. If you feel a summary is necessary, ask the teacher to do it.

2. Non-verbal cues are important: Expressions of interest, accompanied by a short comment such as uh-huh or hmm.. can be effective ways to get the teacher to elaborate on a response.

3. Additional probing questions should be non-directive.
   Some useful generic probes:
      Could you tell me a little more about ...?
      Can you think of anything else about ...?
      Can you add anything to...?
      Could you describe that in a little more detail?
      I'm not sure what you meant by .... Could you say a little more?
      "you said that (repeat statement). Tell me a little more about that.
      Don't forget about wait-time (Gordon calls that the "silent probe").

4. Take advantage of opportunities to show appreciation for the teacher's efforts. A sincere comment about the value of the information the teacher is providing, or a compliment for some interesting thing that the teacher did during class can go a long ways towards easing some of the stress that exists as a result of the entire atmosphere of "being in an experiment".

Discussion of Codes

Code F-1-a: Relates to students' thinking about content. Statements coded as "1" include references to students' misconceptions or alternative ways of thinking, or references to students not changing the way they think. The important aspect of this code is that it indicates that the teacher explicitly accounts for failure to learn in terms of issues about students' thinking about science content. Statements like "they failed to learn....." would NOT be included in this category. Statements like "they still think...." or "they think.... instead of ....." would be included.

Code F-1-b: Reference to students' acquisition (or learning) or information, facts, or concepts. This code is used for statements which refer to students "not learning" or "not understanding." There should be no indication that the student has actively changed their thinking or has abandoned some misconception. Thus, statements like "they didn't get the idea that..." or "they still haven't learned that....." would be coded in this category.

Code F-2: Describes students innate ability. Statements in this category included those which indicated that students' failure to learn was the result of limitations which would not be possible to overcome through normal means of instruction, such as their intelligence, the presence of learning disabilities, the "mainstreamed" kids", etc.

Code F-3: Describes limitations on presently available reasoning skills. ("readiness for learning") Statements in this category include references to students' current reasoning ability, but which do not suggest that the limitations are insurmountable. Thus, statements like "they haven't learned to ....yet" or "they're not ready to think beyond 2 or 3 steps..." or statements which refer to developmental stages would be included in this category.

Code F-4: Refers to lack of communication skills. Statements which account for students' incorrect responses in terms of their ability to communicate what they know or inability to read and comprehend the test questions.

Code F-5: Refers to the nature of the content to be learned. Statements in this category include references to concepts being "too difficult" or "too abstract" or other phrases which suggest that they are inappropriate to teach to the students.

Code F-6: References to attitude, motivation, absences, social distractions. Statements in this category would include phrases indicating that the students don't learn because they don't try, or because there are other things which command their attention.

Code F-7: References to the construction of the question. Statements in this category would include references to confusing or ambiguous wording, or to terms used in the question that were not used during instruction.

Code F-8: Unable to account for students' failure. Statements which indicate that the teacher acknowledges lack of understanding of students' failure to learn.

Code F-9: Other reason not included above.

Code N.A.: Indicates that the teacher was not asked to account for students failure to learn (AND did not respond).

SUMMARY SHEET
FAILURE TO LEARN
PHOTOSYNTHESIS

TEACHER	I food	II def.	III lt.	XVII dark	XVIII bean	XIX gases	XXII water	XXIII moves	XXIV sen	XXV Phs?
11										
12										
13										
14										
21										
22										
23										
24										
25										
32										
33										
34										
35										

Codes: 1-a) relates to students' thinking about content
1-b) relates to students' acquisition of information/facts
2) students' innate ability (intelligence, learning disabilities..)
3) limitations on present reasoning skills
4) communication skills
5) nature of content to be learned (abstract, too difficult)
6) attitude, motivation
7) Question construction (wording, confusing organization)
8) Unable to account for failure (9) other N.A. = not asked

SUMMARY SHEET
FAILURE TO LEARN
RESPIRATION

TEACHER	I	IIA	IIB	III	IV	V	VI	VII	VIIIA	VIIIB	IX	X	XI	XII
11														
12														
13														
14														
21														
22														
23														
24														
25														
32														
33														
34														
35														

Codes: 1-a) relates to students' thinking about content
1-b) relates to students' acquisition of information/facts
2) students' innate ability (intelligence, learning disabilities..)
3) limitations on present reasoning skills
4) communication skills
5) nature of content to be learned (abstract, too dificult)
6) attitude, motivation
7) Question construction (wording, confusing organization)
8) Unable to account for failure (9) other N.A. = not asked

SUMMARY SHEET
FAILURE TO LEARN
MATTER CYCLING

TEACHER	I tree gr	II wt. loss	III space g.	IV tree di	V deer eat	VI soils	VII green plant
11							
12							
13							
14							
21							
22							
23							
24							
25							
32							
33							
34							
35							

Codes: 1-a) relates to students' thinking about content
1-b) relates to students' acquisition of information/facts
2) students' innate ability (intelligence, learning disabilities..)
3) limitations on present reasoning skills
4) communication skills
5) nature of content to be learned (abstract, too dificult)
6) attitude, motivation
7) Question construction (wording, confusing organization)
8) Unable to account for failure (9) other

7-13-86

Description of codes for important planning and teaching resources

The purpose of this set of codes is to categorize teachers' descriptions of important features of the resources they use to plan and teach each unit. The categories included in the codes include a) features which provide teachers with information about the nature of students' thinking or important content (codes , b) features which are important to communicate important information to students or which provide examples of important concepts,) features which enable the teacher to acquire information from students, e) features which provide students with important instructional experiences, f) features related to motivating or stimulating students' interest.

The lists of resources are divided into two sections. The top section includes those resources provided by the science teaching project. For those teachers in treatment groups which did not receive the materials, only the "lists of unit goals" and possibly the "information from workshops" will be applicable. The other resources are marked N.A. (not available) in the second column. Those resources that the teacher identifies as having used are checked in the appropriate column. Those that the teacher identifies as not used are checked in the second column. In some cases, both columns will be left blank, because the resource is not discussed.

Descriptions of codes. The codes used to identify characteristics of each resource used are designed to capture those features that the teacher considered most important. Descriptions of teaching strategies were not included in this section of the analysis. The codes are described below:

1. <u>Provides information about students' misconceptions or thinking</u>. This code is used when the teacher describes a resource as important or used to gain information about students' misconceptions, alternate ways of thinking or ways that they might respond to questions, or any other information about the way their students think about important phenomena.

2. <u>Identifies important content to be taught</u>. This code is used when the teacher describes a resource as important or used to determine which concepts or issues were important or to be taught in a unit.

3. <u>Provides students with examples or important content/information</u>. This code is used when the teacher describes resources as important or used by students to directly acquire important information (such as reading texts, viewing filmstrips or movies...).

4. <u>Promotes discussion or questioning</u>. Used when a resource is clearly described as used or important for class discussion or questioning activities.

5. <u>Provides reinforcement or opportunities to apply new concepts</u>. Used when the teacher describes a resource as important or used to to reinforce, apply, or practice using new concepts.

6. <u>Provides concrete or "hands-on" experience</u>. Used when a resource is described as important or used to provide students with hands-on or concrete experiences, or to make an abstract idea more tangible or visible.

7. <u>Refers to resource being easy for students to read or use</u>. Used when a resource is described as designed at an appropriate level for students to comprehend, such as texts that are readable, movies or filmstrips with appropriate vocabulary and examples.

8. <u>Motivates or stimulates students' interest</u>. Used when a resource is

described as important because it motivates students or stimulates their interest in the lesson.

9. Other. Used for references which do not fit the above descriptions

N.A.. Indicates resources not available to the teacher due to assignment in a particular treatment group.

Coding procedures. Each teacher's response to interview task three "Discussion of Important Planning and Teaching Resources" was read to identify those resources actually used in planning and teaching the unit and the descriptions of how they were used.. Those resources included in the teacher's response were marked as "used" or "not used". Resources not included in the discussion were not marked on the chart. Those identified as most important influences on the teachers planning and/or teaching were identified in the third column of the data summary chart. The importance of a resource was coded and recorded whenever possible, thus some resources not identified as most important also included codes summarizing the teacher's reasons for including them in planning and teaching the unit. In some instances, resources were described as being important for more than one purpose. Multiple codes were recorded to include all the reasons that the resource was used or considered important.

06-15-86 IMPORTANT PLANNING/TEACHING RESOURCES TEACHER NUMBER: _____

PRE-INTERVIEW

RESOURCE	USED	NOT USED	MOST IMP	REASON
student text	___	___	___	___
teachers guide	___	___	___	___
lab activities	___	___	___	___
activity sheets	___	___	___	___
movies, filmstrips, videos	___	___	___	___
magazines, newspapers	___	___	___	___
teacher-related publications	___	___	___	___
high school/college texts	___	___	___	___
transparencies	___	___	___	___
overhead projector	___	___	___	___
study guides	___	___	___	___
district curriculum guides	___	___	___	___
library	___	___	___	___

PHOTOSYNTHESIS

RESOURCE	USED	NOT USED	MOST IMP	REASON
Photosynthesis Goals	___	___	___	___
Goal/Naive Conception chart	___	___	___	___
Power Plant student text	___	___	___	___
Power Plant teachers guide	___	___	___	___
Food in Plants Lab	___	___	___	___
Using Photosynthesis Activity	___	___	___	___
Photosynthesis Transparencies	___	___	___	___
information from workshops	___	___	___	___
student text	___	___	___	___
teachers guide	___	___	___	___
lab activities	___	___	___	___
activity sheets	___	___	___	___
movies, filmstrips, videos	___	___	___	___
magazines, newspapers	___	___	___	___
teacher-related publications	___	___	___	___
high school/college texts	___	___	___	___
transparencies	___	___	___	___

CODES:

1) provides information about students' misconceptions or thinking

2) identifies important content to be taught

3) provides students with examples or important content/information

4) promotes discussion or questioning

5) provides reinforcement of content or opportunities to apply new concepts

6) provides concrete or "hands-on" experience

7) refers to resource being easy for students to read or use to acquire information

8) motivates or stimulates students' interest

9) other

06-15-86 IMPORTANT PLANNING/TEACHING RESOURCES TEACHER NUMBER: ____

RESPIRATION

RESOURCE	USED	NOT USED	MOST IMP	REASON
Respiration Goals	___	___	___	___
Goal/Naive Conception chart	___	___	___	___
Power Cell teachers guide	___	___	___	___
Power Cell student text	___	___	___	___
Exercise, Energy Needs Lab	___	___	___	___
Exhaled/Inhaled Air Activity	___	___	___	___
Respiration Transparencies	___	___	___	___
Workshop information	___	___	___	___
student text	___	___	___	___
teachers guide	___	___	___	___
lab activities	___	___	___	___
activity sheets	___	___	___	___
movies, filmstrips, videos	___	___	___	___
magazines, newspapers	___	___	___	___
teacher-related publications	___	___	___	___
high school/college texts	___	___	___	___
transparencies	___	___	___	___
library	___	___	___	___

MATTER CYCLING

RESOURCE	USED	NOT USED	MOST IMP	REASON
Matter Cycling Goals	___	___	___	___
student text	___	___	___	___
teachers guide	___	___	___	___
lab activities	___	___	___	___
activity sheets	___	___	___	___
movies, filmstrips, videos	___	___	___	___
magazines, newspapers	___	___	___	___
teacher-related publications	___	___	___	___
high school/college texts	___	___	___	___
transparencies	___	___	___	___
library	___	___	___	___

CODES:

1) provides information about students' misconceptions or thinking

2) identifies important content to be taught

3) provides students with examples or important content/information

4) promotes discussion or questioning

5) provides reinforcement of content or opportunities to apply new concepts

6) provides concrete or "hands-on" experience

7) refers to resource being easy for students to read or use to acquire information

8) motivates or stimulates students' interest

9) other

SUMMARY SHEET
ACTIVITIES/STRATEGIES IMPORTANT TO PROMOTE STUDENT LEARNING
ACADEMIC TASKS: CHANGES FOR FUTURE (PHS): INTERVIEW TASK IV AND V (RES. AND M.C.)

TEACHER NUMBER:_____

Description/Statement	Reasons for importance	Code	Page Ref.
PHOTOSYNTHESIS			
1			
2			
3			
4			
RESPIRATION			
1			
2			
3			
4			
MATTER CYCLING			
1			
2			
3			
4			
NOTES FROM PRE-INTERVIEW			
1			
2			

Responses to Interview Tasks
Conceptual Development Perspective

Teacher Number	Task II Failure to Learn	Task III Reasons Why Resources were Considered Important	Task IV Important Teaching Strategies
11	misconceptions; failure to understand important concept; question construction Unable to account for failure (16)	provides examples of concepts; promotes discussion; references to resources providing information about students thinking (5)	discussion; writing down thoughts (55) providing important information emphasizing specific concepts
12	misconceptions; failure to understand important concept; communication skills Unable to account for failure (6)	provides examples of concepts; reinforcement; references to resources providing information about students thinking (2)	discussion; writing down thoughts (35) providing important information emphasizing specific concepts repetition
21	misconceptions; failure to understand important concept; communication skills Unable to account for failure (0)	provides examples of concepts; promotes discussion; references to resources providing information about students thinking (4)	discussion; writing down thoughts (50) making students accountable for assignments repetition
25	misconceptions; failure to understand important concept; question construction Unable to account for failure (17)	provides examples of concepts useful for discussions identifies misconceptions references to resources providing information about students thinking (5)	discussions; writing thoughts (30) emphasizing specific concepts; repetition; holding students accountable for assignments

Responses to Interview Tasks
Content Understanding Perspective

Teacher Number	Task II Failure to Learn	Task III Reasons Why Resources were Considered Important	Task IV Important Teaching Strategies
22	reasoning skills misconceptions failure to understand communication skills Unable to account for failure (0)	provides examples of concepts reinforcement hands-on activities references to resources providing information about students thinking (3)	discussions, writing down thoughts (28) providing important information repetition, hands-on activities

Responses to Interview Tasks
Fact Acquisition

Teacher Number	Task II Failure to Learn	Task III Reasons Why Resources were Considered Important	Task IV Important Teaching Strategies
13	question construction communication skills misconceptions Unable to account for failure (16)	provides examples of concepts reinforcement motivates students identifies important content references to resources providing information about students thinking (1)	displaying enthusiasm, concern (45) providing important information discussions; movies, filmstrips; hands-on activities
14	motivation question construction unable to account for failure (43)	identifies important content provides examples of concepts reinforcement references to resources providing information about students' thinking (1)	reading, labs, activities (36) movies, filmstrips, videos repetition
23	innate ability reasoning skills failure to remember Unable to account for failure (18)	provides examples of concepts identifies important content reinforcement references to resources providing information about students' thinking (0)	movies, videos, filmstrips (33) readings, labs hands-on activities discussion, focusing on specific concepts
33	inappropriate content motivation reasoning question construction Unable to account for failure (17)	hands-on activities provides examples of concepts references to resources providing information about students' thinking (1)	displaying enthusiasm or concern (33) discussions hands-on activities repetition

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